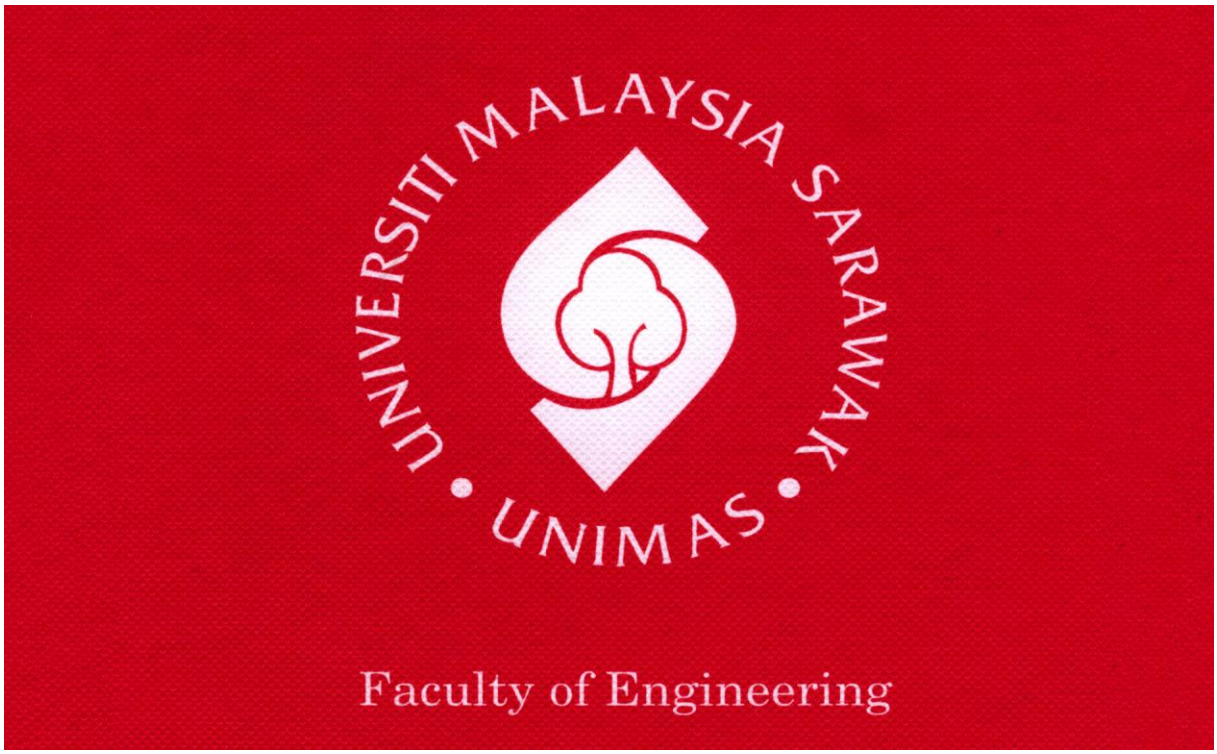

RECYCLE TYRE RUBBER AS FINE AGGREGATES REPLACEMENT IN HOT MIX ASPHALT (HMA)

FONG PAU HUA

Bachelor of Engineering with Honours
(Civil Engineering)
2018

UNIVERSITI MALAYSIA SARAWAK

Grade: WK01

Please tick (√)

Final Year Project Report	√
Masters	
PhD	

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RECYCLE TYRE RUBBER AS FINE AGGREGATE IN HOT MIX ASPHALT (HMA)

FONG PAU HUA

A dissertation submitted in partial fulfillment

of the requirement for the degree of

Bachelor of Engineering with Honours

(Civil Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

2018

ACKNOWLEDGEMENT

First and foremost, I wish to express my deep gratitude to my supervisor, Mr. Larry Silas Tirau for guiding me throughout the period of my thesis work and generously sharing his knowledge with me. Without his patient and guidance, this report would not be successfully completed.

I am also very thankful to my best friends for their help, encouragement, motivation and friendship throughout the thick and thin of my laboratory work period. Highway laboratory technician, Mr. Saiful also deserves special thanks for his assistance in lending his help in the times of needs, especially his guidance and teaching on the laboratory equipment. Furthermore, I wish to extend my sincere gratitude to my senior and others that involved indirectly who provide assistance at various occasions.

Last but not least, a very special thanks to my below mother and father for being so understanding and supportive during my final year of taking this subject and complete the report.

ABSTRACT

The number of scrap tyre generated every year has reached an alarming state due to the rapid development of roadway and high demand in transportation vehicles. Since the scrap tyre rubber is not biodegradable, this will create severe negative impacts to the environment in term on air, water and soil pollution. In order to minimize this massive number of scrap tyre, they need to be recycled and reclaimed to form new product such as asphalt component. Based on the past researches, the usage of recycle tyre rubber has been proven workable to be used in asphalt road pavement industry. Therefore, this research aimed to modify the conventional bituminous mixes by using recycle tyre rubber as a partial replacement to fine aggregate, hoping that a better mixes will be produced and perform better than the conventional mix design. An investigation was conducted by using PEN 60/70 on a range of ACW 14 to investigate the effect of utilization of recycle tyre rubber as a partial fine aggregate replacement of size 0.425mm in ACW 14 mixtures. Total number of 15 samples of control specimens and 27 samples for modified specimens have been prepared. Replacement of fine aggregate by recycle tyre rubber has been set to 12.5%, 25% and 50% in order to test the optimum recycle tyre rubber content for the mix design. Marshall results obtained for both the standard and modified bituminous mixes were found to be in agreement with the specifications prescribed by JKR. The optimum recycle tyre rubber content obtained through this experiment is 12.5% with 75 blows of compaction. From the results, it can be concluded that recycle tyre rubber has performed exceptionally well under the tests needed to confirm for its utilization as fine aggregate replacement materials in ACW 14 and it will shift gears to sustainable pavement construction.

ABSTRAK

Kenaikan bilangan buangan tayar kenderaan terpakai telah mencapai tahap yang membimbangkan disebabkan kemajuan dan pembangunan jalan raya serta permintaan tinggi penggunaan pengangkutan jalan raya. Fenomena ini telah memberi impak negatif kepada alam sekitar dari segi kualiti udara, air dan juga tanah. Sebagai langkah untuk mengurangkan bilangan buangan tayar kenderaan yang terpakai, ia perlu digunakan semula atau dikitar semula untuk dijadikan sebagai salah satu komponen turapan jalan raya. Berdasarkan kajian-kajian yang sebelumnya, penggunaan tayar kenderaan kitar semula telah terbukti mampu digunakan dalam industri pembinaan jalan raya turapan. Dengan ini, kajian ini bertujuan untuk mengubah suai campuran bitumen konvensional dengan menggunakan tayar kenderaan kitar semula sebagai pengganti separa agregat halus, dengan harapan bahawa campuran yang lebih baik akan dihasilkan dan prestasi yang lebih baik daripada reka bentuk campuran konvensional. Satu kajian menggunakan PEN 60/70 ke atas ACW 14 turut dijalankan untuk mengkaji pengaruh penggunaan tayar kenderaan kitar semula sebagai penggati separa agregat halus di dalam campuran ACW 14. Jumlah bilangan 15 sampel spesimen kawalan dan 27 sampel spesimen diubah suai telah disediakan. Penggantian agregat halus dengan tayar kenderaan kitar semula telah ditetapkan kepada 12.5%, 25% dan 50% untuk menguji kandungan kenderaan tayar kitar semula yang optimum untuk reka bentuk campuran. Keputusan Marshall yang diperolehi bagi kedua-dua standard dan diubahsuai campuran bitumen menunjukkan kesinambungan dengan spesifikasi yang ditetapkan oleh JKR. Optimum kandungan tayar kenderaan kitar semula diperolehi melalui eksperimen ini adalah 12.5% dengan pemandatan 75 kali. Secara kesimpulannya, tayar kenderaan kitar semula menunjukkan pelaksanaan yang sangat baik sebagai pengganti agregat halus dalam ACW 14 seiring dengan konsep pembangunan mapan dalam pembinaan jalan raya turapan.

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LIST OF ABBREVIATIONS

RTR	-	Recycle Tyre Rubber
ASSHTO	-	American Association of State Highway and Transportation Officials
AC	-	Asphalt Concrete
ASTM	-	American Society for Testing and Materials
JKR	-	Jabatan Kerja Raya
OBC	-	Optimum Binder Content
SSD	-	Saturated Dry Surface
VFB	-	Void Filled with Bitumen
VIM	-	Voids in Total Mix
VMA	-	Voids in the Mineral Aggregate

CHAPTER 1

INTRODUCTION

1.1 Background

The rapid development of roadways has made automobiles an essential to all. This surcharge development eventually leads to the increment of scrap tyres generation annually especially in Malaysia. Scrap tyres are among the largest and most problematic sources of waste, due to the large volume produced and their durability (Eldin & Senouci, 1992). Scrap tires are neither classified as solid waste or hazardous waste. It is generally considered as business or trade waste; hence there is no specific law or regulation, which governs waste tyre management (Thiruvangodan, 2006). Even though there are specialised recycle companies collected scrap tyres and reprocessed them in order to extract the fibre and metal for varies purposes, the vast majority of a tire composition (crumb rubber) is still being made redundant. Thus, one of the effective measures to reduce the abundance of scrap tyres waste in the environment is to utilize recycle tyre rubber as asphalt component.

Several studies have been conducted to examine the performance of asphalt mixtures that uses recycle tyre rubber from scrap tyres. The studies discovered that modified hot asphalt mixtures have outstanding structures and increased road surface durability, while decreasing maintenance costs, reflective cracking, and noise levels (Maleka, Alkali, & Jaya, 2014). Despite its benefits, hot asphalt mixtures that contain crumb from scrap tyres are relatively uncommon used in Malaysia. Perhaps due to lack of studies that highlights its benefits in Malaysia context. Meanwhile, in

United States of America (U.S.A) the use of crumb rubber as asphalt component started back in 1950 (Mashaan, Ali, Karim, & Abdelaziz, 2012) and have been widely practiced across the states.

Hence, in view of a more environmental friendly and sustainable engineering perspective, it is compulsory to conduct an experimental study on the application of recycle tyre rubber as fine aggregate replacement in hot mix asphalt (HMA) as well as to construct a long-term performance and sustainable asphalt pavement road especially in Sarawak in conjunction with the increment of number of vehicle on the road due to rapid economic growth.

1.2 Problem Statement

In Malaysia, the number of vehicle waste tyres increases steadily every year due to rapid development of roadways (Thiruvangodan, 2006). The author also claimed that estimated 8.2 million or approximately 57,391 tonnes of vehicle waste tyres generated in the country every year. Meanwhile, about 60% of the waste tyres are disposed via unknown routes.

Tire dealer have to confront significant pressure when the accumulation of waste tyres at their premises, often resulting in improper storage of wastes, which consequently cause them to be penalized by the local authority. To handle the situation, they often employ private rubbish collector to collect and dispose their waste tires. In return, private rubbish collector would charge a management fee based on size or type of tyres. Even though, private rubbish collectors charge a fee on the waste tyres collection, it is unrevealed that to what extend these tyres are discharged of in an environmental friendly and legal way.

There are also other industry manufacturers that make use of waste tyres such as recyclers, tyre shredders and other physical users. At the present, Malaysia does not have institutional approach to administer waste tyre management (Periathamby, Hamid, & Khidzir, 2009). The authors also claimed that the existing operating companies are

established purely on business ethics by making profit as main priority. Without an effective policy and management structure in place, it is expensive and complicated for the recycling companies to obtain continuous supply of waste tyres (Manaf, Samah, & Zukki, 2009). Therefore, the demand for waste tires depleted as these companies are now recycling alternative material such as rejected or used gloves and tyre buffing. Consequently, low demand for waste tyres from these industries will generate more solid waste in the environment and this highlights the need to examine for alternative way to recycle these waste tyres.

Roads contribute significantly to economic development and sustainability and induce important social benefits. To accelerate the social and economic growth of Sabah and Sarawak, Pan Borneo Highway was officially launched by the Prime Minister Datuk Seri Najib Tun Razak on 31 March 2015. Pan Borneo Highway will be toll-free since it is the main artery connecting Sabah and Sarawak, and there are no alternative routes between the two states. At the present, some of the existing Trans-Borneo Highway section has been deteriorated rapidly due to its high and heavy usage mainly used by heavy trucks and buses delivering material goods and passenger between cities. Government has spent millions of Ringgit for road maintenance and upgrading the existing road for the safety of road users. Thus, it is necessary to search for a more durable and long-term performance pavement in order to decelerate the deterioration.

Researchers have been searching for alternative material to be used as a modifier in asphalt mixture in order to improve its properties and performance, the recycle tyre rubber is among one of the alternatives. The application of recycle tyre rubber in hot mix asphalt has been long established in advanced countries, most notably the U.S.A as they aimed to tackle the amount of scrap tyres every year, without compromising the quality of road but improving it instead. Besides, modified asphalt mixtures containing tyre rubber powder yield better skid resistance, reduced fatigue cracking, enhanced resistance to rutting, improved tensile strength and toughness, longer pavement lifespan and lessen maintenance costs compared with conventional mixtures (Khatib & Bayomy, 1999; Khosla & Trogdon, 1990).

Nevertheless in Malaysia, this rubberized modified asphalt mixture is less establish and uncommon in the road construction industry (Azahar et al., 2016). Road construction in Malaysia using recycle tyre rubber as filler in HMA is not significant enough. Hence, there is a necessity to carry out experimental study to investigate the overall performance of modified HMA using recycle tyre rubber as fine aggregate replacement based on Malaysia road conditions. Aiming of enhancing the road durability thus reducing pollution and environmental problem caused over the years in Malaysia, especially Sarawak region.

1.3 Research Questions

Based on the problem statement described above, this research is conducted to answer questions stated below:

1. How would asphalt concrete performance affected by the recycle tyre rubber as fine aggregate replacement?
2. What is the optimum recycle tyre rubber content to achieve the desired properties for AC14 asphalt concrete?

1.4 Objective of Study

The purpose of this study to conduct depth analysis to ensure the application of recycle tyre rubber as fine aggregate replacement in HMA corresponds to the required performance of pavement mix design based on JKR standard. To achieve this, batches of samples with different proportion of recycle rubber powder will be added into the modified mix design. These modified samples will then be compared against the unmodified samples. Specifically the objectives of this study is to evaluate performance of recycle tyre rubber modified HMA mixes compare to conventional asphalt mixes in terms of volumetric properties such as Void in Mineral Aggregate (VMA), Void in

Mixture (VIM), and Void Filled with Bitumen (VFB). Hence, the objectives are as shown below.

i. To determine the properties of bitumen and aggregate for mix design.
ii. To evaluate the Marshall properties of recycle tyre rubber mixture with different number of compaction. (35, 50 and 75 blows).
iii. To compare and analyse the performance of recycle tyre rubber modified mixture with original mixture/control.

1.5 Scope of Work

In order to investigate the effects of recycle tire rubber on Hot Mix Asphalt (HMA) properties, the scope of the study was included preparation of ACW 14 Marshall samples with bitumen content without additive were 5.0%, 5.5%, 6.0%, 6.5% and 7.0% as control samples. The optimum bitumen content (OBC) and Marshall Properties was determined and analysed via Marshall Test. This research will be carrying out according to the Marshall Mix Design and Marshall Stability and Flows test.

Total number of 15 control sample ACW 14 (control sample) and 27 samples of recycle tyre rubber (modified sample) as the replacing material are prepared and tested referring to the AASHTO manual. The result on the density, stability, flow, voids in total mix, voids filled bitumen and stiffness from the modified sample and control sample were compared and analyze according to specification stated in JKR/SPJ/2008. All the sample preparation and testing was conducted at Civil Engineering Laboratory (Highway & Transportation Laboratory), Universiti Malaysia Sarawak.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The current chapter shall cover introductions of recycle tyre rubber, previous researches on recycle tyre rubber modified asphalt concrete mixture, methods for bituminous mix design specifically Marshall mix design method. This chapter also intends to provide comprehensive overview of researches that substitutes fine aggregate with recycle tyre rubber for asphalt pavement construction. The evaluations from past findings shall also be revealed in this chapter.

2.1 Recycle Tire Rubber

Recycle tyre rubber can be defined as rubber which obtained by processing used automobile, truck, or bus tyres that no longer suit it purposes due to wear and tear or irreparable damage. With the rapidly increasing number of vehicles on the road, the disposal of scrap tyre is a growing issue. Adhikari, De, & Maiti (2000) have stated that only a few grams or kilograms of rubber (<1%) are abraded out from the tyre after a long run when these tires are not serviceable and discarded. They also claimed that scrap tyre rubber create significant environmental concerns if not recycled and discarded properly. Thus, recycling of scrap tyre rubber is very crucial as rubber is non-biodegradable and

not environment-friendly (Yehia, 2004). The author also highlighted that recycled tire rubber should be considered as a source of new material with economic impact.

2.1.1 Tyre Manufacturing Process

The tyres are manufactured based on five major components which consist of tread, steel belts, bead, steel belts and body plies (ChemRisk, 2013). In the process of tire manufacturing, tyres are assembled with an abundance of materials which encompass natural and synthetic rubber and elastomers; reinforcement filler material; curatives including vulcanizing agents, activators, accelerators, antioxidants, inhibitors, and retarders; extender oils and softeners; phenolic resins and plasticizers; metal wire; polyester or nylon fabrics; and bonding agents (Dick and Rader, 2014). Under extreme heat and high pressure, tyres are fabricated by blending natural and synthetic materials and roll into rubber sheets. The rubber sheets either can be merged with textile sheets or heated into a semi molten state and forced through a die or mould which determines the shape of the sheet. Layering process of rubber, rubber-encased materials, steel belts, and tread rubber will then take place in order to manufacture a well-established tyre. The tyre manufacturing process is then completed by curing the built tyre at a temperature between 150° and 180℃ (300° and 360℉) (ChemRisk, 2013). This process is known as vulcanization which involves the formation of crosslink across the polymer chains of rubber.

Figure 2.1: Component of Radial Tyre

2.1.2 Properties of Tyre Rubber

Tyre plays an important role for most ground vehicles in order to protect the wheel's rim from damage and to provide tire-road traction for maximum acceleration and better handling experience (Nakao & Yamamoto, 2002). Generally, the component of tyres is vulcanized rubber and diverse reinforcing. Rubber matrix that usually used is natural rubbers and synthetic rubbers which have variety of application purposes (Suparat, 2013). Rubber is a high molecular mass, amorphous polymeric substance. The formulation of rubber compounds may differ based on its application. For instance, the constituent of a normal passenger car consist of 58.6 wt % rubber, 29.2 wt % carbon black, 2.9 wt % zinc, 1.8 wt % stearic acid, 1.2 %, sulfur, 5.85 % extending oil, and 0.4 wt% accelerators (Huynh & Raghavan, 1997). There is a high probability that the amorphous regions of the rubber prone to be oxidized. Moreover, rubber also susceptible to biochemical oxidation which result in the production of sulfuric acid. The authors also mentioned that the mechanical properties of rubber may degenerated due to chemicals and microbes infection which will lessen the durability of tyre/rubber hoses as much as approximately 50 %. As a matter of fact, natural rubber exists as glutinous substances organically and deform when exposed to extreme temperature and brittle when cooled down. During this condition, the rubber is not suitable to manufacture product with good elasticity. The inelastic deformation of unvulcanized rubber is due its natural long polymer chain. The polymer chains will undergo deformation in shape after moving independently to each other. Therefore, vulcanization process will aid to create cross-links among the polymer chains to interlock their movements. Hence, the rubber is able to return to its original shape when applied stress is withdrawn from the rubber (LoPresti, 2013).

2.1.3 Recycle Tyre Rubber Processing Methods

Tyres are manufactured to be practically indestructible and lasting which is a good feature to vehicles but this feature made the end-life tyres arduous to be recycled.

However, with the developments of technical in the past decade, mechanical grinding methods and new eco-friendly devulcanizing methods are introduced in order to increase the use of recycle tyre materials.

2.1.3.1 Ambient Grinding

Ambient grinding method is suitable to various size particles, including whole tyres. In an ambient system, the scrap tyre is remain or processed at or above the normal room temperature by using granulation or cracker mills (Rahman, 2004). This is a multi-series process to separate the component of tyre such as the rubber, steel fibers and fabric by mean of a series of mechanical processing machines. Once the metallic contaminants are extracted using magnetic separator, ambient grinding is capable to fabricate rubber crumbs with grain size in the range of 5mm to 0.5 mm. The characteristics of the rubber crumb are uneven in shape and torn particles with large surface area of contact in order to improve the interaction with bituminous material. This grinding method is widely used in practice and likely the most cost efficient processing method of scrap tyres. Figure 2.2 shows the schematic representation of ambient grinding.

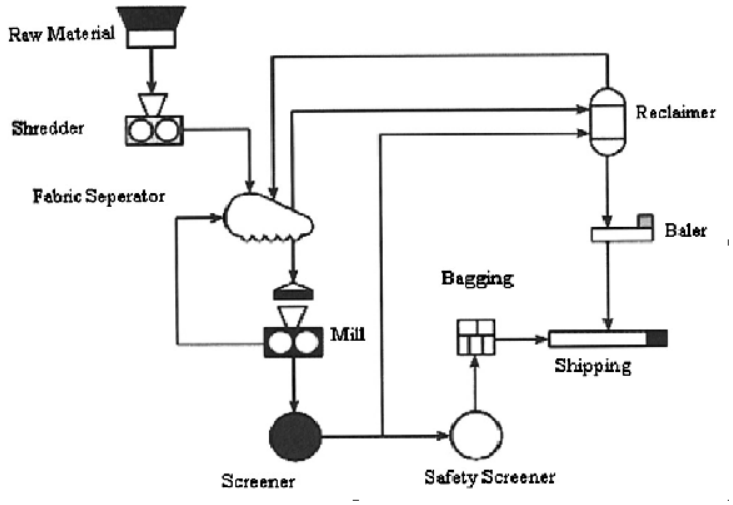

Figure 2.2: Schematic Drawing Representation of Ambient Grinding adapted from (Rahman, 2004)