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UNIVERSITI PUTRA MALAYSIA

PERFORMANCE OF CELLULOSE PALM FIBER AS AN ADDITIVE IN ASPHALT BLENDS

HOSSEIN JAFARIAHANGARI

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By

HOSSEIN JAFARIAHANGARI

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

November 2008

DEDICATION

Dedicated to my family for their love, support and encouragement.

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

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Chairman : Associate Professor Ratnasamy Muniandy, PhD

Faculty : Engineering

Due to the high oil prices, the cost of asphalt binder has increased tremendously. This scenario has warranted demand for higher viscosity and less expensive asphalt for pavement construction. A study was conducted to take advantage of the empty fruit bunch (EFB) of date and oil palm trees (which are considered as wastes) to produce cellulose fiber to be used as additives in the asphalt binder. If these EFBs could be beneficially utilized in any application, it would reduce the load on the nation's landfills. This study comprises three stages. At the first stage of the study the EFBs went through chemical and mechanical pulping to produce cellulose fibers, to be used for blending with asphalt binder. The date palm EFB chemical composition revealed alpha cellulose content of 36.1%, which is a very good source of cellulose. At the second stage a total of 11 blends of bio-mastic asphalt (BMA) were prepared. They consisted of 5 blends with chemically pulped date palm fibers, 5 blends with mechanically pulped oil palm fibers and one control sample that contained no fiber. At the third stage of the study, the rheological properties of the bio-mastic asphalt blends were evaluated with the Dynamic Shear Rheometer (DSR) equipment in accordance with the SUPERPAVE Strategic Highway Research Program (SHRP) requirements. The neat asphalt binders (unaged), Rolling Thin Film Oven (RTFO) aged and Pressure Ageing Vessel (PAV) samples were then measured for complex shear modulus, phase angle, shear strain and viscosity with the Dynamic Shear Rheometer (DSR) equipment and then evaluated with the SHRP requirements. The results indicated that the fibers obtained from the date palm EFB showed the best performance and all BMA blends performed very well compared to the control sample. The control sample which was categorized as PG58 was enhanced to PG76 with an addition of 0.375% date palm fiber. The oil palm has also improved the asphalt binder rheological properties from PG58 up to PG70 with the addition of 0.3% oil palm fiber.

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

PRESTASI GENTIAN SELULOSA PALMA SEBAGAI BAHAN CAMPURAN DIDALAM ASFALT

Oleh

HOSSEIN JAFARIAHANGARI

November 2008

Pengerusi : Profesor Madya Ratnasamy Muniandy, PhD

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Disebabkan oleh kenaikan harga minyak, secara tidak langsung harga asfalt juga turut meningkat. Keadaan ini menjadikan permintaan keperluan aspal likat yang murah bagi kerja-kerja penurapan. Kajian ini dibuat untuk melihat kepentingan bahan buangan daripada tandan buah palma (EFB) dan pokok kelapa sawit menghasilkan serat selulosa untuk kegunaan bahan campuran tambahan bagi asfalt. Sekiranya bahan EFB ini dimanfaatkan dan digunakan, bahan ini akan dapat mengurangkan beban negara. Kajian ini tertumpu kepada tiga tahap. Tahap pertama ialah kajian EFB untuk menghasilkan selulosa melalui proses kimia dan pulpa yang akan digunakan dalam campuran simen asfalt. Kandungan bahan kimia yang terdapat dalam tandan buah palma (EFB) mengandungi alfa selulosa sebanyak 36.1% , ini merupakan bahan yang sangat baik bagi selulosa. Tahap kedua kajian ialah menyediakan 11 sebatian Asfalt Bio Mastik (BMA) iaitu 5 sebatian serat kimia pulpa buah palma, 5 sebatian serat pulpa pokok kelapa sawit dan satu contoh bahan yang tidak mengandungi serat untuk bahan kontrol. Tahap ketiga kajian ialah kandungan rheologikal (rheological) Asfalt Bio Mastik likat di nilai menggunakan

alat Dynamic Shear Rhometer (DSR) berdasarkan keperluan penurapan yang dibuat oleh Strategic Highway Research Program (RTFO). Contoh turapan asfalt (unaged), Rolling Thin Film Oven (RTFO) aged dan Pressure Ageing Vessel (PAV) diukur untuk shear modulus, shear angle, shear strain menggunakan DSR kemudian dinilai berdasarkan keperluan SHRP. Keputusan kajian memperlihatkan bahawa serat yang diperoleh daripada tandan palma (EFB) sangat baik bagi semua sebatian BMA dibandingkan dengan sampel kontrol. Sampel kontrol di kategorikan sebagai PG58 telah berubah kepada PG76 dengan penambahan 0.375% serat buah palma. Minyak sawit juga meningkatkan kandungan rheologikal gabungan asfalt daripada PG58 kepada PG 70 dengan penambahan 0.3% minyak serat palma.

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In the name of Allah, the Most Compassionate, the Most Merciful. All praise is due to Allah, Lord of the Worlds, The Most Compassionate, the Most Merciful. Sovereign of the Day of Judgment. You alone we worship, and to you alone we turn for help. Guide us to the straight way; the way of those whom you have favored, not of those who have incurred your wrath, Nor of those who have gone astray (Al-Fatiha, the Opening chapter of the Holy Quran).

I would like to express my sincere appreciation to all who have contributed in this research. My greatest gratitude's forwarded to my project supervisor, Assoc. Prof. Dr. Ratnasamy Muniand**y** for his guidance, constructive comments, untiring support, invaluable advices and suggestions in completing this research successfully.

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Last but not least, may my family be blessed with good health, long life and happiness for all the love and care they have given me all this while. Thanks also for always having faith in me.

I certify that an Examination Committee has met on 12th November 2008 to conduct the final examination of Hossein Jafariahangari on his Master of Science thesis entitled “Performance of Cellulose Palm Fiber as an Additive in Asphalt Blends” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follow:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotation and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

HOSSEIN JAFARIAHANGARI

Date:

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AB	Asphalt Binder
AC	Asphalt Cement
Agg	Aggregate
AR	Aged Residue
ASTM	American Society for Testing and Materials
av	Average
AOH	Absorbable Organic Halides
AI	Asphalt Institute
BMA	Bio Mastic Asphalt
BOF	Basic Oxygen Furnace
BBR	Bending Beam Rheometer
CDPF	Cellulose Date Palm Fiber
COPF	Cellulose Oil Palm Fiber
CP	Chemical Pulping
CRMB	Crumb Rubber Modified Bitumen
DSR	Dynamic Shear Rheometer
DTT	Direct Tension Tester
P	SBR Polymer
PF	Date Palm Fiber
PMB	Polymer Modified Binder
DSR	Dynamic Shear Rheometer

EFB	Empty Fruit Bunch
ECF	Elemental Chlorine Free
EVA	Ethylene Vinyl Acetate
FRIM	Forest Research Institute of Malaysia
FELDA	Federal Land Development Authority
g	gram
GSLA	Granulated Synthetic Lightweight Aggregate
ha	Hectare
HMA	Hot Mix Asphalt
HWTD	Hamburg Wheel Tracking Device
ITS	Indirect Tensile Strength
JKR	Jabatan Kerja Raya
LVE	Linear Viscoelastic
Max	Maximum
min	Minute
Min	Minimum
NAPA	National Asphalt Pavement Association
OAC	Optimum Asphalt Content
PAV	Pressure Aging Vessel
PG	Performance Grade
PFP	Date Palm Fiber and Polymer
RMP	Refinery Mechanical Pulping
RPM	Revolutions Per Minute
RTFO	Rolling Thin Film Oven

RTFOT	Rolling Thin Film Oven Test
RV	Rotational Viscometer
SHRP	Strategic Highway Research Program
SMA	Stone Mastic Asphalt
SEM	Scanning Electron Microscope
SBR	Styrene Butadiene Rubber
TAPPI	Technical Association of the Pulp and Paper Industry
TMP	Thermal Mechanical Pulping
TCF	Total Chlorine Free
t	Ton
T	Temperature
TF	Textile Fiber
TFP	Textile Fiber and Polymer
TSR	Tensile Strength Ratio
USM	Universiti Sains Malaysia
UPM	Universiti Putra Malaysia
U.S	United States
U.S.A	United States of America
WA	Western Australian

CHAPTER 1

INTRODUCTION

1.1 Background

Asphalt binders have been widely used in flexible pavements because of their good adhesion to mineral aggregates and viscoelastic properties (Akmal and Usmani 1999). Unfortunately, asphalt mixture or coating layer shows severe temperature susceptibility such as high-temperature rutting, medium-temperature fatigue and low-temperature cracking damage. Therefore, asphalt mixtures should be modified in some way to improve their rheological properties.

According to Roberts et al. (1996) an estimate of 500 million tons of hot mix asphalt was produced and placed in pavement in the United States alone, costing about $10.5 billion. Scientists and engineers are constantly trying to improve the performance of these pavements through programs such as the Strategic Highway Research Program (SHRP); SHRP began developing new performance related tests for measuring the physical properties of asphalt binder.

Modification and stabilization of the asphalt binder is one approach to improve the pavement performance especially for gap-graded mixtures such as Stone Mastic Asphalt (SMA) which require higher viscosity asphalt binder. A common method for asphalt binder modification is by adding polymer, although rubber and other oil based materials are being used to enhance the viscosity of the base binder. The rheological performance of the traditionally 80/100 penetration-graded asphalt