PAVEMENT CONDITION PERFORMANCE ON CRUMB RUBBER ROAD IN KUALA KRAI, KELANTAN

NAZIRUL MUBIN BIN ZUKIRNAINI

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Faculty of Engineering
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DEDICATION

This work is dedicated to the sincerest,

Loving and caring parents,

My beloved Father and Mother,

Zukirnaini Bin Mustapha,

Wan Nazila Binti Wan Ahmed,

My beloved Father and Mother in law,

Saadi Bin Che Ismail,

Hasnah Binti Mohd Nor,

And my supportive wife,

Siti Sahirah Binti Saadi.

All my dear children,

Nafeesha Inara, Naila Irdina and Niyaz Iskandar.

Hopefully these efforts given consideration and rewarded by Allah.

As the Prophet Muhammad S.A.W said:

“Whoever follows a path to seek knowledge,

Allah will make the path to Jannah (Paradise) easy for them.”

(Shahih Muslim)

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ABSTRACT

Paved roads are the main public transportation infrastructure in Malaysia. Asphaltic pavements require a hefty amount of thoughts and engineering to be made viable to keep up with the growing traffic as the country develops. The constant increase in traffic loads by calls for improvements need to be done in order to maintain a quality, yet economical paved roads. One of the critical breakthroughs is the use of crumb rubber as additive in the binding substance of asphaltic pavements. Thus, this study aims to assess the effectiveness of crumb rubber modified asphalt (CRMA) pavements in Kuala Krai, Kelantan. This research was done through both controlled experiment in a laboratory and also on site. The physical properties of the bitumen in terms of their penetration, softening points, penetration index and flash points have been further tested. For the asphalt mixture, they were tested in regards to their Marshall properties such as stability, Void-In-Mix (VIM), flow and stiffness. The field test begins with the coring test in order to assess the thickness of the asphalt pavement layers in 16 spots along the study location. The densities and bitumen content of the samples were then evaluated. Generally, CRMA proves its efficacy in providing an effectual performance. In almost all aspect of experimentation revealed that CMRA was the better choice. It is relatively stable, with sufficient VIM percentage to provide flexibility. The field test did not contradict with these findings. Conclusively, CMRA is able to accommodate and provide good riding quality while also being durable to sustain all its challenges.

ABSTRAK

Jalan berturap adalah infrastruktur pengangkutan awam utama di Malaysia. Turapan *asphalt* memerlukan banyak idea dan kejuruteraan agar dapat membangun secara praktikal dengan lalu lintas yang semakin meningkat seiring dengan kemajuan negara. Peningkatan lalu lintas yang berterusan, menyebabkan kerja-kerja penambahbaikan perlu dilakukan bagi mengekalkan jalan berturap yang berkualiti dan ekonomik. Salah satu penyelesaian penting adalah dengan penggunaan serpihan getah tayar kenderaan sebagai bahan tambahan dalam bahan pengikat turapan *asphalt*. Oleh itu, kajian ini bertujuan untuk menilai keberkesanan turapan *Crumb Rubber Modified Asphalt* (CRMA) di Kuala Krai, Kelantan. Penyelidikan ini dilakukan melalui eksperimen terkawal di makmal dan juga di lokasi. Sifat fizikal bitumen dari segi penusukan, titik lembut, indeks penusukan dan titik kilat telah diuji lebih lanjut. Untuk campuran asfalt, bahan-bahan berkenaan diuji dengan ujian asphalt (*Marshall Test*) seperti kestabilan, *Void-In-Mix (VIM)*, aliran dan kekerasan. Ujian lapangan dimulakan dengan ujian *coring* untuk menilai ketebalan lapisan turapan asfalt pada 16 tempat di sepanjang lokasi kajian. Kemudian, ketumpatan dan kandungan bitumen sampel telah dinilai. Secara amnya, CRMA telah terbukti keberkesanannya dalam memberikan prestasi yang berkesan. Dalam hampir semua aspek eksperimen, CMRA telah menunjukkan bahawa ia adalah pilihan yang lebih baik. Ia agak stabil, dengan peratusan VIM yang mencukupi untuk memberikan fleksibiliti. Keputusan ujian lapangan tidak bertentangan dengan rekabentuk yang telah diluluskan. Kesimpulannya, CMRA mampu menampung dan memberikan kualiti yang baik dan juga tahan lama untuk menanggung beban aliran lalu lintas yang semakin meningkat.

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LIST OF ABBREVIATIONS

CRMB	-	Crumb Rubber Modified Binder
CRMA	-	Crumb Rubber Modified Asphalt
CR-GGA	-	Crumb Rubber – Gap Graded Asphalt
CR-SMA	-	Crumb Rubber – Stone Mastic Asphalt
CR-OGFC	-	Crumb Rubber – Open Graded Friction Course
CR-SAMI	-	Crumb Rubber – Stress Absorbing Membrane Interlayer
CMB	-	Cup Lump Modified Binder
CMA	-	Cup Lump Modified Asphalt
HMA	-	Hot Mix Asphalt
AC 14	-	Asphaltic Concrete 14
ASTM	-	American Society for Testing and Materials
BS	-	British Standards
PI	-	Penetration Index
MS	-	Malaysian Standards
VIM	-	Voids in mix
PG 76	-	Performance Grade 76
Pen. 60-70	-	Penetration Grade 60-70

LIST OF SYMBOLS

°C	-	Celsius
%	-	Percent
g	-	Gram
N	-	Newton
N/mm	-	Newton/millimeter
mm	-	Millimeter
cm	-	Centimetre
um	-	Micrometre
Pa.S	-	Pascal per second
kPa	-	Kilopascal
rpm	-	Revolutions per minute

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CHAPTER 1

INTRODUCTION

1.0 Background Study

In pavement structures, wearing course and base coarse aggregates are mixed and bound using bitumen. Asphalt is used in road pavement as it's very economical and fulfills the roadway design requirements, for example; good ride quality, skid-resistant surface, quiet surface and low maintenance. However, asphaltic pavements do have some weaknesses, especially in extreme climates where it becomes brittle and hard in cold environments and soft in hot environments making it easy to crack when the temperature fluctuates (Al-maamori and Hussen, 2014). Another major factor for road damage is the current traffic capacity and the volume of road users that increases year by year, defecting and affecting the pavement condition. Heavy traffic and high loading weight are also significant factors affecting the quality and pavement performance. Therefore, to decrease damage and defect, an improvement is needed in the road pavement structures. Globally, many additive materials such as Polymer Modified Asphalt (PMA), Stone Mastic Asphalt (SMA), Cold in-place recycling (CIPR), Glassphalt, Cup Lump Modified Asphalt (CMA) and Crumb Rubber Modified Asphalt (CRMA) are used to make road pavements stronger (Huang *et al.*, 2007).

In previous years , the growing popularity of crumb rubber, a recycled material from End-of - Life Tyres (ELTs), has led to several studies to be carried out in order to improve the material cycle where rubber, produced as a by-product of crushing and sieving scrap tyres, has become the resource needed in another production process, such as the construction of road pavement layers. Crumb Rubber Modified Asphalt (CRMA) has various applications in the production of asphalt mixtures (Issa, 2016). The aim is to find an alternative method of disposal of tyres and to improve the performance of asphalt mixtures. Rubber, in general, has a wider range of performance temperatures than bituminous mixtures, as they do not melt in heat and do not crack in

cold temperatures. However, the performance of rubberized materials varies considerably depending on the processes and technology used. Some studies, indicate that CRMA modified mixtures are less affected by moisture damage compared to traditional mixtures, and that rubber particles contribute to the completion of higher performance of both binders and mixtures at high temperatures (Farina *et al.*, 2014). On the other hand, if other processes are adopted, certain studies have shown that a higher volume of air voids would be present due to the decreased compaction of the mixture could lead to a higher moisture content. Therefore, these types of CRMA mixes are more susceptible to moisture than conventional mixes.

Besides that, crumb rubber is an appropriate pavement additive due to one of its characteristics, which is the ability to support the weakness of asphalt. The elastic property of crumb rubber also has the potential to improve skid resistance and asphalt durability (Farina *et al.*, 2014). The usage of crumb rubber is proven to be good and reliable. Moreover, crumb rubber can also help in decreasing the effect of exhaustion and cracking that occur on most pavements. In addition, it can save the cost for the maintenance of roadway pavement as pavements are less vulnerable to damages as a result of the crumb rubber additives.

The addition of crumb rubber typically results in an increase in the complex modulus of the binder as well as a reduction in the phase angle, particularly at high temperatures, which has a favourable effect on the rutting resistance (Hassan et al . 2014). However, these materials are not without limitations. For example, the instability during storage is one of the disadvantages of the industrial production of this material. The rubber modified bitumen has a higher heterogeneity and there is a significant difference in density between the bitumen and the rubber granules. When that method is applied, the rubber particles have the propensity to sink to the bottom, and also decreasing the storage constancy (Chen *et al.*, 2018).

It can be understood from previous considerations that there are a number of different types of processes and technologies when crumb rubber is used in asphalt mixture applications that result in different performance and durability. With this in mind, this study provides scientific research with a description and nomenclature of

key mechanisms, processes and technologies related to the use of crumb rubber in road pavements.

1.1 Problem Statement

The inappropriate management of solid waste such as rubber tyres and plastic bags may progress into very serious environmentally related issues. Several studies have shown that about 90% of solid waste is disposed of in open dumps and landfills, creating problems and hazards to public health and the environment (Sharholy *et al.*, 2007). Waste tyres are one of the environmental problems in Malaysia. This problem needs to be urgently solved because waste tyres are not easily decomposed. The recycling of such tyres would be one method to save the space. Besides that, the application of recycled automobile tyres and plastics also can solve the environmental problem.

Additionally, the failures of pavement have increased significantly over the years due to the increase in road traffic which is proportional to the degree of insufficient maintenance. Over the years, the damage of roadway pavement in Malaysia has been increasing. A great deal of maintenance work needs to be done to reduce defects or damage on the roadway. This is because of the heavy traffic load in Malaysia. When the road users increase, the loading on the road will simultaneously be increased and the pavement will develop complications if the pavement cannot support the high loading or volume (Sulyman *et al.*, 2014).

Moreover, asphalt cannot withstand drastic weather changes as it hardens in cold environments and softens in hot environments. Previous studies have shown that a number of failures have caused its quality and pavement performance to decrease due to low temperature cracking, extreme fatigue, and rutting at high temperatures (Chen *et al.*, 2018).

Thus, the potential of crumb rubber as an additive in asphalt pavement has been further investigated in this research.

1.2 Objectives

The main objective of this project is to investigate the strength and condition of road pavement when crumb rubber is used as additive in asphalt pavement. The specific objectives for the project are:

i. To identify Crumb Rubber Modified Bitumen (CRMB) properties compared to penetration grade bitumen.

ii. To investigate the performance of Crumb Rubber Modified Asphalt (CRMA) compared to other types of asphalt mixtures.

1.3 Scope of Study

The research has involved the study of the performance of modified bitumen using the waste materials crumb rubber has been added as a modifier to the bituminous mixture by carrying out laboratory procedures using the equipment available in the road laboratory. The bituminous mixture sample was tested (in the laboratory and field) for its performance and analysis was carried out based on the results.

1.4 Significance of Study

The aim of the project is to study the performance of crumb rubber in modified bitumen. By doing this, it will enable the reduction of costs as well as improve the performance of flexible pavement for future road construction due to the involvement of a more environmentally friendly materials.

This research is important in order to solve the problem of pavement strength along with environmental issues which arise from waste tyres. Both issues can be resolved by reusing scrap tyres by producing crumb rubber that will then be used in road construction by adding it as a sub-base or surface coarse pavement layer.

One of the major advantages of using CRM in road pavements is that, it can improve the resistance of bitumen to surface initiated cracks, decrease the fatigue, reflection, and cracking, improve toughness as well as a reduction in road pavement maintenance costs (Liu *et al.*, 2009).

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