MICROWAVE PROPERTIES OF BITUMEN MODIFIED WITH WASTE COOKING OIL (WCO)

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Transportation)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2019

DEDICATION

Specially dedicated to my beloved family.

ACKNOWLEDGEMENT

First of all, profound thanks to my indefatigable supervisors, Dr. Md Maniruzzaman B. A. Aziz and Dr. You Kok Yeow for his supervision, guidance, instructions, advice and encouragements throughout this mission. I really appreciated the supportive comments and suggestions.

For my supportive family, I thank you so much for the affections and inspiring me through my difficult times. Their supports made all of my dream possible. In addition, my exceptional thanks to all my friends for their amiable support and encouragement during this project.

Last but not least my appreciations to my able wife and children for their endurance and patience during the course of my study. Finally, my regard to those who involved directly and indirectly in helping me to complete this research project and their names are not mentioned. I seek everyone's apology for any inconvenience caused throughout the work. Thank you and God bless.

ABSTRACT

Bitumen is a rheological, viscoelastic, thermoplastic and extremely complex material that has hydrocarbons as its predominant molecules with slight traces of others. Bitumen is semi solid at room temperature, liquid at high temperature and solid at very low temperature. Due to its complexity, till date complete understanding of its properties have not been fully known. Various techniques/methods have been developed by many researchers in order to study the behaviour of this complex material. In this work, we studied the performance of bitumen PEN 60 – 70 and PG 76 modified with Waste Cooking Oil (WCO) using the conventional tests and, Dielectric Constant (DC) and Loss Factor (LF). The conventional tests conducted were penetration, softening point and viscosity tests. The DC measurement was carried out at 2.45 GHz (ISM Band) while the LF was measured at 500 MHz frequencies. The results of the conventional tests show that increasing the percentage of WCO has effect on the bitumen binders by increasing their penetration values and at the same time decreasing their softening point and viscosity. Also based on the DC value, the performance of PG 76 bitumen binder reduced with the increment in the WCO percentage. However, the results of the LF for two modified bitumen binders were illogical. Comparatively, the modified PG 76 bitumen binder will performance better than the modified PEN 60 – 70 bitumen.

ABSTRAK

Bitumen adalah bahan rheologi, viskoelastik, termoplastik dan sangat rumit yang mempunyai hidrokarbon sebagai molekul utama dan juga sedikit kesan lain. Bitumen separa pepejal pada suhu bilik, cair pada suhu tinggi dan pepejal pada suhu yang sangat rendah. Kerana kerumitannya, sehingga kini, pemahaman lengkap tentang sifatnya belum diketahui sepenuhnya. Pelbagai teknik / kaedah telah dibangunkan oleh banyak penyelidik untuk mengkaji kelakuan bahan kompleks ini. Dalam kerja-kerja ini, kami mengkaji prestasi bitumen PEN 60 - 70 dan PG 76 terubahsuai dengan Minyak masak buangan (WCO) dengan menggunakan ujian konvensional dan, Dielektrik berterusan (DC) dan faktor kegagalan (LF). Ujian konvensional yang dijalankan adalah penembusan, titik pelunakan dan ujian kelikatan. Pengukuran DC dijalankan pada 2.45 GHz (Band ISM) manakala LF diukur pada frekuensi 500 MHz. Keputusan ujian konvensional menunjukkan bahawa, peningkatan peratusan WCO memberi kesan tehadap pengikat bitumen dengan meningkatkan nilai penembusan dan pada masa yang sama mengurangkan titik pelembutan dan kelikatan. Juga berdasarkan nilai DC, prestasi pengikat bitumen PG 76 berkurang dengan kenaikan dalam peratusan WCO. Walau bagaimanapun, keputusan LF untuk dua pengikat bitumen yang terubahsuai adalah tidak logik. Sebagai perbandingan, pengikat Bitumen PG 76 terubahsuai akan lebih baik daripada bitumen PEN 60 - 70 terubah suai.

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LIST OF ABBREVIATIONS

AASHTO	-	American Association of State Highway and Transportation Officials
ASTM	-	American Society for Testing and Material
PEN	-	Penetration
PG	-	Performance Grade
WCO	-	Waste Cooking Oil
DC	-	Dielectric Constant
UTM	-	Universiti Teknologi Malaysia
LF	-	Loss Factor
IEEE	-	Institution of Electrical and Electronics Engineering
TEM	-	Transverse Electromagnetic Mode
MUT	-	Material Under Test
MW	-	Microwave
SuPerPave	-	Superior Performance Pavement
SN	-	Sample Number
D	-	Dipersitivity
MSI	-	Molecular Size Index

LIST OF SYMBOLS

δ	-	Minimal error
D, d	-	Diameter
F	-	Force
v	-	Velocity
p	-	Pressure
I	-	Moment of Inersia
r	-	Radius
Re	-	Reynold Number
Z	-	Impedance in MUT
$\eta = Z_0$	-	Impedance of Free-Space
μ_0	-	Permeability of the Free-Space
λ_d	-	Wavelength in MUT
λ_0	-	Wavelength in Free-Space
c	-	Velocity of Light in Vacuum
v	-	Velocity of Wave in a Medium
v_d	-	Velocity of Wave in MUT
v_0	-	Velocity of Wave in Free-Space
f	-	Frequency

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

Flexible pavement consists of aggregate particles (coarse and fine) that are glued together by bitumen binder at high temperatures. Traditional bitumen binder is a residue found through the crude petroleum refining process. Due to the improvement in environmental regulations for new drilling, declining existing resources, and changes to the refining process that maximize the fuel quantity while curtailing bitumen residue have recently increased the cost of bitumen (Haifang Wen., 2013). Thus, it becomes more imperative to explore the likely alternative binder material to completely or partially replace the petroleum-based bitumen for the sustainable developments of flexible pavements.

Several ways to modify bitumen exist. For the road construction industry, modification entails the addition of either liquid or solid into the bitumen or asphalt: fillers, chemical agents, wetting adhesion agents, polymers, waste oil, additives to reduce the bitumen viscosity. All additives should ideally enhance the performance of the constructed roads.

Bitumen plays a significant role particularly for coating in construction of pavement. In improving the physical intertwining of bituminous mixtures, bitumen functions as suitable binder. But, as its ages overtime, bitumen properties changes traceable to mixing, transport, paving and storage on site. The composition of bitumen of bitumen has its greatest effect on aging. Oxidation and volatility combine together are mostly the cause of physical and rheological properties change that instigates failure which is from consistency change (hardening) to embrittlement. The occurrence of oxidation is usually concurrently with loss of minor molecular weight volatiles. Concentrations, temperature and environment determine the rate at which the loss is occurring. Since the loss rate rely on such conditions, to handle bitumen at high temperature volatility is important. Therefore, bitumen aging give rise to deterioration and considerable distress like cracking, fatigue and rutting (Asli and Karim, 2011).

Bitumen binder can be modified with WCO by blending at different proportions of the oil contents. Modification of bitumen binder and blending recycled bituminous concrete with WCO showed improvement in the performance qualities of the resulting blends from previous research (Chen *et al.*, 2014b; Sun *et al.*, 2017; Wen *et al.*, 2012).

Microwave is an effective problem-solving tool for the determination of material parameters. Musil and Zacek (1986) highlighted the importance of microwaves for the determination of microwave material parameters which is closely related to microparameters of the materials. They further stated that the properties of materials medium and the electromagnetic field quantities are described by permittivity ε and permeability μ of a medium. Bartley and Begley (2005) conducted an experiment based on improved free-space calibration and reported that the dielectric properties (permittivity) of a material are fundamental and unique, and independent of measurement techniques. The dielectric value denotes the material capacity in storing and then allowing the traversing of electromagnetic energy as a result of imposition of electrical field upon it. It can be defined also as a measure of the capability of a material in an electromagnetic field to turn out to be polarized, and thus respond to electromagnetic waves propagation. Materials dielectric properties are interrelated to the electric dipole moment and influence by the applied electric field frequency, materials composition and temperature (Aziz *et al.*, 2010; Chang *et al.*, 2010).

1.2 Problem Statement

According to Chebil et al (2000), bitumen binder that is produced through the process of crude petroleum oil refining usually does not show the anticipated properties for road pavement applications. Neat bitumen, which shows unsatisfactory properties as a pavement construction binder needs to be improved with different kinds of additives consisting fine materials, polymers, oils and carbonaceous materials. Consequently, substantial amount of research need to be carried out by means of the method through the process of modification on improvement of the properties of bitumen binder (Azahar *et al.*, 2016a).

Bitumen modification by means of additives can be regarded as one of the efficacious engineering solutions that should currently be practiced (Bahia *et al.*, 2001) so as to decrease deterioration and improve strength of a bituminous layer. The performance properties of a bituminous layer like fatigue, resistance to permanent deformation and so on should be improved.

Currently, microwave and radio-frequency signals are employed for a wide variety of applications. This comprises of wireless communication systems, mobile phone, radar, telemetry, medicine, biology, agriculture, industrial process control, etc. Significant efforts have also been dedicated in the direction of the development of electromagnetic application in highway engineering (Chang*, et al.*, 2010). According to Ma and Okamura (1999), microwave measurement methods are dynamic and their parameters can be measured instantaneously, and the waves have no effect on the Material Under Test (MUT) in any way (Nyfors and Vainikainen, 1989). According to Khan and Ali (2012), every material have different electrical characteristics and these characteristics are dependent on the material dielectric properties. Valuable information is provided by these properties which helps engineers and researchers in utilising such information in design, material characterisation or for monitoring process quality. Thus, microwave will be used in this study to determine the parameters of bitumen modified with WCO.

1.3 Research Objectives

The aim of this study is to investigate the microwave properties of bitumen modified with WCO. In order to achieve the aim, the following objectives were set:

(a) To evaluate the physical properties of PEN 60 – 70 and PG 76 bitumen modified with WCO and their microwave properties.

(b) To develop a correlation between the physical and microwave properties of bitumen modified with WCO.

1.4 Scope of the Study

In order to achieve the objectives of this study, the research emphasised on the use of microwave techniques to determine the properties of bitumen modified WCO. The microwave properties of the modified binder were determined using Open-ended Coaxial Probe (OCP) method. The study also included the determination of physical tests such as penetration, softening point and viscosity for both conventional and modified bitumen of PEN 60 – 70 and PG 76. The modification was done by substituting the base binder with 0.0, 1.5, 3.0 and 4.5% of the WCO. Samples were prepared with different percentages of WCO and bitumen binder at a mixing temperature of 165° C for PEN 60 – 70 and 185° C for PG 76. The WCO was collected from restaurants within the Universiti Teknologi Malaysia (UTM) main campus in Johor.

1.5 Research Significance

Petroleum bitumen, which is the *derivative* of crude oil refining, is normally used in construction of pavement. However, petroleum scarcity is increasing because it is a non-renewable resource, this contributed to the supply of petroleum bitumen to be short. Discovering bitumen substitute will be a way of resolving this problem. Waste materials utilization to partially substitute bitumen from other industries will not only decrease bitumen utilization but also increase the performance of bitumen in pavement. This will have countless good social and economic consequences to the recycling of resources and sustainable development, and at the same time reduce pollution and disposal problems. Also, the use of microwave will provide additional method in analysing modified bitumen.

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