UNIVERSITI PUTRA MALAYSIA

EFFECTS OF SUSPENDED AND UNSUSPENDED ADDITIVES IN SHORT-TERM AGING PROCESS OF BINDER

TAHSEEN SAAD ALI

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By

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Abstract of the thesis presented to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science.

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April 2014

Chairman: Prof. Ratnasamy Muniandy, Phd

Faculty: Engineering

Recently, numerous additives have been blended in asphalt binder to enhance the performance of pavement mixture. However, the use of these modified binders can be problematic as their outcomes on site and in road construction are unpredictable. Meanwhile, many stick to using the same known additives because they are tested and the results predictable and do not experiment with new and possibly better alternatives that could yield improved results. The poor correlation of fatigue and rutting potentials of asphalt binder with the asphalt mix is the main concern in this research.

Modified asphalt properties are different in specifications according to the additive type and behavior within the modified binder and as a result of this, there is a fear of unpredictable pavement failure. Such a passive attitude will mean ignoring the potential advantages of the asphalt concrete mix in favor of the asphalt binder which faces problems of rutting and fatigue. Accordingly, the additives are classified into two groups: non-suspended and suspended modified binders. Moreover, the suspended additives continue to be used and the inherent problems remain. These two groups have been compared as they are totally different in their physical properties – one melts while the other is suspended within the binder formation.

This study evaluates the non-suspended and suspended additives. Each group consists of different types of additives. Group one (melted) is divided into two additives, ethylene vinyl acetate and tire rubber powder. Group two (suspended) consists of hydrated mineral filler and oil palm cellulose fiber.

The physical tests penetration and softening point and the superpave test represents rotational viscosity, rolling thin film oven test RTFO for short-term aging and lastly DSR which are used to evaluate the non-suspended and suspended additives. The main tool for group evaluation is conducted by using the dissipated energy approach to diagnose the failure. The stress sweep test is chosen to run the DSR test.

The results reveal the superior resistance to the shear resistance that is represented by the non-suspended additives modified binders. The limit state is established for the

non-suspended additives especially for the NSEU (2%-8%) and NSEA (4%-8%). Lastly, the non-suspended modified binders reduce the rutting problems more than the suspended additives modified binders.

Abstrak tesis dilcemulcalcan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KESAN BAGI BAHAN TAMBAH TERAMPAI DAN TIDAK TERAMPAI DALAM PROSESPENUAAN JANGKA PENDEK BAGI BAHAN PENGIKAT

Oleh

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April 2014

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Sejak kebelakangan ini, pelbagai bahan tambah telah dicampurkan dalam pengikat aspal untuk meningkatkan prestasi bagi turapan campuran. Walaubagaimanapun, penggunaan bagi pengikat yang telah diubahsuai akan menjadi satu masalah kerana dapatan mereka keatas tapak dan dalam pembinaan jalan adalah diluar jangka. Sementara itu, ramai pihak yang masih menggunakan bahan tambah yang sama kerana ianya telah diuji dan hasilnya dapat dijangka dan tidak mencuba yang baru dan mungkin alternatif yang lebih baik yang mana mampu menghasilkan dapatan yang lebih baik. Korelasi yang tidak sesuai bagi kemungkinan bagi kelusuhan dan pengeluman bagi pengikat aspal dengan campuran aspal adalah fokus utama dalam kajian ini.

Sifat aspal yang diubahsuai adalah sangat berbeza dalam spesifikasi berdasarkan kepada jenis dan sifat dalam pengikat ubahsuai dan sebagai hasilnya, terdapatnya kegusaran berkenaan kegagalan dalam turapan yang tidak terjangka. Sikap pasif sebegini bermaksud tidak menghiraukan kelebihan yang berpotensi bagi campuran konkrit aspal daripada pengikat aspal yang mana menghadapi masalah kelusuhan dan pengeluman Secara berasingan, bahan penambah telah dikumpulkan kepada dua kumpulan iaitu tidak terampai dan pengikat ubahsuai terampai. Tambahan lagi, bahan penambah terampai berterusan digunakan dan masalah yang seringkali dihadapi berulang. Kedua-dua kumpulan ini telah dibandingkan dan mereka benar-berna berbeza dalam sifat fizikal mereka – satu cair manakala satu yang lain terampai dalam formasi pengikat.

Kajian ini menilai bahan tambah yang tidak terampai dan terampai. Setiap kumpulan mengandungi jenis bahan tambah yang berbeza. Kumpulan satu (cair) telah diasingkan kepada dua bahan tambah, etilena vinil asetat dan serbuk tayar getah. Kumpulan kedua (terampai) mengandungi penapis mineral yang hidrat dan fiber selulosa minyak kelapa sawit.

Ujian fizikal penebusan dan poin kelembutan dan ujian 'superpave' mewakili kelikatan berputar, ujian filem oven nipis berputar RKTO bagi penuaan jangka masa pendek dan akhirnya DSR yang mana telah digunakan bagi menilai bahan tambah

tidak terampai dan terampai. Peralatan utama bagi penilaian kumpulan telah dijalankan dengan menggunakan pendekatan tenaga 'terlesap' untuk mendiagnosis kegagalan. Mod kawalan stress telah dipilih untuk menjalankan ujian DSR.

Dapatan kajian menunjukkan rintangan yang besar kepada rintangan ricih yang diwakili oleh bahan tambah tidak terampai yang diubahsuai pengikat. Tahap had telah dikuatkuasakan bagi bahan tambah tidak terampai terutamanya bagi NSEU (2%-8%) dan NSEA (4%-8%). Akhir sekali, bahan tambah tidak terampai pengikat ubahsuai mengurangkan masalah pengeluman lebih daripada bahan tambah terampai pengikat ubahsuai.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment 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

AC :- Asphalt cement

AASHTO: - American Association of State Highways and Transportation Officials

ASTM : - American Society for Testing and Materials

ANN : - Artificial neural network

ANOVA: - analysis-of-variance

BTD : - Bareclona Traccion Directa

CRM : - Crumb rubber modified

DER : - Dissipated Energy Ratio

DMA : - Dynamic mechanical analysis

DSC : -Differential scanning calorimetry

DTT : - Direct tensile test

DPSE :-Dissipated pseudostrain energy

EBA :-Ethylene butyle acrylate

EVA :-Ethylene vinyl acetate

FAM :-Fine aggregate matrix

HDPE :-High density polyethylene

HMA :-Hot mix asphalt

HMF : -Hydrated mineral filler

LDPE :-Low density polyethylene

LVR :-Linear viscoelastic range

NS : - non-suspended

NSEA : - non-suspended (ethylene vinyl acetate) aged

NSEU :- non-suspended (ethylene vinyl acetate) unaged

NSRA :- non-suspended (tire rubber powder) aged

NSRU : - non-suspended (tire rubber powder) unaged

COPF : - Cellulose oil palm fiber

PAV :-Pressure aging vessel

PSI :-Percent severability index

PV :-Plateau value

RDEC:-Ratio dissipated energy change

RTFOT:-Rolling thin film oven test

RP :-Rest period

RV :-Rotational viscometer

RAP :-Recycle asphalt pavement

S :- Suspended

SBS :-Styrene-butadiene-styrene

SEBS:-Styrene-ethylene-butadiene-styrene

SHRP:-Strategic highway research porogram

SMA:-Stone mastic asphalt

TEM:-Transmission electron microscopy

TFOT:-Thin film oven test

TI :-Thickness index

TSR :-Tensile strength ratio

UCL:-Universal decaracterization de Ligantes

CHAPTER 1

INTRODUCTION

1.1 Background

Asphalt binder has been a successful material to bind the aggregate particle and to make together the asphalt concrete. In the recent century, transportation has seen a lot of development particularly since War World II. Cities have become bigger due to significant population increase. Such development has had a great impact on transportation with subsequent implications on roads and road networks.

In addition, the improvement of transportation has been accompanied by major problems on the highways. In the early years of the automotive industry, the load applied on the pavement was low even and designers did not have to contend with many problems affecting the pavement at that time. The problems started with the increasing traffic volume that subjected existing pavements to high loads. Since then, the challenge faced by researchers has been to prevent distress on the pavements or at least increase the maintenance period and both are controlled by the cost.

The major factors which affect pavement performance are the load and the environmental conditions, which lead to two types of pavement deformation permanent deformation (rutting), and fatigue cracks, rutting occurs due to high temperature and the traffic load that the pavement surface is subjected to. Fatigue cracks are the result of low temperatures and the repetitive load on the pavement surface.

It can therefore be concluded that pavement deformations are caused by either environmental factors or traffic load and most of the time both contribute to deform the pavement surface. Before War World II, simple designs did exist, but after the war there was rapid development in transportation that led to the emergence of road pavement failure. Efforts to address this problem are still going on The aim of this study will be to investigate the factors related to failure in pavements under climatic and load conditions and make recommendations for solution.

1.2 Problem Statement

Nowadays, the world has encountered a problem of high petrol prices and in general, it has affected highway construction. In other words, the cost factor increases with increasing demand for paving roads and highways. This study will therefore also consider the related economic problems.

(Johnson, Bahia, & We, 2007, and Johnson, Bahia, & Cppnen, 2009) insisted there is no correlation between the fatigue in the asphalt binder and that in the mix although different binders ranking under several load factors were considered. After Johnson (Zhou, Mogawer, & Li, 2012) the binder fatigue parameter of superpave has poor relationship with the asphalt mix fatigue based on test procedure conducted.

This discussion begins with the hypothesis of how additives behave differently within the binder composition, which can be summarized in two mechanisms: non-suspended (NS) and suspended (S) additives. Based on the shear resistance measured, the hypothesis is non-suspended solid additives have increased shear resistance as compared with suspended solid additives.

When suspended additives are added to the binder, they stay within the binder combination as solid partials and no melting or dissolving occurs and this is defined as a suspended mechanism approach. On the other hand, dissolved additives melt within the binder composition at high temperatures. As such, at low temperatures they may not stay in a homogenous form, especially within the asphaltic mixture combination. Furthermore, the modifier may undergo non-homogeneity behavior which reveals a lack of distribution of the modifier within the binder's molecular structure, which is called melted mechanism approach. Such a hypothesis may have a distinct effect on the unclear relation between fatigue and rutting in the binder and in the mixture. In other words, when the modified binders are tested under fatigue and rutting conditions, it shows extreme results. In the field, when the same modified binders are utilized to produce the mix design, they do not reveal the same indicated property obtained from the previous modified binders test. The problems are still occurring in the pavement despite various types of additives being used so far.

The aging terms definitions begin from the short term to the long term. At the plant mix while the mix is prepared the asphalt film thickness will be under two affecting factors of temperature and time of the mix; the higher the temperature and the longer the delaying time of the mix the higher the aging will be and this is referred to as short-term aging and it is due to volatilization.

Asphalt samples taken from a project completed for a certain period of time were subjected to laboratory tests to recover the asphalt binder and it was found that there was an increase in the asphalt binder's viscosity compared to the initial viscosity. The increased of viscosity was due to oxidation of the asphalt binder since the pavement was compacted till the coring sample and the laboratory tests is defined as long-term aging (Bell, 1989). The ultraviolet is also considered one of the factors involved in the aging phenomenon that researchers have been concerned about (Wu, Pang, Liu, & Zhu, 2010).

The quite common distress in asphaltic concrete such as, fatigue cracks and rutting, is caused by aging of the asphalt which increases the viscosity and then, the asphalt stiffness will increase at low temperature which makes the asphalt concrete prone to cracks. (Robertson, 1991) clarified that high and low temperatures have a damaging effect and contributes to the aging phenomenon to produce the distress in pavement construction. At low temperatures, the asphalt binder becomes brittle and then, the fatigue problem occurs. At high temperatures, the asphalt binder becomes soft while the high load stress generated by the traffic movement causes rutting as shown in Figure 1.1 and the final findings are tabulated in Table 1.1

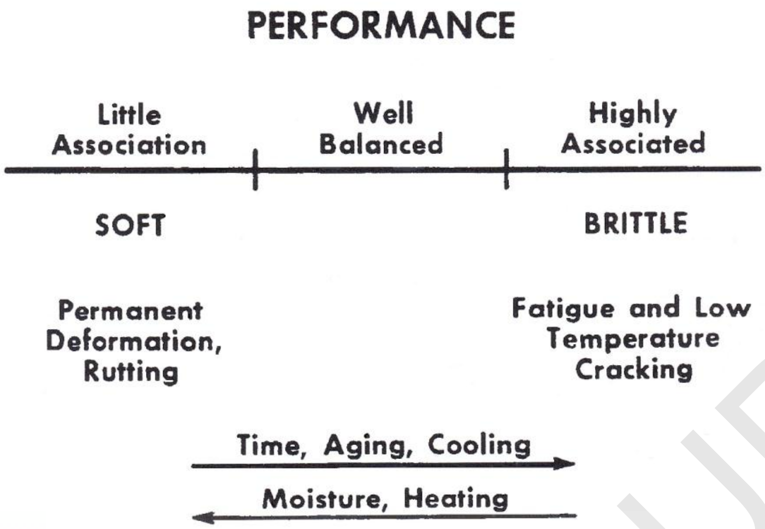

Figure 1.1: Illustrating of various pavement distresses under the effect of temperature, time and oxidation (Robertson et al., 1991).

Table 1.1: The summary of findings for the problem statement.

Source	**Problems**
Zhou et al., 2013	poor relationship between the fatigue of binder & AC
Johnson et al., 2007, 2009	Fatigue and rutting correlation with asphalt mix
Bell, 1989	Long and short- term aging progress in asphalt binder
Robertson, 1991	High and low temperature problem

1.3 Objectives of Study

The rheological properties are the significant part in this study. The NS and S groups can be characterize based on their concentration with the lower and upper limits needed to be added to fulfill the pavement construction neediness. Lastly, comparing the deformation techniques relationship with in the aged and unaged property for the asphalt binders for the NS and S MB groups to find the correlations.

1- To determine the rheological properties of modified binders.
2- To establish a limit state boundary for aged and unaged asphalt
3- To establish a correlation between the modified asphalt aged and unaged property of rutting performance of binders.

1.4 The importance of the Study

In the recent years, the asphalt binders are modified with numerous types of asphalt. Currently, those types are classified based on their blending mechanism. They are named non-suspended (NS) and suspended (S). for example, polymers and rubber characterized as NS and cellulose fibers and mineral filler characterized as S.
The DSR has been widely used to evaluate the rheological properties, as it is used to measure fatigue and rutting potentials of bituminous materials. The non-suspended and suspended groups are evaluated in DSR to find which group is more compatible with such important equipment.
Finally, the compatibility of the additive types used in the current research with the 80/100 penetration grade binder. This is highlighted in the literature that some of the binders and their modifiers did not meet significant results due to incompatibility.

1.5 The scope of the study

There are a huge number of additives used to modified the asphalt binders. In general, they blend in two blending mechanisms non-suspended solid and suspended solid groups. Independently, each group has a huge numbers of additives. In the current research, the non-suspended additives include polymer EVA and tire rubber powder which they are wildly used in the pavement construction as well as most of the researchers studied their properties. The suspended additives include the oil palm cellulose fiber and the mineral filler due to their usage which is lowering the drain down and induce moisture damage agent and also due to their common use in the pavement construction.

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