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Investigation on Fatigue Resistance of Asphalt Mixture Containing Crumb Rubber

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Abstract: The increase of this disposal waste tire surely will increase the amount of waste tires at stockpiled or landfill that can threated the human health and environment nearer to the landfill area. In addition, nowadays utilization of waste product in construction industry is going rapidly. Crumb Rubber Powder (CRP) is the one type of waste product which produced in the waste or broken tire from the process of ambient granulating and cryogenic grinding. In this study, CRP was utilized in the Hot Mix Asphalt (HMA) as added material mineral by 1%, 2%, & 3% replacement of the total mixture on the conventional HMA. For this study CRP content that utilized in asphalt mixtures. The mechanical properties were evaluated by Marshall Mix on volumetric test, Indirect Tensile Fatigue Test (ITFT), Softening point of bitumen and Penetration of bitumen. These findings have helped to clarify the role of CR in asphalt mixtures. The objective of this study, it already reaches a goal when it determines the optimum bitumen content by 5.5%. Next, the second objective on evaluating fatigue resistance of rubberized asphalt mixture was not suitable by adding crumb rubber on the total weight of the mixture. It is already proven by the testing on the UTM machine (Indirect tensile fatigue test) when the cycle on adding CR gets the lower cycle and deformation (mm) compared to conventional HMA. It produced about 0% of CRP added in HMA will reach the greatest result of fatigue resistance compared to the added CRP in HMA. Then, on 2% of mixture that will conduct the lowest fatigue cracking that due to the lowest number cycles and low deformation (mm). Next, it can be determining that by the previous studies the highest percent replacement added content of CRP will conduct the lowest performance of fatigue resistance at 2% added compare to the conventional HMA of asphalt mixture.

Keywords: Crumb Rubber Powder (CRP), Hot Mix Asphalt (HMA), Indirect Tensile Fatigue Test (ITFT)

1. Introduction

In developed a healthy environment in Malaysia to reduce the waste material such as waste tire. Tire wastes are non-biodegradable and have a negative influence on the environment. Inadequate waste

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management can result in hazardous contamination, decreased soil fertility, and higher space consumption at disposal sites [1]. For sure it will help to growth our economic and it can create employment opportunities for the people of Malaysia [2]. The country's yearly production of waste tires from automobiles is expected to be 8.2 million tons, or 57,391 tons. When discarded tires pile up on their property, tire sellers are put under a lot of stress. They don't have any direction or help from their bosses or authorities when it comes to proper waste tire management and disposal. Obtaining a consistent supply of discarded tires is costly without a policy and management framework in place. Unfortunately, a scrap tires disposal on the stockpile’s was the biggest environment problem in the world.

The increase of this disposal waste tire surely will increase the amount of waste tires at stockpiled or landfill that can threatens the human health, environment near the landfill area. The piles take up valuable land that could be used for agriculture or infrastructure. Big fires result in large fires, revealing hazardous chemicals and toxins in the air. The piles provide a perfect habitat for mosquitoes and other pests, resulting in health issues. Tire pyrolysis refers to the complete process of recycling tires. It is one of the most environmentally beneficial tire recycling methods accessible [3].

2.0 Literature Review

2.1 Bitumen binder

Binders is graded in Marshall it using a bitumen grade of 60/70. Asphalt mixtures, bitumen emulsion, cut-back bitumen, and modified bitumen are all made with Bitumen Grade 60/70. The vacuum distillation of crude oil produces bitumen 60/70, which has the greatest boiling point, is the heaviest, and most polar component. Asphaltene and maltene make up 60/70 bitumen. The asphaltene molecules, which are heavy and insoluble, give bitumen 60/70 its body and softening point, while the maltenes, which are greasy, make asphalt flexible. Asphaltene molecules dissolve in aromatic solvents such as toluene, but not in heptane.

2.2 Asphalt concrete mixture

Dry process method uses for the purpose of preparing asphalt mixture and enable to reduces the tensile strength of asphalt mixes, the addition of crumb rubber may impair the mixture’s cohesiveness. Furthermore, they discovered that due to weak Asphalt stiffness modulus, fatigue performance, and adhesive strength between rubber particles and binder mixes containing a substantial proportion of crumb rubber were worse than typical mixes [4]. In the figure 2.1 show a picture of dry process method procedure that particles replace a tiny amount of the mineral aggregate then mixing in the asphalt before the asphalt is added in the dry phase.

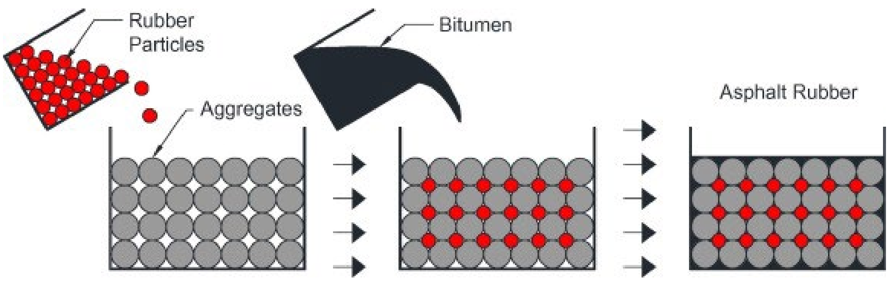

Figure 2.1: Dry process method

2.3 Crumb rubber modified asphalt mixture

The performance of rubber modified asphalt mixes is claimed to be influenced by physical features of rubber such as type, amount, shape, and gradation. To guarantee that the desired performance is obtained, the size, shape, and texture of the rubber particles employed to change the mixture vary depending on the suggested uses. Figure 1 depicts various sizes of crumb rubber generated for recycling purposes.

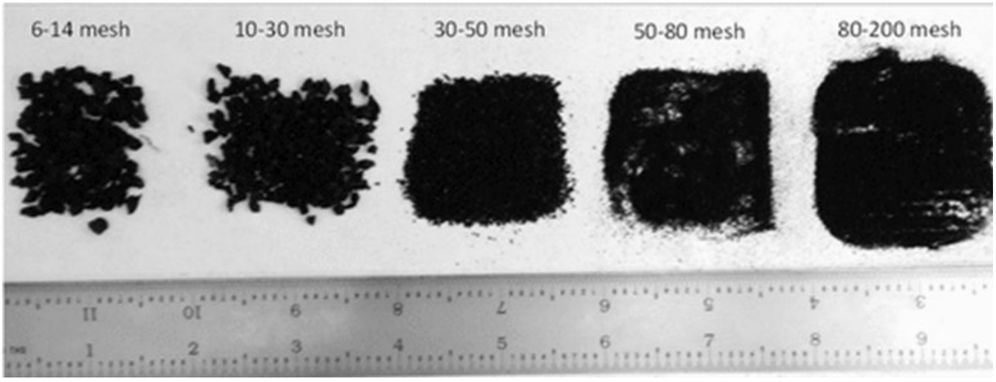

Figure 1: The different size of crumb rubber

Rubber particles with irregular forms and a large surface area are more likely to react with bitumen to form a modified binder at high temperatures. In addition, excessive traffic and high loading weight have an impact on pavement material, causing cracking, fatigue cracking, and rutting at high temperatures, reducing road pavement quality and performance [5]. Rubber particles with a cubic form and a low surface area are common in aggregates and are ideal for use as an elastic aggregate in the dry process because they blend well into the aggregate mix. Ambient granulating (cracker mill process) and cryogenic grinding are the two major ways for processing scrap tires. Both methods lower the tire's size and remove the steel belting and fiber from the rubber compound [6].

Crumb rubber is an excellent choice for pavement additives because it has the ability to support the asphalt's weaknesses. Not only that, but a rise in tire waste could be avoided, avoiding an environmental hazard. Crumb rubber (CRM) is a rubber made from waste tires, including truck, vehicle, motorcycle, bicycle, and industrial tires [7]. Synthetic rubber, natural rubber, complete rubber hydrocarbons, and acetone extractable are all present in crumb rubber, giving it high longevity, viscosity, softening point, and resilience. It's also been discovered that the mix's performance responds better response to fatigue-related issues including cracking and plastic deformation [8].

3. Materials and Method

In this finding the material used is crumb rubber powder that added in the total weight of mixture. Furthermore, the size of 0.425mm & 0.150mm crumb rubber were use in this study to get the data. The total weight of sample is 1200g with a different gradation of AC14. Before mix all the material aggregate need in oven with the temperature of 165°C for 2 hours. For bitumen grade 60/70 the temperature also set on 165°C for 1 hours before can mix the sample. Next, mixing sample for 120 minutes then prepare a mole for compaction the sample for a temperature of 155°C and 75 blows by the automatic Marshall compact.

3.1 Softening point

The softening point is defined as the temperature at which a bitumen disc softens and sags downward at a distance of 25 mm. Two horizontal discs of bitumen, cast in a shouldered brass ring, each hold a steel ball that is heated at a regulated rate in a liquid bath. The sample must be cooked in an oven at a temperature of 100°C above the estimated softening point until it has become sufficiently fluid to pour, and samples must not be heated for more than 30 minutes. The test must be redone with new samples if the two temperatures deviate by more than 1°C.

3.2 Penetration of bitumen

A penetrometer is used to measure penetration by applying a typical needle to a under a bitumen specimen particular circumstance. One tenth of a millimeter is the unit of measurement for this distance. The American Society for Testing and Materials (ASTM) D5 protocols are followed. Testing involves bringing a carefully at right angles to the surface of the specimen, place a dimensioned needle loaded to 100 ± 0.05 g and allowing it to get into the bitumen for 5.1 seconds. In tenths of a millimeters, the penetration (Deci millimeter, dmm) is determined.

3.3 Optimum bitumen content

Each specimen was first immersed in a water bath at 60°C for 40 minutes before being placed in the Marshall test apparatus. Each specimen's bulk specific gravity, density, and voids analysis were determined. The specimen had been radially crushed at a constant strain rate (51mm per min).

3.4 Indirect tensile fatigue test

The test should begin with a 250 KPa loading amplitude. Throughout the test, the load and horizontal deformation must be continuously monitored and recorded at pre-determined intervals. The first 200 load cycles should be monitored constantly in order to calculate the initial stiffness modulus. Next, the test must be terminated when visible cracking appears on the vertical axis or when the dynamic tensile strain exceeds twice its original value.

Figure 3.1: Indirect tensile fatigue test on UTM

4. Results and Discussion

The findings and outcomes that are relevant to achieving the study's goal. Aside from that, this chapter explain into the interpretation of the results acquired from the preceding research's evaluation. Furthermore, the effects of adding CR as an added material in HMA are discussed and compared for each of the prior studies.

4.1 Asphalt binder properties

4.1.1 Softening point of asphalt binder

The results are summarized in Table 4.1. Because the temperature difference between balls A and B was less than 1°C, the softening point experiment did not need to be repeated.

4.1.2 Penetration test

Table 4.1 illustrates the results of a penetration test performed in accordance with ASTM D5-2005 procedures, with the results accepted by the JKR standard (JKR 2008).

Table 4.1: Softening point of asphalt binder

Testing	**Result**
Softening point (°C)	55.5
Penetration (m)	69.8

4.2 Optimum bitumen content

The estimated binder content in this study is 5.5 %. As a result, many tests with the expected binder content conducted. Table 4.3 lists the attributes of the trial mix.

Table 4.2: Properties of trial blend

Bitumen Content (%)	Gmm	Gmb	Gsb	VIM (%)	VMA (%)	VFB (%)
4.0	2.508	2.285	2.670	8.9	17.8	49.9
4.5	2.490	2.290	2.670	8.0	18.0	55.4
5.0	2.471	2.334	2.670	5.6	16.9	67.0
5.5	2.453	2.342	2.670	4.5	17.0	73.4
6.0	2.436	2.348	2.670	3.6	17.3	79.2

4.3 Indirect tensile fatigue test

The number of cycles counted was used to assess the fatigue characteristic. Figure 4.8 represent the number of cycles against sample for the fatigue test. The highest number of cycles started with 0% of sample, then 3% follow with 1% and 2% of sample. For control 0% added CR sample get more than 27000 cycles, for 1% sample added CR get 22433 cycles, for 2% added with CR get 14478 cycles and 3% added CR get 26628 cycles. Among the added sample with crumb rubber the highest data was 3% with the cycles 26628, then 1% at 22433 cycles, lastly at 2% at 14478 cycles. Furthermore 0% without added with CR get the highest fatigue resistance compares to the sample that added with CR. As we can see on the 2% sample get a lower fatigue resistance compare to the other sample. This is because for 2% sample crumb rubber went through a permanent strain grows with each load cycle, eventually leading to failure after only a few loading cycles [9].

Table 4.5 show a maximum deformation based on the cycles to the sample. The highest number of cycles were the highest fatigue resistance, it is proven on the lower maximum deformation in millimeter at 0% sample.

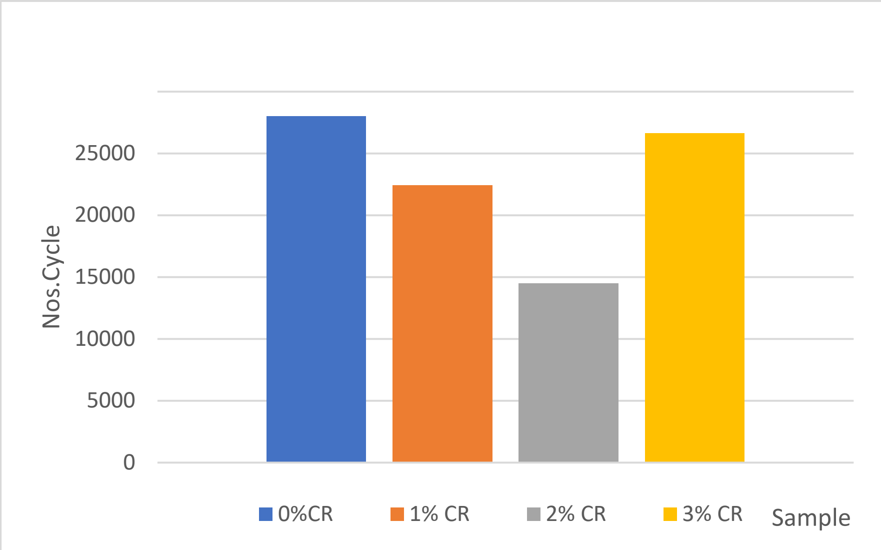

Figure 4.1: Number of cycles against samples

Table 4.3: Value of sample deformation

Sample (% CR)	Numbers of cycle	Maximum deformation (mm)
0%	>27000	0.659
1%	22433	15.243
2%	14478	14.933
3%	26280	15.265

5. Conclusion

To analyses the qualities of the bitumen employed in this investigation, softening and penetration tests were undertaken. Furthermore, the impacts of CR as an additional material in HMA mixes are shown in this work, achieving the goal to evaluate the effects of CR as an added material in HMA mixtures. The given findings have helped to clarify the role of CR in asphalt mixtures. In general, CR can be utilized widely in HMA technologies as replace material compare to added on total mixture since it had a less fatigue resistance on the asphalt mixture after CR was added to the mixture. In terms of Marshall stability and flow tests, the samples prepared have yielded low result compare to the sample without CR.

In addition, by added CR as added material in asphalt mixture reach low fatigue resistance compare to the conventional HMA without added CR was that identified by the number of cycles of failure. Also, the deformation on loading are higher than the conventional HMA. According to the findings of this study, when the sample is not mixed with CR, it produces high of data in fatigue resistance samples than when the sample is mixed with CR. This has a significant impact on the failure of crumb rubber mixed samples as well.

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