STUDY ON AGEING PROCESS OF POLYMER MODIFIED BITUMEN

NURUL ‘IZZATI BT AB RAHIM

Thesis submitted in fulfillment of the requirements

for the award of the degree of

Bachelor of Chemical Engineering in Chemical Engineering

Faculty Of Chemical & Natural Resources Engineering

UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

Bitumen is a very complex combination of organic compound and contain high proportion of hydrocarbons with high carbon numbers. The main application of bitumen is in road industry because of its good adhesion to mineral aggregates and its physical properties. The major failure modes using only bitumen in the road construction are rutting, cracking and ageing. In cold climates, cracking in pavements may be an extensive problem. Low temperature cracking is caused by thermally induced tensile stresses exceeding the tensile strength of the pavement material. By modified the bitumen using polymer which is Ethylene Vinyl Acetate (EVA) is an alternative to increase the physical and chemical properties of 80/100 bitumen due to short term ageing effect. The sample of polymer modified bitumen is prepared using Toluene as a solvent to bind the polymer with bitumen. The sample then undergoes the short term ageing process using Thin Film Oven (TFO) before being characterized using FTIR, Softening Point test, penetrometer, viscometer and TGA. Experimental results showed that increasing EVA content in the bitumen will reduce the quality of the bitumen grade, but will improve the performance of bitumen on the environment. Therefore, the best EVA content to be brought together with bitumen is 2-4%.

ABSTRAK

Bitumen adalah kombinasi yang sangat kompleks terdiri daripada bahan organik dan mengandungi sebahagian besar hidrokarbon dengan bilangan karbon yang tinggi. Penggunaan utama bitumen adalah dalam industri penghasilan jalan raya kerana mempunyai fungsi lekatan yang baik terhadap agregat mineral. Punca kegagalan utama yang menggunakan bitumen sebagai bahan utama dalam pembinaan jalan raya adalah keretakan dan penuaan. Keretakan ketika suhu iklim rendah disebabkan oleh tegangan terma didorong oleh penekanan melebihi kekuatan tegangan bahan turapan. Pengolahan bitumen menggunakan polimer iaitu Ethylene Vinyl Acetate (EVA) ialah satu alternatif untuk meningkatkan sifat fizikal dan kimia bitumen grade 80/100 akibat kesan penuaan jangka pendek. Sampel bitumen yang diolah bersama polimer disediakan menggunakan Toluene sebagai pelarut untuk menyatukan polimer dan bitumen. Sampel kemudiannya menjalani proses jangka pendek penuaan menggunakan Thin Film Oven (TFO) sebelum dianalisis dengan menggunakan FTIR, Analisis Softening point, penetrometer, Viskometer dan TGA. Hasil uji kaji menujukkan bahawa semakin banyak kandungan EVA di dalam bitumen akan mengurangkan kualiti grade bitumen tersebut tetapi akan meningkatkan ketahanan bitumen terhadap persekitaran. Oleh yang demikian, kandungan EVA yang terbaik untuk disatukan bersama dengan bitumen adalah 2-4%.

TABLE OF CONTENTS

CHAPTER2 LITERATURE REVIEW

CHAPTER3 METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius

LIST OF ABBREVIATIONS

cm	centimeter
cm^{-1}	per centimeter
EVA	Ethylene Vinyl Acetate
FT-IR	Fourier Transform Infrared Spectrometry
IDT	Initial Decomposition Temperature
h	hour
L	litre
MDT	Maximum Decomposition Temperature
mg	miligram
ml	mililiter
mm	milimeter
PI	Penetration Index
PMB	Polymer Modified Bitumen
rpm	revolution per minutes
TFO	Thin Film Oven
TGA	Thermogravimetric

ABSTRACT

Bitumen is a very complex combination of organic compound and contain high proportion of hydrocarbons with high carbon numbers. The main application of bitumen is in road industry because of its good adhesion to mineral aggregates and its physical properties. The major failure modes using only bitumen in the road construction are rutting, cracking and ageing. In cold climates, cracking in pavements may be an extensive problem. Low temperature cracking is caused by thermally induced tensile stresses exceeding the tensile strength of the pavement material. By modified the bitumen using polymer which is Ethylene Vinyl Acetate (EVA) is an alternative to increase the physical and chemical properties of 80/100 bitumen due to short term ageing effect. The sample of polymer modified bitumen is prepared using Toluene as a solvent to bind the polymer with bitumen. The sample then undergoes the short term ageing process using Thin Film Oven (TFO) before being characterized using FTIR, microstructure analysis, penetrometer, viscometer and TGA. The increasing of EVA content in bitumen will increase the viscosity of sample and will reduced the value of penetration.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Bitumen are commonly uses especially in road industry because of their good adhesion to mineral aggregates and their physical properties (Luo & Chen, 2010). However, during the last decade increase in axle loads, heavy traffic, severe climatic conditions and construction failures led to a need to enhance the properties of the base bitumens. Consequently, the properties of bitumen need to be improved with regard to performance-related properties such as resistance to permanent deformation, low temperature cracking, wear, stripping and ageing (Mouillet et al., 2008).

Bitumen is one of the fossil organic material that produce from the bottom of the vacuum distillation columns in the crude oil refineries (Kebritchi et al., 2010). It's that will evolves with time , due to ageing process. It also thermoplastic material and have important limitations due to their temperature sensitivity (Lamontagne et al., 2001) . Using bitumen in the construction of asphalt pavements for more than a century will affect many aspects of road performance (Mouillet et al., 2008).

The specific performance enhancers have been investigated such as polymers in order to obtain the improved bitumen characteristic and properties. Plenty of polymer can be used in the preparation of polymer-modifies emulsion such as Ethylene Vinyl Acetate (EVA), Styrene Butadiene Rubber (SBR) latex, Styrene Butadiene Styrene (SBS), Polychloroprene latex and natural rubber latex. Using the polymer modified bitumen

emulsion present a safer and more environmental friendly binder for enhancing the properties of roads (Forbes et al, 2001).

1.2 PROBLEM STATEMENT

The major failure modes using only bitumen in the road construction are rutting, cracking and ageing. In cold climates, cracking in pavements may be an extensive problem. Low temperature cracking is caused by thermally induced tensile stresses exceeding the tensile strength of the pavement material. The degree of cracking may be influenced by many types of factors, such as material, structure and environmental factors. For example, mixture of a bitumen need to be flexible at high and low temperature. This to prevent pavement cracking and rutting (Mouillet et al., 2008).

Bitumen ageing is one of the principle factor causing the deterioration of road pavements (e.g. Cracking, rutting and the road moisture will damage). Ageing is a very complex process in conventional bitumens and the complexity increases when polymer modified bitumens are involved. This ageing is cause by the oxidation process where the oxygen from the surrounding air .Moreover ageing also causes by the temperature and the changing of the weather (Lu & Isacsson, 2000).

Using the polymer modified bitumen is an alternative method in order to increase the bitumen performance. Moreover it can improve in performance durability, mitigation of pavement distress, and reduced life cycle costs compared to unmodified asphalt emulsions or hot mix asphalt surface dressings (Lu & Isacsson, 2001).

1.3 OBJECTIVES OF STUDY

Based on the research background and problem statement described in the previous section, the objective of this research to study the ageing process and properties of polymer modified bitumen

1.4 SCOPE OF RESEARCH

In order to handle the above mentioned objectives, the following scopes were drawn:

a) Preparing the polymer modified bitumen using the toluene as a solvent.

b) Preparing the ageing process of polymer modified bitumen using Thin film Oven

c) The prepared polymer modified bitumen will be characterized by using FTIR , Softening Test, Penetrometer and TGA.

1.5 BENEFITS AND SIGNIFICANT OF RESEARCH

The rationale and significance of this research is to create a safer and more environmentally friendly binder for enhancing the properties of road. Besides that the polymer modified bitumen will offer improvement of the road performance. Using polymer modified bitumen will help reduce maintenance and the life cycle costs of the road.

CHAPTER 2

LITERATURE REVIEW

2.1 BITUMEN

2.1.1 Overview of bitumen

Bitumen is a very complex combination of organic compound and its contain high proportion of hydrocarbons with high carbon numbers.Bitumen is the residual product from distillation of crude oil in petroleum refining and produced to meet a variety of specifications based upon physical properties. The common refining process used for producing bitumen is straight reduction to grade from petroleum crude oil or blend. This process is usually using atmospheric and vacuum distillation as major equipment. Bitumen can be further processed by blowing air through it at elevated temperatures to alter its physical properties for commercial application (Asphalt Institute, 2011).

2.1.2 Application of Bitumen

According to Asphalt Institute Inc., the current world consumption of bitumen is approximately 102 Million tonnes per year. Figure 2.1 show the percentage global bitumen use. At least 34% from 102MT per year bitumen are use in North America, followed by 30% had been used in Asia and pacific and at least 20% bitumen use in European Union.

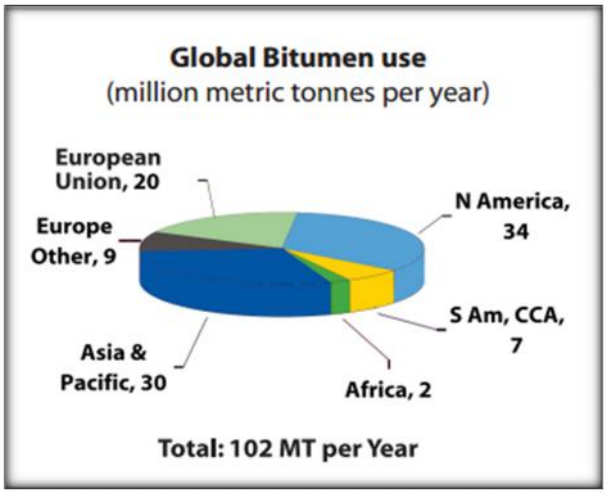

Figure 2.1: Global Bitumen use

From 102 MT/yr consumption of bitumen, 85% of all the bitumen is used as the binder in various kind of asphalt pavements: pavements for roads, airports, parking lots, etc. The other 10% of bitumen is used for roofing and the rest of the bitumen , about 5% of the total is used for a variety of purposes, each very small in volume. This sector is referred as ‘Secondary Uses’ (Asphalt Institute, 2011).

2.1.3 Properties of Bitumen

Bitumen is an organic liquid mixture that is highly viscous, black, sticky, entirely soluble in carbon disulfide, and composed primarily of highly condensed polycyclic aromatic hydrocarbons. Bitumen also known as asphalt or tar (Hirst, 2003). Bitumen are the residual product obtain by fractional distillation of crude oil at the bottom fraction. Bitumen one of the most complex molecules found in nature and the one with the highest boiling point.

At ambient temperature in-situ, bitumen is solid and virtually non-volatile and the vapor pressure of in-situ bitumen is below the limit of detection for normal instrumentation. Normally bitumen is heated to >140 ^{o}C to become liquid to facilitate transportation and handling (Asphalt Institute, 2011).

2.1.4 Types and structures of bitumen functional group

Generally the chemical composition of bitumen is similar, but with some variation depending upon the original crude oil and on the process used during refining and blending. Bitumen can be described as complex mixtures containing a large number of different chemical compounds of relatively high molecular weight. The molecules contain in bitumen are combinations of alkanes, cycloalkanes, aromatics and hetromolecules (which is contain sulphur, oxygen, nitrogen and heavy metals). The significance of molecules containing hetero-atoms in bitumen chemistry is the ability to form molecular associations, which strongly influence the physical properties and performance of bitumen.

Functionality of bitumen related on how molecules interact with each other or/and with aggregate surfaces or/and other materials. Typically, bitumen contains predominantly cyclic hydrocarbons (aromatic and/or naphthenic) and less quality of saturated components which are mainly very low in chemical reactivity. Figure 2.2 below show the example of broad chemical types present in bitumen (Asphalt Institute, 2011).

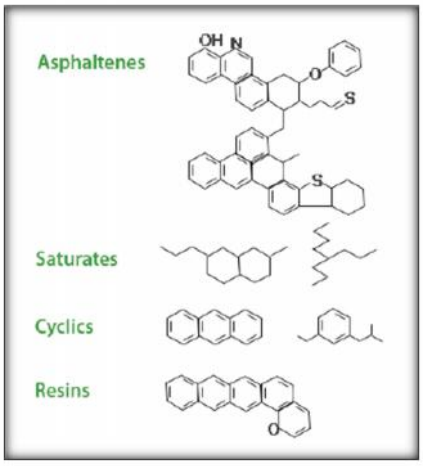

Figure 2.2: Example of broad chemical types present in bitumen

2.2 POLYMER

Polymer is molecules which consist of a long, repeating chain of smaller units that called monomer. Polymer consist billions of atoms and have the highest molecular weight among any molecules (Anissimov, 2011).

2.2.1 Type of Polymer

The common polymer that usually use in the bitumen modification are :

i. Plastomers

ii. Elastomers

EVA (Ethylene-Vinyl-Acetate) and PE (Polyethylene) are example of plastromers and SBS (Styrene-Butadiene-Styrene) is the most used elastomer. Basically, plastomers will increase the viscosity and stiffness of the bitumen while elastomers will improve the elastic behavior of the bitumen (Rooijen et al, 2006). These type of polymers usually provide in the form of pellets or powder which can easily diluted to the required polymer content by blending with base bitumen by using low to high shear mixers (Sengoz et al, 2009).

2.3 POLYMER MODIFIED BITUMEN

2.3.1 Overview of Polymer Modified Bitumen

Polymer modified Bitumen (PMB) is relate to the process for preparation of polymer and rubber based modified binder which is useful for the construction of roads catering to heavy traffic and also for the formation of airfields and surfacing. It also used as interlayer for sealing of cracks, preventive maintenance of flexible and can delay the reflective cracking (Juno Bitumix Private Limited, 17 Oktober 2011).

Bitumen modified with polymer is a common means of providing resistance to pavement deformation. Polymer modified bitumen emulsion is on alternative to improve the pure bitumen performance (Mouillet et al., 2008). It also can improve resistance in cracking which result in stronger and more durable overlays even in extreme climatic conditions. Both elastomer and plastomer modified bitumen have been apply successfully in situations where rutting was a problem with penetration grade bitumen (up to alimit). However, the bitumen should not be too stiff, because that may result in brittle asphalt mixtures, which has caused severe cracking failures with some types of plastomer modified bitumen in practice (Rooijen et al, 2006).

When bitumen is added in a compatible elastomer (such as SBS), it will absorb the oily fraction from bitumen which causes the polymer swell. After a while, the swelled polymer starts to dissolve in the bitumen. This physical process takes at least several hour and can be influenced by the production process and the use of additives. Meanwhile Plastomersmelt at high temperature and when added to bitumen it will appear as small droplets that are dispersed in the bitumen. The bigger the volume of the polymer in the bitumen, the more it will affect the properties of the bitumen (Rooijen et al, 2006).

2.3.2 Interaction between polymer and bitumen

The result of the mutual effect of polymer and bitumen are the morphology of polymer modified bitumen, influenced by bitumen composition, polymer nature and ratio. Commonly, polymer is insoluble to some degree in the bitumen matrix by resulting eventually in gross separation of both phase. These phase may become either continuous phase or dispersed, depending on polymer nature, concentration and ability to swell with maltene molecules (Eweed, 2011).

In general at lower polymer content the small polymer spheres swollen by bitumen compatible fractions are spread homogeneously in a continuousbitumen phase. By increasing polymer contain will resulting a continuous polymer phase. Figure 2.3 below show the microstructure of polymer modified bitumen which contains high polymer content and low polymer content (Rooijen et al, 2006).