The Effect of Crumb Rubber on Properties of Asphalt Mix by Dry Process

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Abstract—**the use of crumb rubber modifiers by dry process is not used extensively in asphalt applications as the wet process. This study aims to investigate the effect of crumb rubber modifiers on properties and performance of asphalt mix by dry process. Thus, a set of asphalt mixtures containing various percentages of crumb rubber modifiers mixed by the dry process were tested. Moreover, the effect of modifying conventional asphalt mixture with crumb rubber polymers was evaluated. In addition, a comparative assessment was made to evaluate rubberized mixtures and unmodified bitumen mixture. The mixtures were assessed by using the Marshall Stability test, the wheel tracking test and the moisture susceptibility test. The study revealed that an addition of crumb rubber modifiers to conventional asphalt mixture enhances pavement stability and increases its resistance to rutting and moisture damage. The study concludes that an addition of 2% of CR to unmodified AC16 gives the most satisfactory results among other rubberized mixtures.**

Index Terms: **Crumb rubber, Rutting, Modified asphalt mixture, Pavement performance, Dry process**

I. INTRODUCTION

The increase in the number of cars in recent times has led to increased road usage, resulting in higher volume of traffic and tire pressure on roads. The resulting effect has been premature deformation and failure in asphalt pavements, generating serious concern among many highway and State agencies [1, 2]. To combat this challenge, most governments have adopted the use of additives and modifiers in enhancing the performance of asphalt pavements.

Due to the increasing trend of road usage by motorists, scrap tires has also been on the increase. Disposing these scrap tires poses a serious environmental concern as they are mostly burned or left at the mercy of nature to decompose as is prevalent in most developing countries like Malaysia. Therefore, the need for an effective technique for recycling discarded tires is been considered by most countries.

One such technique is to convert these discarded tires to crumb rubber (CR) modifier [3]. CR, gotten from discarded tires, is made up of natural or synthetic rubber [4]. The crumb rubber is used in asphalt applications to improve the performance of asphalt pavements i.e. reduces traffic noise and improves resistance to cracking and rutting [5].

II. RESEARCH PROBLEM

The use of crumb rubber to improve the performance of hot mix asphalt (HMA) is not a new practice and has been applied over the years [6]. Crumb rubber is mainly blended in asphalt mixture by two methods; commonly referred to as the wet process and the dry process [7]. In the wet process, the CR is blended with bitumen at a temperature of 191°C to 218°C for 1 to 2 hours [8]. In this process, the bitumen is first modified before it is added to a mixture, which in turn modifies the mixture properties as well. In contrast to the dry process, the crumb rubber is combined with aggregates before blending with the bitumen [1]. The quantity of crumb rubber in dry process is about 2 – 4 times that used in wet process [9]. Among these two methods, the wet process is the most widely used. On the other hand, the dry process is not as commonly used as the wet process because of poor results shown by previous studies [10]. These results and findings made the technique loose credence and forced many practitioners to adopt the wet process.

However, this research opens a new frontier to the application of crumb rubber on asphalt pavements by capitalizing on the flaws previously overlooked by past researchers in which the mixtures of the different percentages of CR and bitumen was not taken into consideration.

This study investigates the effect of crumb rubber contents on total air voids VTM in the compacted hot mixture as well as its stability.

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III. METHODOLOGY

It tends to evaluate the effect of asphalt mixture containing various crumb rubber percentages on the properties of asphalt mixtures and behavior of asphalt pavement for resisting rutting by using a dry process technique. The 60/70 penetration grade bitumen was used in this study with an addition of various percentages of crumb rubber (CR) i.e. (0.5%, 1.0% 1.5% and 2% of the whole mixture weight).

The total air voids VTM and stability were evaluated by using a theoretical maximum density test, Marshall Stability and flow test respectively. Moreover, the resistance of the modified and unmodified asphalt samples to deformations (rutting) was evaluated by using the wheel tracking machine test. Furthermore, the moisture susceptibility test was used to assess the potential for moisture damage on asphalt mixtures.

IV. MATERIALS USED FOR THE STUDY

The materials used in this study were aggregates of bitumen, and crumb rubber.

A. Aggregate

Aggregate used in the study consist of coarse aggregates, fine aggregates and filler. The laboratory tests carried out in this study were sieve analysis ASTM C136 - 06, washed sieve analysis, specific gravity and water absorption of fine and coarse aggregates ASTM C127 - 12, and theoretical maximum density TMD ASTM D2041. Ordinary Portland cement was used as filler. A dense-graded asphalt mixture AC16, frequently used in the wearing course of asphalt pavement, was used in the study. Figure 1 displays a gradation of aggregates used in this study [11].

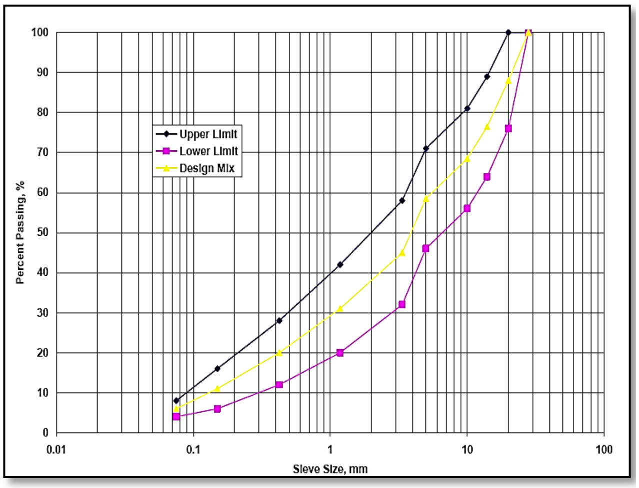

Figure 1 . Gradation of Aggregates [11]

B. Bitumen

The bitumen used for the research is 60/70 penetration grade bitumen. This bitumen is widely used in the constructions of major roads in Malaysia[12].

C. Crumb rubber

The crumb rubber used in this research was derived from waste tires with a particle size of 0.6mm – 0.65 mm.

D. Asphalt mixture proportions

The dry mixing technique was employed for the purpose of the research. Specified proportions of crumb rubber modifier aggregates was mixed before being added to the bitumen [1]. The materials mixed samples were then tested. Mixtures of Asphalt specimens and aggregates of CR (0.5 %, 1.0 % 1.5 % and 2 % of the entire mixture weight) was prepared for Marshall test. The asphalt samples were prepared in Marshall moulds with a diameter of 101.6mm ASTM D.1559 & AASHTO T.245 [13]. The standard specifications of the Marshall samples such as the optimum bitumen contents, the density and Marshall stability are presented in Table 1 below [11]. The Marshall samples, each containing crumb rubbers, were then subjected to a total of 75 compaction blows on each side of the specimen.

TABLE 1. Criteria for Asphalt Design Using Marshall Method [11]

		Heavy Traffic		Medium Traffic		Light Traffic	
		Min	Max	Min	Max	Min	Max
Number of compaction blows, each end of specimen		75		50		35	
Stability	(lb)	750	-	500	-	500	-
	(N)	3,336	-	2,22	-	2,224	-
Flow	(units of 0.01 in.)	8	16	8	18	8	20
	(mm)	2	4	2	4.5	2	5
% Air Voids	Surfacing or Leveling	3	5	3	5	3	5
	Base	3	8	3	8	3	8

V. EXPERIMENTAL RESULTS AND DISCUSSION

Marshall stability and flow tests [11] were carried out to evaluate the effect of crumb rubber contents on maximum load carried by a compacted specimen at a temperature of 60°C. The effect of the addition of different crumb rubber percentages on bitumen contents in asphalt mixture was assessed. The wheel tracking test was conducted to ascertain the performance of various rubberized asphalt mixtures under loading as well as their resistance to rutting. The effect of moisture on rubberized asphalt mixtures was evaluated using a moisture susceptibility test.

A. Marshall stability test

Asphalt specimens with various CR contents (0.5, 1, 1.5, and 2 %) and plain (unmodified) mixture were tested using Marshall method. The results of the Marshall tests are shown in Fig. 2 and Fig. 3 below. It is obvious that the optimum bitumen contents (OBC) in the various specimens were influenced by the addition of CR. The results indicate that a mixture without any additive recorded a lower OBC of 5.12% as against a higher value when crumb rubber content was added to the asphalt mixture. This shows that OBC value increases with the presence of crumb rubber, which has a low specific gravity. The findings reveal that modified bitumen obviously has higher resistance to rutting and friction sliding of the surface layer.

Figure. 3 exhibits the effect of crumb rubber addition on mixture stability. It shows that stability slightly increases as CR contents in the mixture increases. From the findings, we deduce that the stability of asphalt mix is primarily affected by the internal friction of aggregates and the viscosity of bitumen hence, the viscosity of bitumen increases as a result of adding crumb rubber to the bitumen.

Although a previous study [14] asserts to the result of this study i.e. that an addition of crumb rubber enhances the properties of hot asphalt mix and increase the pavement stability by using a dry process, it however failed to show in detail the effect of various values or aggregate mix of crumb rubber on properties of hot asphalt mix.

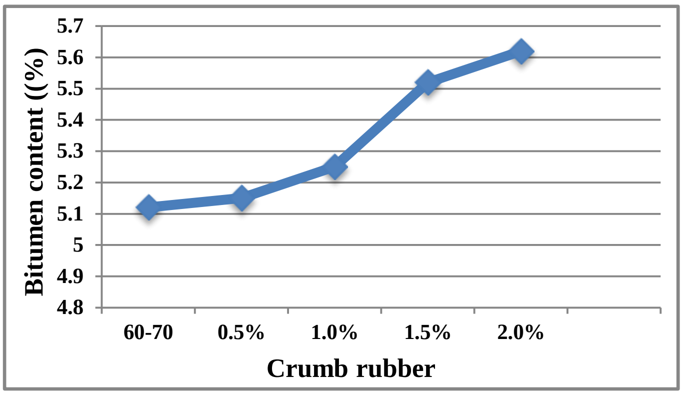

Figure 2. Effect of Crumb Rubber Percentages on Bitumen Content in the Mix.

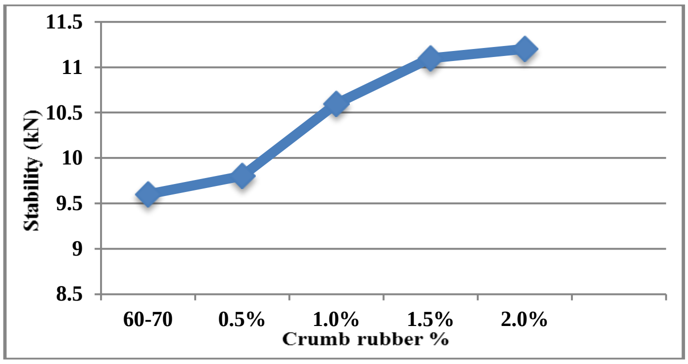

Figure 3. Effect of Crumb Rubber Contents on Compacted Specimen Stability

B. *Wheel tracking test*

The wheel tracking test was used in this study to evaluate the resistance of compacted specimens to rutting under loading. This test simulates the effect of traffic load as a result of the frequent passage of a loaded wheel, by the occurrence of rutting in the specimen; hence, rutting is monitored and recorded. In this manner, it was possible to examine the effect of utilizing different percentages of CR in a dry process mixing and at the same time compare this results with that of conventional (without additives) mixtures.

Once the OBC was obtained from the previous step, the specimens of various crumb rubber contents were compacted in steel moulds measuring about 408mm × 256mm with a thickness of 55mm. In order to achieve a minimum density of 98 %, a vibrating compactor with a frequency of 3,000 rpm was used on the samples, after which the wheel trafficking machine test was run on the specimens. Firstly, the compacted specimens were retained in an oven under a temperature of 60°C for about 4 hours. The temperature of water in the wheel trafficking machine was also maintained at 60°C. The speed of the loaded wheel was set to 40 cycles per minute. The test was run for 10,000 cycles and the rutting depth in the specimens were collected at intervals of 2000, 4000, 6000, 8000, and 10000 cycles. Fig. 4 depicts the results of this test.

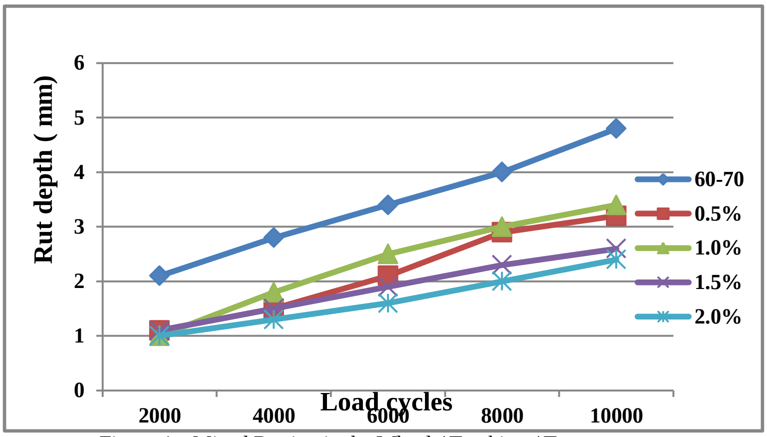

Figure 4. Mixed Rutting in the Wheel t\Tracking t\Test.

Figure. 4 above shows the effect of CR on hot asphalt mixtures. It reveals that the mixtures with crumb rubber prove to have better rutting resistance than the conventional (without additives) mixtures. Furthermore, as percentages of crumb rubber increases, the rutting depth decreases which prove that the addition of CR as a modifier in the asphalt mixture definitely enhance the pavement performance. We conclude that adding of CR in asphalt mixtures considerably improves the mixture response to rutting (deformation). Therefore, the asphalt mixture AC16 with crumb rubber of 2 % is a yields the highest deflation resistance in asphalt pavement.

This result is consistent with previous studies [15], which asserts that an addition of crumb rubber to hot asphalt mixture by using a dry process increase rutting resistance in the wheel tracking test.

C. *Effect of moisture on asphalt mixtures*

The moisture susceptibility test was used to examine the potential for moisture damage on asphalt mixtures, as well as to determine whether or not crumb rubber is effective, and to find out what percentage of crumb rubber is needed to maximize its effectiveness. This test was carried out in compliance to ASTM D4867M. The result of the test reveals the tensile strength ratio TSR for all mixtures as shown in Figure. 5 below.

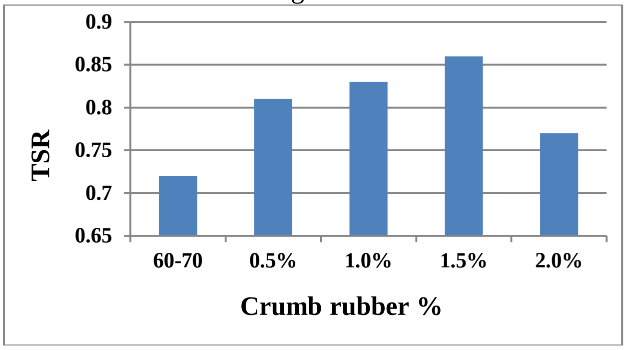

Figure 5. Effect of Moisture on Asphalt Mixtures

Figure. 5, above clearly reveals that rubberized asphalt mixtures have higher TSR values than normal (unmodified) asphalt mixtures which means that the rubberized asphalt mixtures are less susceptible to moisture damage. Among different rubberized asphalt specimens, AC16 with CR 1.5% yielded the highest value of TSR and yields the best resistance to moisture damage, even better than CR 2% with modified AC16. The result of this study is consistent with past studies [16] where CR was added to a mixture by wet process,. We therefore conclude that the effect of CR on pavement moisture damage is not affected by process methods i.e. dry or wet.

VI. CONCLUSION

This research investigated in detail the effect of using different crumb rubber percentages in the asphalt mixture by dry process technique. The study involved utilizing four different rubber percentages in asphalt mixture: 0.5%, 1%, 1.5%, and 2%, of a total mixture weight. A comparative assessment was made to evaluate these different crumb rubber percentages or aggregates with unmodified asphalt mix. Based on the results of the laboratory tests, the following conclusions can be drawn:

- Asphalt mixture modified with 2% CR yields the highest resistance to rutting.
- The stability of modified asphalt is higher when modified with CR and is directly proportional to the quantity of CR added.
- Asphalt mixture modified with CR is more resistant to moisture damage than unmodified asphalt mix.
- The effect of CR on pavement moisture damage is not affected by process methods i.e. dry or wet.

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BIOGRAPHIES

Dr. Ahmed Salama Eltwati received his bachelor’s degree in civil engineering from Benghazi University in 2007, and his master’s degree in Highway & Transportation Eng. (Civil Engineering) from Universiti Teknologi Malaysia in 2010. Then, he pursued his Ph.D. study in Highway Engineering at Universiti Teknologi Malaysia and got his Ph.D. in 2015. He has 3 years of site experience in infrastructure and building work from 2006 to 2009. He has published several indexed journal paper in ISI. He has been working as cooperated lecturer in University of Benghazi since 2016. Currently, he is lecturer in Materials Science department in Star Bright University. His research interest focuses on the development of rut and fatigue prediction models for flexible pavement and study of recyclable materials in asphalt concrete.