



UNIVERSITI PUTRA MALAYSIA

**DEVELOPMENT OF CRACK MEANDER PROTOCOL FOR FATIGUE
RESISTANCE IN STONE MASTIC ASPHALT MIXTURE USING
CELLULOSE FIBERS**

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FK 2011 33

**DEVELOPMENT OF CRACK MEANDER PROTOCOL FOR FATIGUE
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CELLULOSE FIBERS**

By

SIROUS RADKEYA

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirement for the Degree of Doctor of Philosophy**

April 2011

DEDICATION

To my most beloved wife

for all understanding, patience and support during all difficulties
and for her help during my study

To my lovely son, Shayan,

To my dearest parents, brothers, and sisters

To my friend, Hamed,

for his technical help during my study

And

Thank you for everything and God bless you

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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April 2011

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One of the major distresses in asphalt pavement is fatigue cracking, which is caused by cyclic traffic loading. These cracks may begin as micro-cracks that grow, propagate, and combine into macro-cracks. The fatigue resistance of bituminous materials has been investigated in the laboratory using various fatigue test methods for many years. But the move for modeling the crack propagation during fatigue procedure has been recently started. This study was undertaken based on three objectives: first, to find out the rheological characteristics of cellulose oil palm fiber blended asphalt prior to use in Asphalt mixture. Investigating mechanical and chemical properties of cellulose oil palm fiber, physical properties of aggregate and asphalt binder were first stage of first objective followed by determination of optimum asphalt content (OAC). Blending asphalt binder with different percentages of cellulose oil palm fiber was also carried out as a part of first objective which completed by determination of rheological properties of blends and investigating

behavior of blends (neat, RTFO aged and PAV aged) using Dynamic Shear Rheometer (DSR). The second objective was to evaluate the fatigue resistance of Stone Mastic Asphalt (SMA) with various proportions of cellulose fiber. Based on OAC obtained from first objective, twelve slabs (six slabs for beam samples and six slabs for cylindrical samples) were prepared using Turamesin for carrying out second objective. Four point beam fatigue test and indirect tensile fatigue test were used to investigate the effect of different percentages of cellulose fiber on fatigue life of SMA mixtures. It was found that adding 0.2 to 0.4 percent of cellulose fiber results best in fatigue performance of both asphalt binder and asphalt mixture. Evaluation the effect of different percentages of cellulose fiber in crack propagation and to correlate between cracks and fatigue resistance was defined as third objective. The main focus of third objective was to develop a crack meander protocol for the fatigue resistance of stone mastic asphalt mixture using cellulose fiber. AS a part of third objective, a new computer program called Measurement and Mapping the Crack Meander (MMCM) was designed and developed. MMCM was aimed for measuring and mapping the cracks of SMA samples from beginning to the end of fatigue test. Based on the MMCM results and reports, the behavior of crack propagation was modeled and the resistance to crack propagation was evaluated by introducing Crack Propagation Rate (CPR) and Crack Area Development (CAD). Finally all the different mixtures (no fiber, 0.2% fiber, 0.4% fiber, 0.6% fiber, 0.8% fiber and 1.0% fiber) were ranked using direct comparison of CPR and CAD. In most cases PF0.2 showed the best resistance against crack propagation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

**DEVELOPMENT OF CRACK MEANDER PROTOCOL FOR THE
FATIGUE RESISTANCE OF STONE MASTIC ASPHALT MIXTURE USING
CELLULOSE FIBERS**

Oleh

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April 2011

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Salah satu daripada kegagalan jalanraya adalah retakan lesu yang mana disebabkan kitaran beban trafik. Keretakan ini bermula dengan keretakan mikro yang berkembang, merebak dan bergabung menjadi keretakan makro. Rintangan lesu oleh bahan- bahan di dalam campuran bitumen disiasat dimakmal menggunakan pelbagai ujian lesu setelah bertahun- tahun. Tetapi, baru- baru ini kajian tentang model perkembangan keretakan ketika prosedur kelesuan telah dimulakan. Kajian ini dijalankan berdasarkan tiga objektif; pertama, untuk menentukan karakter reologi gentian selulos kelapa sawit bersama asphalt yang digunakan dalam campuran asphalt. Penyiasatan ciri- ciri mekanikal dan kimia gentian selulos kelapa sawit, ciri- ciri fizikal agregat dan asphalt adalah peringkat awal dalam objektif pertama diikuti dengan penentuan kandungan optimum asphalt (OAC). Campuran asphalt dengan berbeza- beza peratus kandungan gentian selulos kelapa sawit juga adalah sebahagian daripada objektif pertama yang telah diselesaikan dengan penentuan ciri-

ciri reologi dan penyiasatan sifat- sifat campuran tersebut (asfalt asli/baru, penuaan RTFO dan penuaan PAV) menggunakan ‘Dynamic Shear Rheometer’ (DSR). Objektif kedua adalah untuk menilai rintangan lesu Asfalt Mamah Batu (SMA) dengan berbeza- beza kandungan gentian selulos. Berdasarkan OAC yang diperoleh dari objektif pertama, dua belas papak (enam untuk sampel rasuk dan enam untuk sampel silinder) disediakan menggunakan Turamesin untuk melaksanakan objektif kedua. Ujian lesu rasuk empat titik dan ujian lesu tegangan tidak langsung digunakan untuk menyiasat kesan perbezaan peratus kandungan gentian selulos keatas kelesuan campuran SMA. Didapati penggunaan 0.2 hingga 0.4 peratus gentian selulos memberi keputusan terbaik dalam prestasi kelesuan untuk asfalt mahupun campuran asphalt. Penilaian kesan keatas perbezaan peratus gentian selulos didalam perkembangan keretakan serta untuk menghubungkan antara keretakan dan rintangan lesu dilaksanakan objektif ketiga. Fokus utama objektif ketiga adalah untuk membangunkan protokol ‘crack meander’ untuk rintangan lesu asfalt mamah batu menggunakan gentian selulos. Sebahagian daripada objektif ketiga, satu program komputer baru dinamakan Pengukuran dan Pemetaan ‘Crack Meander’ (MMCM) telah direka dan dibangunkan. MMCM bertujuan untuk mengukur dan memetakan keretakan sampel SMA dari mula hingga akhir ujian lesu. Berdasarkan keputusan MMCM, perlakuan perkembangan keretakan telah dimodelkan dan rintangan perkembangan rintangan keretakan dinilai melalui pengenalan Kadar Perkembangan Keretakan (CPR) dan Perkembangan Kawasan Keretakan (CAD). Akhir sekali, semua campuran (tanpa gentian, 0.2% gentian, 0.4% gentian, 0.6% gentian, 0.8% gentian dan 1.0% gentian) disusun kedudukannya menggunakan perbandingan langsung CPR dan CAD. Dalam kebanyakan kes, 0.2 peratus gentian menunjukkan rintangan yang terbaik terhadap perkembangan keretakan.

ACKNOWLEDGEMENTS

Firstly, I would like to acknowledge the value of discussions with my supervisor Prof. Madya Dr. Ratnasamy Muniandy for his invaluable advice, encouragement, guidance, and support. I also gratefully acknowledge the contribution of the supervisory committee members Prof. Madya. Dr. Ahmad Rodzi Bin Mahmud and Senior Lecturer Dr. Hussain Bin Hamid for providing me the opportunity to complete my studies under their valuable guidance.

The work described in this thesis was made possible by the Civil Engineering Department of Universiti Putra Malaysia with providing the numerous facilities and support for this research work.

Last but not least, my very special thanks to all my friends who were directly and indirectly involved in this research and cooperated with this study.

APPROVAL SHEETS

I certify that a Thesis Examination Committee has met onto conduct the final examination of Sirous Radkeya on his thesis entitled " Development of Crack Meander Protocol for the Fatigue Resistance of Stone mastic Asphalt Mixture Using Cellulose Fibers " in accordance with the Univesrities 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 Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work as per program except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently submitted for any other degree at Universiti Putra Malaysia or at any other institutions.



SIROUS RADKEYA

Date: 7 April 2011

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