UNIVERSITI PUTRA MALAYSIA

EFFECT OF BLENDING PROCESS ON RHEOLOGICAL AND VOLUMETRIC PROPERTIES OF ASPHALT BINDER

ABBAS SOLOUKI

EFFECT OF BLENDING PROCESS ON RHEOLOGICAL AND VOLUMETRIC PROPERTIES OF ASPHALT BINDER

By

ABBAS SOLOUKI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

June 2015

DEDICATION

This thesis is dedicated with love to

My Dear Dad,

For his patience and never ending support which, makes me proud of being his son. I am what I am today because of your wisdom, guidance, and positive inspirations

My Magnificent Mother,

For her precious blessings, pure sweet love, and patience throughout my entire life. I cherish every moment of being your son

My Best Brothers,
For being my friends and companion and for all the fun we share in our life

And last but not least,

My Wonderful Wife,
For providing me with peace, love, joy and endless support during my studies without which, I could have not succeeded

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

EFFECT OF BLENDING PROCESS ON RHEOLOGICAL AND VOLUMETRIC PROPERTIES OF ASPHALT BINDER

By

ABBAS SOLOUKI

June 2015

Chair: Professor Ratnasamy Muniandy, PhD
Faculty: Engineering

The improvement of asphalt binder physical properties is possible through the addition of polymers. However, due to different physical and chemical properties of additives, each modifier requires its unique blending processing conditions. Despite these facts, not much attention has been paid to the effects of blending process on the rheological properties of asphalt binders. Therefore, it was hypothesized that different blending parameters could affect the rheological properties of asphalt binders, which in turns influence the overall performance of polymer modified blends and mixtures. As a result, three different objectives were set for the current study which were 1) to establish a blending matrix for asphalt binder modification, 2) to determine the effect of blending process on the rheological properties of asphalt binders, and 3) to determine the effect of blending process on the volumetric properties of asphalt mixtures. The blending matrix was established by selecting different parameters which potentially affected the blending outcome and the modified binders were prepared according to the established matrix. Different binder tests including softening point temperature, rotational viscosity, and dynamic shear rheometer (DSR) tests were conducted on EVA and Sasobit modified binders. Finally, the optimum asphalt content of mixtures was obtained for samples prepared at three different motor speed values of 400, 1200, and 1800 using the two mentioned polymers. The results indicated high binder stiffness for binders processed at higher blending speeds compared to binders blended at lower speeds. This was observable through higher softening point temperatures, higher viscosity values, and higher complex modulus measurements. Therefore, an increase in motor speed values increased the overall stiffness of the modified binders. Additionally, the stiffness of asphalt binders also increased with an increase in additive content. Likewise, the optimum asphalt binder content increased for mixtures

containing stiffer binders. It was concluded that an increase in motor speed pre-aged the binder sample during the preparation process which led to its increased stiffness. It has to be mentioned that the pre-aging phenomena is undesirable since it will reduce the overall service life of pavements. The application of lower motor speed during blending is highly suggested.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN PROSES PENCAMPURAN TERHADAP REOLOGI DAN ISIPADU SIFAT-SIFAT ASFAL SIMEN

Oleh

ABBAS SOLOUKI

Jun 2015

Pengerusi: Profesor Ratnasamy Muniandy, PhD
Fakulti: Kejuruteraan

Penambahbaikan prestasi simen asfal mampu dilakukan melalui kaedah pengubahsuaian polimer. Bahan polimer dicampurkan bersama simen asfal untuk menambah kekuatan struktur lapisan jalan dan sekaligus meningkatkan ciri-ciri rheologi campuran asfal.Namun demikian, perbezaan diantara ciri-ciri fizikal dan kimia bahan tambah polimer memerlukan proses pencampuran yang unik dan rumit bagi memastikan kualiti bahan adalah terjamin. Kajian terdahulu berkaitan campuran bahan polimer tidak banyak menjurus kepada proses campuran,jenis ubahsuai serta kesan proses campuran kepada ciri-ciri rhelogi simen asfal.Ini secara tidak langsung mempengaruhi keseragaman campuran bahan polimer didalam simen asfal terubahsuai.Pelbagai kajian berkaitan cara-cara ubahsuai campuan asfal –polimer dilakukan bagi mendapatkan campuran yang sesuai untuk simen asfal. Hipotesis kajian adalah menjurus kepada proses campuran polimer dan simen asfal yang mana proses yang berlainan mempengaruhi prestasi keseluruhan campuran asfal terubahsuai.Kajian ini memfokuskan kepada tiga objektif utama iaitu; 1) menghasilkan matrik campuran yang sesuai untuk pengubahsuaian simen asfal; 2)Menentukan kesan proses campuran terhadap ciri-ciri rheologi simen asfal terubahsuai dan 3) Meramal kesan proses campuran kepada cirri-ciri isipadu campuran asfal. Kajian dimulakan dengan menentukan matrik campuran yang memberikan kesan secara langsung terhadap parameter yang mempengaruhi prestasi akhir campuran tersebut. Asfal yang diubahsuai disediakan dengan menggunakan tiga nilai rpm berbeza 400, 1200 dan 1800 rpm. Tempoh pengadunan yang digunakan adalah 240 dan 20 minit untuk Ethylene vinyl acetate (EVA) dan pengikat sasobit yang telah diubahsuai. Akhirnya, pengadunan dijalankan di dua suhu pencampuran yang berbeza iaitu pada suhu 170oc dan 130oc untuk EVA dan pengikat sasobit. Ujian pengikat yang berbeza termasuk suhu titik lembut, kelikatan putaran dan ujian rheometer ricih dinamik telah dijalankan ke atas pengikat diubahsuai. Akhirnya, kandungan asfal optimum campuran disediakan pada tiga nilai rpm yang berbeza iaitu 400, 1200 dan 1800 telah diperolehi

menggunakan dua polimer yang berbeza. Secara umumnya, keputusan menunjukkan kekukuhan pengikat tinggi untuk pengikat diproses pada kelajuan pengadunan lebih tinggi berbanding dengan pengikat dicampur pada kelajuan yang lebih rendah. Ini dapat dilihat melalui penurunan suhu yang lebih tinggi mata, nilai-nilai kelikatan yang tinggi dan ukuran modulus kompleks yang lebih tinggi. Oleh itu, peningkatan dalam nilai rpm telah meningkatkan kekukuhan keseluruhan pengikat yang telah diubahsuai. Di samping itu, kekukuhan pengikat asfalt juga meningkat dengan peningkatan dalam kandungan tambahan. Selain itu, kandungan asfalt bitumen optimum juga meningkat untuk campuran yang mengandungi pengikat yang lebih keras. Kelajuan rpm yang lebih tinggi semasa pengadunan mewujudkan pusaran yang menyedut udara di dalam sebatian pengikat. Oleh itu, pengikat mengalami penuaan seterusnya meningkatkan tahap kekukuhan mereka. Walau bagaimanapun, penuaan separa bukan parameter wajar kerana ia mengurangkan hayat perkhidmatan jalan.

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I certify that a Thesis Examination Committee has met on 30 June 2015 to conduct the final examination of Abbas Solouki on his thesis entitled “The effect of blending process on rheological and volumetric properties of asphalt binder” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AASHTO	American association of state highway officials
AC	asphalt cement
ANOVA	Analysis of variance
AR	aged residue
ASTM	American Society for Testing and Materials
cP	centipoise
cSt	centistokes
DSR	Dynamic shear rheometer
ESEM	Environmental Scanning Electron Microscopy
EVA	ethylene vinyl acetate
HMA	hot mix asphalt
JPJ	Malaysian road transport department
JKR	Public works department of Malaysia
LDEP	low density polyethylene
OAC	optimum asphalt content
OBT	Optimum blending time
PAV	pressure aging vessel
PG	performance grading
PMB	polymer modified asphalt binder
RPM	revolutions per minute
RTFO	rolling thin film oven
SB	styrene-butadiene
SBR	Styrene-butadiene rubber
SBS	styrene-butadiene-styrene

SHRP	strategic highway research program
SMA	stone mastic asphalt
Superpave	superior performing asphalt pavements
UPM	university putra Malaysia
VA	vinyl acetate
WMA	warm mix asphalt

CHAPTER 1

INTRODUCTION

1.1 General Background

From the very first day of their construction, ancient roads, and now modern asphalt pavements, have shown their great role and influence on mankind's life by facilitating transportation of goods and people from one location to another. In the early 20th century, Petroleum refining gained attention as an option for producing various products such as kerosene, fuels, and lubricants, as shown in Figure 1.1.

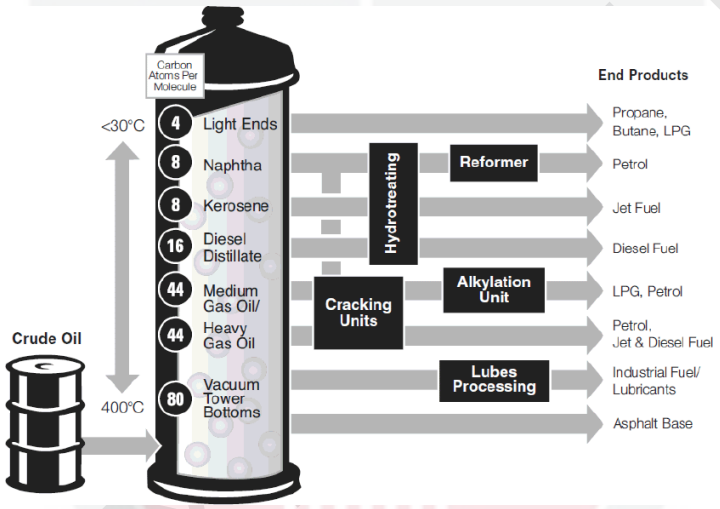

Figure 1.1. End Products of Oil Refinery Process
(Source: Exxonmobil, 2006)

The final product of the mentioned process was asphalt binder which gained more attention after the discovery of their suitability of use as paving materials (Kanabar 2010). Asphalt binder has been used in roads, highways, and airport runways from since and has shown desirable performance. Figure 1.2 shows the refinery Yield of asphalt compared to the rest of the refinery process products (percentage) for USA in year 2012. Asphalt binder allocates only 2 percent of the total products.

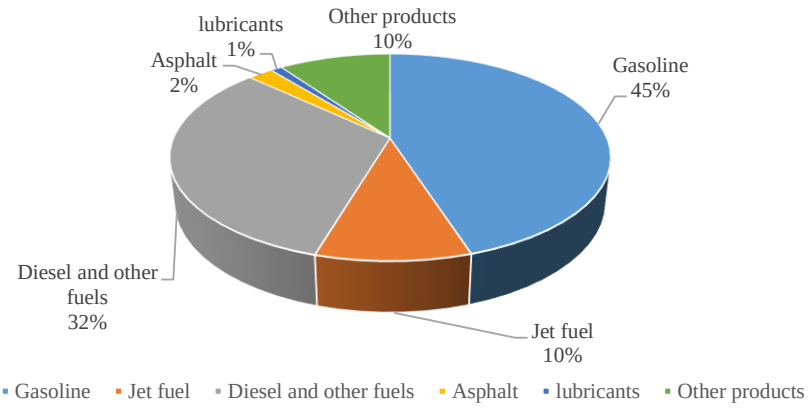

Figure 1.2. Percentage of Product Yield from Crude Oil Refinery Process in USA
(Adapted from EIA, 2013)

The total reported road mileage in Malaysia was 182,628 km in 2012, of which, about 78.27% was categorized under paved roads and the remaining 21.73% was unpaved roads. The growth rate of paved road showed an approximate increase of 194% from 2008 to 2012, and had reached 142,938 km in length in 2012 (Economic Planning unit 2013). Furthermore, the total number of vehicles registered in Malaysia had risen by 35% by the end of 2012 compared to the end of year 2007 and reached a total of 22,702,221 vehicles. It has to be mentioned that these figures include motorcycles and deregistered vehicles as well. Additionally, the total number of newly registered vehicles with JPJ (Malaysian Road Transport Department) is shown in Figure 1.3, which presents high figures regarding annual vehicle registration and production rates (Malaysian Automotive Association 2013; Yap 2013).

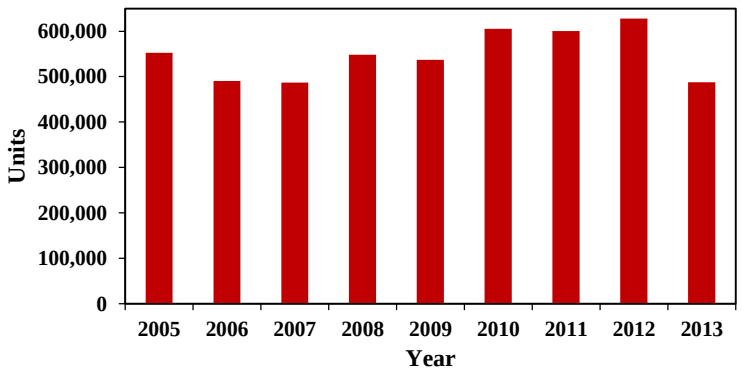

Figure 1.3. Newly Registered Vehicles
(Adapted from "Malaysia Automotive Association," 2013)

Over the past decades due to various factors such an increase in vehicle production and traffic rates, introduction of new axle configurations, and an increase of tire pressure, the

need for durable pavements which show more resistant to pavement distresses has increased (Airey 2002). Climates could be pointed out as yet another factor which can directly affect pavement performance and durability. Asphalt pavement performance is decreased at high and very low pavement temperatures due to rutting and low temperature thermal cracking. Furthermore, fatigue cracking occurs at intermediate pavement temperatures. In addition, the need for pavement replacement and/or rehabilitation would be reduced dramatically for durable pavements. Although asphalt allocates only 5 to 7% of the total materials in the mix, it represents half of the total cost of the project. These factors have imposed the necessity of improving the physical and mechanical properties of asphalt pavements (Haddadi et al. 2008; Airey 2002). Moreover, asphaltic pavements are composed of both mineral aggregates and asphalt binders. The aggregates have a certain range of gradation and comply with certain specifications. Furthermore, asphalt binders can be introduced in either neat or modified state to pavement mixture (Delgadillo 2008). It is worth mentioning that the performance of an asphalt pavement is based on both the quality and strength of aggregates and asphalt binders; therefore, enhancing pavement performance is possible through the improvement of these factors.

1.2 Problem Identification

The improvement of asphalt binder properties is possible through various methods. Among the available methods, asphalt binder modification has gained attention over the past decades. Asphalt binders can be modified with different types of materials such as fibres (Abtahi et al. 2010), polymers (Yildirim 2007), and warm mix asphalt (WMA) additives (D'Angelo et al. 2008). Polymers are added to asphalt binders to strengthen the pavement structure, and enhance its rheological properties.

Due to the difference in terms of physical and chemical properties, each additive requires its unique blending processing conditions. Consequently, various aspects can affect blending results such as temperature, time of blending, percent of additives, the amount of asphalt binder, state of material, and the speed of blending (Haddadi et al. 2008; García-Morales et al. 2007; Pérez-Lepe et al. 2003). Generally, in Malaysia 80-100 penetration graded asphalt binder is the most common asphalt binder compared to other available bitumen. In addition, the 80-100 asphalt binder is also used as the base bitumen in the process of modified asphalt binder production. Furthermore, the introduction of polymers into asphalt binders is an important issue, as the homogeneity of the mix is directly related to pavement performance. Despite these facts, not much attention has been paid to homogeneity, process of blending, production of modified asphalt binders, and the effects of blending process on the rheological properties of asphalt binders.

It is hypothesized that different blending parameters can affect the rheological properties of asphalt binders, which in turns affects the overall performance of the polymer modified mixtures. Therefore, a study was conducted in order to investigate the potential effects of the blending process on the performance of asphalt binders in terms of rheological properties. Furthermore, the current study will be an opportunity to investigate and compare the different methods used for asphalt binder modification.

1.3 Objectives

The overall objective of this study was to evaluate the effects of blending process on the rheological properties of asphalt binders. The detailed objectives for the present research are as follows:

1. To establish a blending matrix for modified asphalt binders
2. To determine the effect of blending process on the rheological properties of asphalt binders.
3. To determine the effect of blending process on the volumetric properties of asphalt mixtures.

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