A STUDY ON THE STRENGTH OF CRUMB RUBBER MODIFIED BITUMEN USING VARIOUS CRUMB RUBBER SIZES

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ABSTRACT

Asphalt use in road pavement because it’s very economical and fulfil the roadway design requirements such as good ride quality, ski –resistance surface, quiet surface and low maintenance. However, consumption of asphalt has some weakness, as it become brittle and hard in cold environments and soft in hot environments hence easy to crack. Besides that, today capacity or volume of the road user that increases year by year is one of the factors that make the road pavement prone to defect or damage such as cracking. Hard traffic and high loading weight also one of the factors affecting the quality of performance pavement and it becomes worst because of overloading on the road. Hence, to reduce damage and defect, an improvised road pavement structures is needed. This experiment will do modified in Asphalt with mix with different crumb rubber (2mm, 0.425mm, and 0.15mm) used as additives. The samples preparation consists of the production of the Marshall Mix specimens. Total of samples is 36 samples will prepare in the laboratory with proper method and apparatus. The samples is designed according to requirement for aggregate course wearing (ACW) using the JKR standard. The range percentage of asphalt was used in this study is 4% until 6%. The size of the sample is same to be prepared 1200 gram plus wastage. From the Marshall Stability and flow test the result is 19.522kN and 18.865kN for experimental samples and constants sample respectively. The conclusion, the crumb rubber can improve the workability, durability and provided higher density of the Hot Mix Asphalt. Furthermore, it gave the pavement a better performance and higher quality pavement for the future development. This finding also helps to save the budget to pavement for the future development. This finding also helps to save the budget to maintain the road in a good condition all the time being. Thus, it is an economical method to be applied in the road construction in order to increase the strength of pavement. In the future, hopefully this finding can encourage new research to be conducted in the different ways and usage.
ABSTRAK

Asfalt adalah salah satu bahan yang digunakan di dalam pembinaan struktur jalan raya kerana ia sangat jimat dan memenuhi aspek jalan raya yang di perlukan seperti kualiti yang bagus, permukaan yang boleh mencengkam, tidak mengeluarkan bunyi dan penyelenggaraan yang murah. Walau bagaimanapun, penggunaan asphalt mempunyai sedikit kelemahan, dan salah satu kelemahannya adalah mudah untuk mengeras apabila cuaca sejuk dan lembut semasa cuaca panas dan mudah retak. Selain itu, kapasiti atau kuantiti pengguna jalan raya yang semakin bertambah setiap tahun ini akan menyebabkan permukaan struktur jalan raya terdedah kepada keretakan. Berat yang melebihi kesan dan trafik yang sentiasa melebihi kemampuan jalan juga adalah salah satu factor penyebab permukaan jalan raya selalu mempunyai masalah. Maka, untuk mengurangkan kerosakan dan kesan pembaharuan perlu untuk menguatkan struktur permukaan jalan raya. Eksperimen ini akan melakukan pembaharuan kepada asfalt didalam permukaan jalan raya dengan memasukkan getah tayar yang dipotong dengan berbeza saiz getah tayar (2 mm, 0.425 mm dan 0.15 mm). Jumlah 36 sampel akan dihasilkan di makmal dengan peralatan yang lebih cekap. Sampel akan dihasilkan mengikut spek JKR yang memerlukan mengikut kelas yang telah ditetapkan iaitu ACW. Peratusan julat yang digunakan di dalam eksperimen ini adalah 4% hingga 6%. Berat sampel ialah 1200 gram. Daripada Ujian stability yang dijalankan 19.522 Kn DAN 18.865 Kn untuk sampel ujikaji dan sample tetap mengikut urutan. Kesimpulannya, hirisan getah tayar boleh meningkatkan kebolehkerjaan, kecekapan, panjangkan jangka usia dan ketumpatan yang tinggi pada terapan tayar.
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LIST OF ABBREVIATIONS

TITLE

CRM Crumb Rubber Modified
HMA Hot Mix Asphalt
VMA Voids Mix Aggregate
VFA Void Filled Asphalt
VTM Voids Total Mix
ASTM American Society for Technology and Material
CHAPTER 1

INTRODUCTION

1.1 Background Study

Binder is a general description for the glue used in asphalt pavements. These liquid binders can be call as tars or asphalt binder or bitumen. The terms “asphalt binder” has been selected to more specific describe the asphalt material and any modifiers or ingredients. The terms asphalt, asphalt cement, and asphalt binder referring more specifically to their petroleum origins and asphalt binder referring to the asphalt to the asphalt cement and any other added ingredient that provides the engineering adhesive used in asphalts pavements. Characteristic of asphalt is sticky, black and highly viscous liquid or semi-solid of petroleum. In pavement structures, asphalt is very importance in road because wearing coarse and base course need asphalt to mix in aggregate. Asphalt use in road pavement because it’s very economical and fulfill the roadway design requirements such as good ride quality, skid –resistance surface, quiet surface and low maintenance. However, consumption of the asphalt has some weaknesses, and of them is it become brittle and hard in cold environments and soft in hot environments hence easy to crack when the weather change from hot to cold. Moreover, today capacity or volume of the road user that increases year by year is one of the factors that make the road pavement prone to defect or damagesuch as cracking. Hard traffic and high loading weight also one of the factors affecting the quality of
performance pavement as it becomes worst because of overloading on the road. Hence, to reduce damage and defect, an improvised is needed in the road pavement structures. In worldwide, it has many additives material such as Styrene Butadiene Styrene (SBS), Synthetic Rubber-Styrene-Butadiene (SBR), natural rubber, and Crumb Rubber Modified (CRM) to make it a strength the road pavement increased. The use of commercial polymers such as SBS and SBR is very expensive materials than crumb rubber very economical.

Crumb rubber very suitable to be the additives in pavement because it has the characteristic that can support the weakness of asphalt. Not only that, increase than that in tyres waste could be eliminated thus environmental problem can be avoided. The use of crumb rubber in asphalt materials became of interest to the paving industry because in the crumb rubber it has an elastic property which had the potential to improve the skid-resistance and durability of asphalt. The usage of crumb rubber is proving to be good and reliable. Besides that, crumb rubber can reduce the issue of fatigue or cracking occur on most pavement. At once, it can solve the damage and defect. Moreover, it can save the cost for the maintenance roadway pavement because ingredients in crumb rubber more benefits to solve the problem and also can solve environmental problem from waste tyres. Figure 21 show the pavement layer which is crumb rubber will include in binder course only. The thickness of the overall layer is similar with normal asphalt pavement using asphalt as binder. The constant layer is sub-base and sub-grade. The crumb rubber only in surface coarse and binder coarse because to avoid the pavement to crack on the surface or has a defect caused by heavy traffic loading.

Figure 1: The Pavement Layer
Crumb rubber modified (CRM) is a rubber from waste tyres which is truck tyres, car tyres, motorcycle, bicycle or automotive tyres. The crumb rubber contains synthetic rubber, natural rubber, total rubber hydrocarbon and acetone extractable, which make a crumb rubber have high durability, viscosity, high softening point and better resilience. This due to the different portion of natural rubber synthetic rubber, and other components between truck tyres, passenger car tyres, and motorcycle tyre, bicycle tyres and others automotive tyres. A truck tyre has 80 per cent natural hydrocarbon and 18 per cent natural rubber compared 9 percent in an others automobile and 2 per cent in tyre treads. For truck tyres, it must separate between steel and fibres in tyres. Tyre rubber will be liquid nitrogen and is easily fractured in a hammer mill. While, ambient temperature produces sponge-like crumb rubber with big surface area.

Figure 2: Transformation of the waste tyre to Crumb rubber

Figure 2 shows from the waste tyres become crumb rubber using ambient grinding process. This is one of the processes to produce crumb rubber. This mechanical process will produce an irregularly shaped particle with a large surface area and varies from size 0.425mm to 4.75mm. After, this processes, it will produce the shape or crumb rubber or the specifically known particle morphology such as Figure 2. The ambient grinding will produce rough irregular shape with high surface area. Crumb rubbers have five grading:

1) Tire granule shall consist of granule tire crumb, black only guaranteed, and metal, free sized. Magnetically separated materials are not acceptable. Fluff from tire cord removed.
2) Groups, tire granule consist of granulated tire crumb, black and white guaranteed metal free, sized 40mesh.

3) Tyre granule consists of crumb, black only magnetically separated.

4) Tire consist of granulated the crumb and the last, the granule consist of unclassified of granulated tire crumb, sized, and not separated.

Another process to produce crumb rubber is cryogenics process; it will produce the shape of crumb rubber look like an angular or prismatic shape and smooth surfaces. This process uses liquid nitrogen to freeze the recycle tyre rubber until it becomes brittle, and then uses a hammer mill to shatter the frozen rubber into smooth particles with lower surface area than those obtained ambient process. In addition, it has two another processes to produce crumb rubber. The processes are wet-grinding and hydro jet size. Wet-grinding will be produce from solid to liquid and Hydro jet size reduction one of the technique of processing rubber tyre recycle into finer particles with the help of pressure water.

1.2. Problem Statement

Over the years, the damage in roadway pavement in Malaysia is kept on increase. Lots of maintenance work need to be repaired to reduce defect or damage on the roadway. This is because of heavy traffic load or increasing road users in Malaysia. Statistic from Ministry Of Transport Malaysia, the road users increase from 2009 to 2010 and is expected to keep on increasing for the next 10 years. When the road user increase, the loading in the road will be increased and the pavement have a problem if the pavement cannot support the high loading or volume (Sulyman, 2014).

Moreover, asphalt cannot withstand drastic weather changes because asphalt is hard in cold environments and soft in hot environments. Previous studies showed that number of failures represented by the low temperature cracking, fatigue cracking, and the rutting (or permanent deformation) at high temperature, causing its quality and pavement performance to decrease. Besides that, asphalt also has a thickness problem, bleeding, flushing and drain-down. The roadway pavement in Malaysia is always has a defect which mainly because of excessive load and high temperature. Therefore to overcome this problem, crumb rubber is suggested as one of the methods
that might be able to solve the environmental problem and roadway pavement. Crumb rubber will increase the strength and will give elastic in the roadway pavement.

Besides that, waste tyres are one of the environmental problems in Malaysia. This problem needs to be urgently solved because waste tyres are not easily disposed. Statistic from Ministry of Environment Malaysia stated that, waste tyres in Malaysia increase every year because the waste tyre is depending on amount of road user in Malaysia. Recycled the tyres will be one of way to save the space. The global problem with landfill disposal of automobile tires and plastics can only be solved by the feasible option left, and that is recycling and utilization of the recycled products (Rokade, 2012). It is thought that the application of recycled automobile tires and plastics will not only solve the environmental of these industrial solid wastes problem but also act as very promising modifiers for the improvement of asphalt pavement material.

Therefore, the potential of crumb rubber as additive in asphalt pavement will be tested in this research. A crumb rubber will prevent the pavement to crack in the cold or melt in the heat. It can also increases film thickness in the aggregate that can prevent bleeding, flushing and reduce noises. Crumb rubber also has higher durability than asphalt. So, crumb rubber will be used as additives in asphalt pavement. The concentration and size of crumb rubber will be balanced with asphalt. By using this method, the strength of pavement will be increased and the environmental rescue of wastage tyres could be reduced.

1.3 Objective of the Study

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

a) To investigate different sizes of crumb rubber that will influence the strength of road pavement.

b) To determine the strength of crumb rubber modified asphalt to be used as surface course.
1.4 Scope of Study

1. Laboratory testing such as Marshall Stability, compression, and balance and water bath test will be conducted to achieve the objectives.

2. The crumb rubber material was obtained from the exhausted bicycle tyres.

3. The quantity of bicycle tyres and aggregates similar with typical asphalt pavement design.

4. The project consists of 30 samples of preparation. There are 15 will be control samples prepared in order to compare it with the samples mixed with the crumb rubber.

5. Finally, the strength of the samples was determined by using civil engineer laboratory manual UMP test according and the material standard is following the JKR Specifications 4.1.4.2 and ASTM or BS standard.

1.5 Significant of Study

This research is important to solve the problem of pavement strength and environmental problem which is come from waste tyres. Both issues will be solved by reuse the scrap tyres and produces crumb rubber before using it in the road construction by adding as sub base or surface coarse pavement layer. Furthermore, the used of crumb rubber in the road will reduce noises, prevent bleeding, flushing and drain down, increase the performance life, very economically and increase safety.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The first problem of the asphalt is it wills brittle in cold environments and soft in hot environment. In addition, when hard traffic and high loading weight will give the effect for pavement material such as cracking, fatigue cracking, and the rutting at high temperature, causing its quality and performance in pavement of roads to decrease (Al-maamori, 2014). This will make the roadway need maintenance year by year. The properties of asphalt-Aggregate mixed such as stiffness, stability, durability, fatigue, resistance, fracture, characteristics, skid Resistance, permeability, and workability majority depends on the content of asphalt. If contain asphalt only the pavement is not fully efficiently because asphalt have a limitation and it need additives. That caused range of rheological and durability properties the asphalt not sufficient for resistance on distresses caused by the increase traffic and total loading on current highway (Bahia, 2006).
Impact of heavy transport in pavement can be seen in different types of defects. Defects in flexible pavements can be placed into one of five classes. These classes are cracking, distortion, disintegration, slippery surfaces and surface treatment problems. For the cracking, it have alligator cracking, edge cracks, edge joint cracks, reflection cracks and lane joint cracks. Reflection cracks normally occur in asphalts overlays. These cracks reflect the cracks pattern in the pavement structure underneath. There are most frequently found in asphalt overlays over Portland concrete and cement-treated bases. Reflection cracks are normally caused by vertical or horizontal movements in the pavements beneath the overlays, resulting from traffic loads, temperature and earth movements. Therefore, as asphalt replacement or modifications need to be carried out to ensure that asphalt is strong enough yet economical to be used as road pavements.

2.2 Modification Asphalt

Asphalt modification is a process done to enhance the strength and life of pavement. Modifications can combined or put an additive to asphalt. Thermoplastic, polymers, thermo set, polymers, reinforce agents; adhesion, promoter, catalyst, chemical reaction, crumb rubber and aging inhibitors use in modified of asphalt, only to strength the road pavement and avoid the maintenance every year. Not all types of modifiers are being currently used. The frequency of use varies significantly depending on marketing of the modifiers, experience of contractors and agencies and cost (Bahia, 2006). The effect of mineral fillers, polymeric and crumb rubber additives on performance-related properties of asphalt cements have been analyzed using data collected for a normal binders. The analysis measured using new characterization technique developed by the Strategic Highway Research Program (SHRP).

For the polymeric additives, it contains styrene-butadiene (SB) based-modifiers and polyethylene-based modifiers. The result gets to reduce the sensitivity of rheological properties to temperature and loading frequency. Polymer, result is a higher stiffness and a lower phase angle. At intermediate and low temperatures, the effects are less pronounced and can be favourable (Bahia, 2006). While, mineral fillers result is similar in effects similar to the modifiers with respect to reduction in dependency of asphalt rheology on temperature and loading frequency. However, result shows an increased in stiffness at all temperatures and frequencies. The effect at high temperatures are
favourable, their effects at intermediates and low temperatures are not favourable and can be determined with respect to fatigue and thermal cracking (Bahia, 2006). Therefore, it is necessary to improve the quality of asphalt by the material which can play the role as a binder to achieve increasing viscosity and elasticity, diminution of temperature higher softening point and aging resistance (Al-maamori, 2014).

Crumb rubber modifiers included ambient shredded crumb rubber, cryogenic grinded and a crumb rubber plastics composite. All crumb rubbers were produced from whole tire stock with maximum particle size of 5.0 mm and minimum size is 0.425mm. The result also is similar with effects to polymer modification. From the data, crumb rubber modifiers in reduction of stiffness at the intermediate and low temperatures if their stiffness is less than the stiffness of the asphalt matrix (Bahia, 2006).

Moreover, the crumb rubber modified (CRM) is the additives to avoid damage in the road pavement. Where, conventional bitumen Crumb Rubber Modified Bitumen (CRMB) is mostly used. Its advantages are:

1. Lower susceptibility to daily & seasonal temperature variations
2. Higher resistance to deformation at elevated pavement temperature
3. Better age resistance properties, higher fatigue life of mixes
4. Better adhesion between aggregate & binder
5. Prevention of cracking & reflective cracking

It can also reduce noise emissions (Losa, 2003). Physical properties of rubber such as type, quantity, shape, gradation are said to affect the performance of rubber modified asphalt mixtures (Norhidayah Abdul Hassan et al, 2014). Therefore, this study attempt to determine suitable crumb rubber size that would affect the strength, durability, stiffness, stability, durability, fatigue resistance, fracture resistance, skid resistance, permeability and workability of the asphalt. To modify the asphalt pavement, it has two processes which are dry process and wet process. The dry process involves the blending of crumb rubber with hot aggregates prior to mixing with bitumen and
substitutes a proportion of the mix aggregate with coarse rubber, thereby causing the rubber to function essentially as an elastic aggregate within the mixture while wet process is a whereby fine rubber is blended with hot bitumen to produce a ‘rubberised bitumen’ binder (Norhidayah Abdul Hassan et al, 2014). Although decades of research have been dedicated to the study of CRM mixtures, results produced have been largely inconsistent. The difference in wet mixing process and dry mixing process are illustrated in below Figure 2.1 and Figure 2.2. Figure 2.1 show the wet process method where rubber particles are mixed with asphalt at elevated temperature prior to mixing with the hot aggregates. Figure 2.2 show the dry process, where rubber particles replace a small portion of the mineral aggregate in asphalt mix before the addition of the asphalt.

The main differences between these processes rubber many process is much coarser than wet process rubber, amount of rubber; the dry process uses rubber 2 to 4 times as much as the wet process, function of rubber; in the dry process it acts more like the binder, and finally the ease of incorporation into mix; the dry process no special equipment is equipment is required while in the wet process special mixing chambers, reaction and blending tanks, and oversized pumps and required.

### 2.3 Engineering Properties

Some of the engineering properties of CRM that are of particular interest when CRM is used in granular base application include gradation, bearing strength, compacted density, moisture content, permeability, and durability.
2.3.1 Gradation:

The gradation for milled CRM is governed by the spacing of the teeth and speed of the pulvering unit. Wider tooth spacing and the higher speed results in larger particle sizes and coarser gradation. CRM can be readily processed to satisfy requirements for granular base and sub base specifications, such as AASHTO.

2.3.2 Compacted Density:

Due to coating of asphalt cement on RAP aggregate, which inhibits compaction, the compacted density of blended granular material tends to decrease with increasing CRM content.

2.3.3 Permeability:

The permeability of blended granular material containing CRM is similar to conventional granular base course material.

2.3.4 Ductility:

The ductility is a distinct strength of bitumen, allowing it to undergo notable deformation for elongation. The ductility is defined as the distance in centimetre, to which a standard sample or briquette of the material will be elongated without breaking. The finer rubber particles resulted in higher ductility elongation and also, that toughness would increase as rubber content increases (Mashaan et al., 2011). A combined effect of both time and temperature was noted with minimum elastic recovery value improved at maximum time and maximum recovery value of two hours and 240 Celsius, respectively (Jnesen et al., 2006). However, the modified binder was susceptible to decomposition and oxygen absorption. There were problems of low compatibility, because of the high molecular weight but the recycled tyre will decrease reflective cracking, which in turn increase durability.

2.4 Benefits using of Crumb Rubber

One of the major advantages of using CRM in road pavements is that, it can improve bitumen resistance to surface initiated cracks, the reduction of fatigue/reflection cracking, the reduction of temperature susceptibility, improved durability as well as the reduction in road pavement maintenance costs (Liu et al., 2009).
Adding the crumb rubber provides a number of environmental, strength and economic benefits by reducing:

- Demand for aggregates;
- Demand for bituminous binders;
- Waste

2.4.1 Reduced Demand for aggregates

Aggregate resources are becoming more and scarcer, especially in urban areas where most heavily trafficked pavements are located. It takes so expensive when want make maintenance or repair the defect of the road. Therefore, when use the crumb rubber it will reduce cost for maintenance and it will re-used significant benefits.

2.4.2 Reduced demand for bituminous binder

The quantity of additional bitumen asphalts is needed to produce road highway material is reduced because the CRM already contains some bitumen. This provides benefits in terms of reduced cost and lower energy demands with respect to both the production and distribution binders.

2.4.3 Reduced waste

Using CRM in pavement applications means that fewer waste materials are going to landfills. This saves valuable space in landfills. This is an important factor considering the cost of establishing environmental compliance for new landfill variations. Now, quantity of the waste tyres is increase every year, and it will be give the effect or impact to environment. The waste tyres very difficult to disposal because if use the wrong method to disposal it will give the effect. Therefore, when using this method to save the environment, it alsogives the benefits in economy and quality structure road pavement.
2.5 Summary

The weakness of the current method today, needed modifications or improvement because to avoid the maintenance work increase as an effect from the heavy load from road user rises every year. When the maintenance work increases, hence the cost will also increase to repair every road damaged effect from the road user and weather.