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Evaluation Performance of the Asphalt Concrete with Crumb Rubber

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Abstract

Many researchers have been researching alternative materials to be used as modifiers in asphalt mixtures to improve their properties. This study presents a study of laboratory evaluation of the performance of hot-mixed asphalt (HMA) using crumb rubber as an additive. It is noted that crumb rubber was identified to have potency as a modifier in HMA due to the elastic behavior exposed by the rubber particles, especially in reducing the rutting potential. This research used fine crumb rubber Shred (2.36-0.85 mm) obtained by an ambient-temperature grinding process from discarded truck tires to modify asphalt concrete. The fine crumb rubber with different contents, i.e. 2.5%, 5%, 7.5%, and 10%, was incorporated into the mixture using the dry process method.

Keywords: Crumb rubber, Asphalt content, Asphalt concrete, Aggregate.

1. Introduction

It is essential to understand the materials involved in pavement construction. Therefore, crumb rubber could be an alternative material in improving the quality of hot mix asphalt.

In the process, most of the steel wires and reinforcing fibers or fluff of the recycled tires are removed. The crumb rubber is often served and separated in categories based on gradation to meet the requirements of a particular application or agency.

Roadways are important in our daily lives. A lot of money is spent annually by governments on the construction and maintenance of roadways. It would greatly benefit the Libyan economy if we could extend the service life of the roads. In order to enhance pavement performance, it is essential to understand the materials involved in pavement construction. Therefore, crumb rubber could be an alternative material in improving the quality of hot mix asphalt.

The purpose of this study is to evaluate the effect of adding crumb rubber into asphalt mixes. Asphaltic concrete (hot-mix asphalt) is a continuously dense-graded mixture of coarse and fine aggregates, mineral filler, and bitumen produced hot in a mixing plant. It is delivered, spread, and compacted while hot.

Hot mix asphalt concrete is produced by heating the asphalt binder to decrease its viscosity and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300°F (roughly 150°C) for virgin asphalt and 330°F (166°C) for polymer-modified asphalt, and the asphalt cement at 200°F (95°C). Paving and compaction must be performed while the asphalt is sufficiently hot.

In this study In comparison between the two types (without and with crumb rubber) of properties of the hot mix asphalt toward the Marshall properties to get optimum asphalt content, indirect tensile strength (ITS) at different test temperatures (30°C, 40°C, and 60°C) and unconfined compressive strength (UCS) at 30°C, indirect tensile strength modulus (ITSM) at 40°C, and permeability test The resilient modulus measured in the indirect tensile mode according to ASTM D 4123 effectively reflects the elastic properties of asphalt mixtures under repeated load. The coarse aggregate morphology quantified by angularity and surface texture properties affects the resilient modulus of asphalt mixes; however, the relationship is not yet well understood because of the lack of quantitative measurement of coarse aggregate morphology [1].

2. MATERIALS AND METHODS

A. Crumb rubber

Used car tires were collected on a large scale and subjected to shredding and chipping processes. These were applied using an automatic machine that can cut up tires into tiny particles of various sizes. The dimensions of the particles are presented in Figure 1.

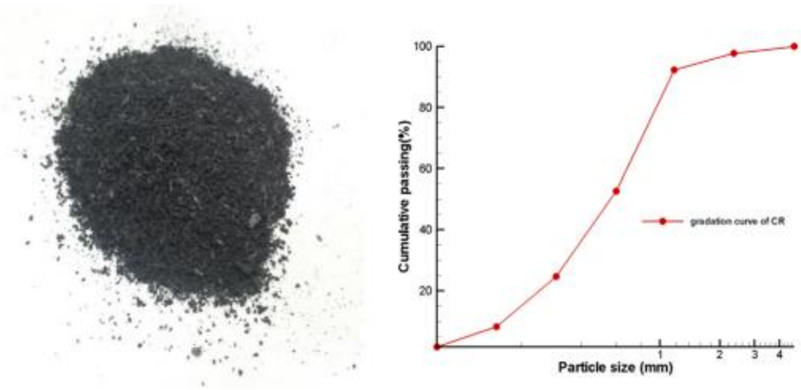

Fig 1: Appearance of CR and Its Gradation Curve

B. Asphalt

The properties test of asphalt AC60/70 produced by PT. Pertamina. Table 1 presents the results of properties test asphalt AC60/70.

Table 1: Result Properties Test of Asphalt Ac 60/70

characteristics	Result	Specification
Specific Gravity Of Asphalt	1.045	MIN 1
Pentetration (mm)	63.5	60-79
Ductility (cm)	164	Min 100
Flash point and fire point (°c)	320 - 326	Min 200
Softening point (°c)	48.35	48-58
Asphalt solubility in TCE (tri chlore enthelyn)/CCL	99.59	Min 99

C. Aggregate

The fine and coarse aggregate utilized in this study was obtained from quarries that Available in the study area. As a result, the interlocks between particles were improved. Table 2 and Table 3 give a variety of fundamental engineering characteristics of the aggregate used in this study .H.T. Tai Nguyen et al (2018), the aggregate was used as the material for the split mastic asphalt mix. Based on the properties test of coarse aggregate and fine aggregate results as:

Table 2: Result Properties Test Fine Aggregate

Properties	**Result Fine aggregate**	**Specification**
Bulk specific gravity of fine aggregate	2.52	≥ 2.5
SSD specific gravety of fine aggregate	2.59	≥ 2.5
Apparent specific gravety of fine aggregate	2.72	≥ 2.5
Waer apsorption of fine aggregate	2.94	≤ 3.0

Table 3: Result Properties Test coarse Aggregate

Properties	**Result Fine aggregate**	**Specification**
Bulk specific gravity of coarse aggregate	2.64	≥ 2.5
SSD specific gravety of coarse aggregate	2.67	≥ 2.5
Apparent specific gravety of coarse aggregate	2.714	≥ 2.5
Waer apsorption of coarse aggregate	1.02	≤ 3.0
Abration	21.31	≤ 40
Adhesiveness	99	≥ 95

3. Comparison of Marshall Test

A. Stability

Table.4: Stability of AC Modified With and Without Crumb Rubber

Asphalt content	**Stability**				
	0% CR	**2.5% CR**	**5% CR**	**7.5% CR**	**10% CR**
5.00	1035.33	896.78	784.31	747.51	731.87
5.50	1336.90	1056.50	883.42	884.20	769.38
6.00	1412.80	1181.26	962.00	901.33	774.43
6.50	1328.01	1172.59	921.08	900.28	718.15
7.00	1166.02	1029.50	846.48	809.21	649.58

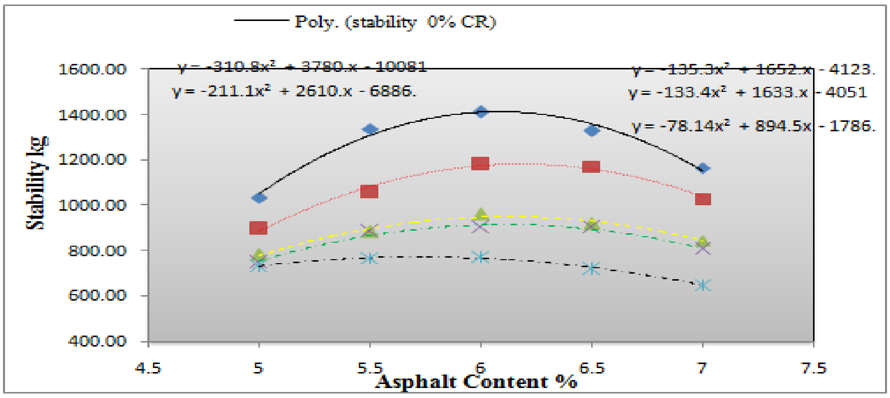

Fig 2: Comparison of Flow Test for AC With and Without CR

Through the comparison of the stability test results in Table 4 and Figure 2, it was obtained that the asphalt concrete without crumb rubber with asphalt content of 6% has an optimum stability value of 1412.80 kg. On the other hand, AC modified with 2.5% CR has an optimum stability value of 1181.26 kg at 6.0% asphalt content; AC modified with 5% CR has an optimum stability value of 962.0 kg at 6.5% asphalt content. AC modified with 7.5% CR has an optimum stability value of 901.33 kg at 6.0% asphalt content. AC modified with 10% CR has an optimum stability value of 769.38 kg at 5.5% asphalt content. Thus it can be concluded that the higher crumb rubber percent decreases stability. Further injection of crumb rubber into the mixture led to a decrease in the value of stability because application of excessive crumb rubber decreases the coarse aggregate contact point within the mixture. The addition of crumb rubber will give higher penetration or softer asphalt. As a result, the mixture becomes more flaccid so as to contribute to the decrease in the value of stability. Low stability suggests low quality of aggregates. The stability of aggregates decreases with an increase in crumb rubber content [6, 9]. It was found that increasing the crumb rubber reduces the stability of AC, with a higher percent of crumb rubber yielding the lowest stability value. However, Al-Qadi et al. (2009) reported that crumb rubber has more effect on the performance of asphalt mixture by increasing the Marshal Stability and Flow.

B. Flows

Table 5: Flow of AC Modified With Crumb Rubber

Asphalt content	Flow				
	0% CR	2.5% CR	5% CR	7.5% CR	10% CR
5.00	2.80	3.00	4.00	4.37	5.03
5.50	3.22	3.53	4.13	4.80	5.03
6.00	3.40	3.80	3.97	5.17	5.35
6.50	3.17	3.47	3.60	4.61	5.13
7.00	2.67	2.80	2.80	3.73	6.13

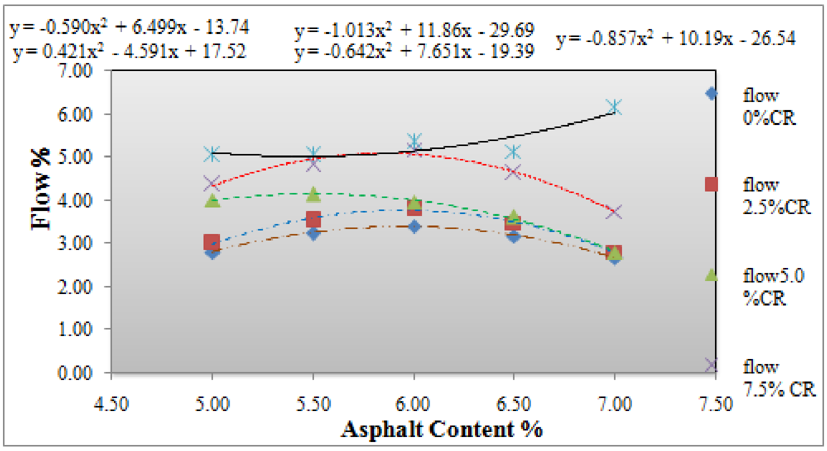

Fig.3: Comparison of Flow Test for AC With and Without CR

Through the comparison of the Flows test results in Table 5, Figure 3, it was found that the flow test value of asphalt concrete increased as the crumb rubber content increased from 0% to 7%. Higher flow values may be related to the increase of air voids (more compaction required) by using more CRM in the mixture, which leads to a more flexible mixture.

Thus it can be concluded that the higher the crumb rubber content, the more it increased flow, but higher asphalt content decreases flow. With the addition of the asphalt content, the mixes become more flexible, and the resistance to deformation decreases, resulting in a high flow value. Mashaan et al. (2013) similarly reported that the addition of crumb rubber modifier to asphalt concrete increases the flow of the mixture until optimum crumb rubber content is reached.

C. Void Filled With Asphalt (VFWA)

The analysis of the VFWA test results in Figure 3 showed that modified with 0%, 2.5%, 5.0%, 7.5%, and 10% CR have maximum VFWA values of 80.60, 82.82, 73.37, 93.10, and 56.94, respectively. Thus it can be concluded that an increase in the percent of crumb rubber content increases the VFWA. The reason is that voids provide spaces for the movement of the asphalt cement or asphalt rubber binder within the compacted mix. The mix design of asphalt and rubberized AC asphalt paving mixes is a trade-off between high binder content to enhance long-term durability and performance and sufficient in-place void space to avoid rutting, instability, flushing, and bleeding, as it is clearly shown in Table VI of the VFWA.

Table 6: VFWA of AC modified With Crumb Rubber

Asphalt content	**VFWA**				
	0% CR	**2.5% CR**	**5% CR**	**7.5% CR**	**10% CR**
5.00	61.44	59.96	54.60	58.44	46.82
5.50	66.89	67.97	59.63	64.05	49.94
6.00	70.31	71.41	65.84	70.79	56.41
6.50	75.92	74.99	70.68	79.92	57.26
7.00	80.60	82.82	73.37	93.10	56.94

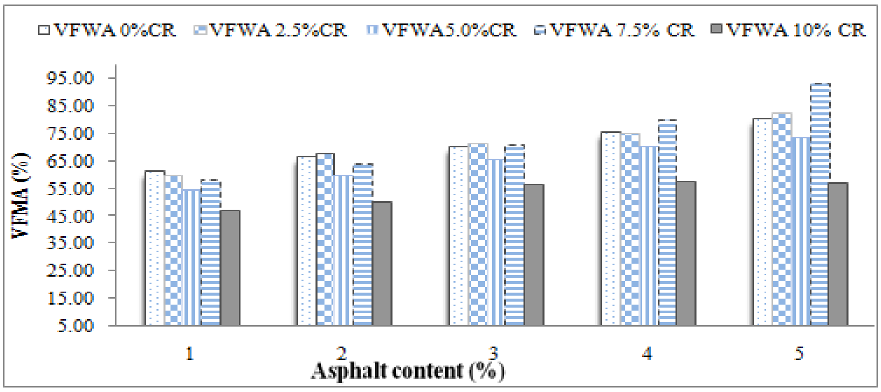

Fig 4: Comparison of VFWE Test for AC With and Without CR

D. *Voids In Mix (VIM) Test*

Through the comparison of the Voids In Mix test results in Table 7, Figure 4, it was found that the Voids In Mix value of asphalt concrete without crumb rubbers is 6.91 at asphalt content of 5%, while AC modified with 2.5%, 5.0%, 7.5%, and 10% CR has maximum Voids In Mix values of 7.37, 8.96, 7.78, and 11.84, respectively, at asphalt content of 5%. Thus it can be concluded that higher crumb rubber and asphalt content increase voids in the mix. This is supported by Ibrahim et al. (2018), found that crumb rubber particle size can affect the optimum binder content for open-graded friction courses. The durability of HMA is a function of the VIM or porosity. In general, the higher the porosity, the less permeable the mixture will be and vice versa. Too many voids in the mix (high porosity) will provide passageways through the mix for the entrance of damaging air and water. Too low porosity could lead to flushing, where the excess bitumen squeezes out of the mix to the surface [5].

Table .7: VIM of AC modified with crumb rubber

Asphalt content	**VFWA**				
	0% CR	**2.5% CR**	**5% CR**	**7.5% CR**	**10% CR**
5.00	6.91	7.37	8.96	7.78	11.84
5.50	6.14	5.77	8.04	6.79	11.46
6.00	5.59	5.32	6.82	5.46	9.77
6.50	4.65	4.79	5.98	3.64	10.10
7.00	3.73	3.23	5.53	1.18	11.02

This relationship between VIM of the asphalt concrete AC and asphalt concrete modified with crumb rubber is shown in figure 5.

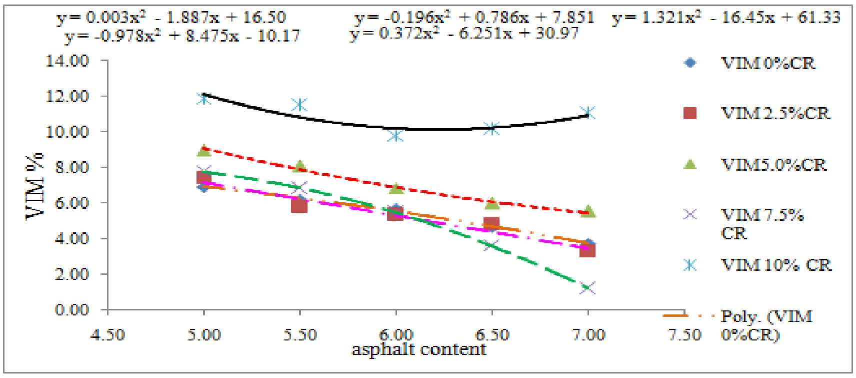

Fig 5: Comparison of VIM Test for AC With and Without CR

E. Indirect Tensile Strength Test (ITS).

The strength test was used to determine the tensile strength and strain of the mixture specimens. Specimens were monotonically loaded to failure along the vertical diametric axis at the constant rate of 3 in/min (76.2 mm/min)

The indirect tensile strength test is one type of tensile strength test used for stabilized materials. This test involves loading a cylindrical specimen with a compressive load along two opposite generators. This results in a relatively uniform tensile stress acting perpendicular to and along the demurral plane of the applied load. This results in splitting failure generally occurring along the diametric planes. Three samples for each type of asphalt concrete without and with CR were tested at temperatures of 30˚C, 40˚C, and 60˚C

Figure 6 and Table 8 shows the summarized result of indirect tensile strength test each type of asphalt concrete without and with crumb rubber in OBC.

Table 8: Results of Indirect Tensile Strength Test at OBC

AC type	ITS @30 C(MPa)	ITS @40 C(MPa)	ITS @60 C(MPa)
without CR	242.23	117.81	42.40
with CR 2.5%	144.45	76.03	17.31
with CR 5.0%	129.10	52.84	10.95
with CR 7.5%	100.21	43.55	9.89

This relationship between the ITS and the different temperatures is shown in Figure 6 .

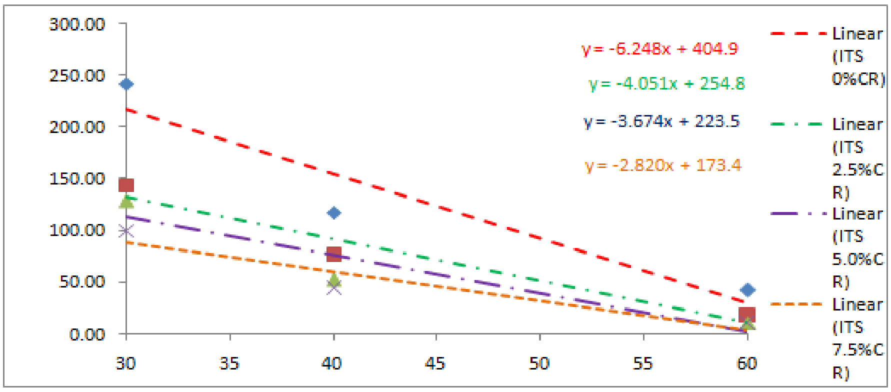

Fig .6: Results of ITS Each and Asphalt Concrete Modified Without and With CR

F. Unconfined Compressive Strength Test (UCS)

This test is used to determine the resistance to permanent deformation of a bitumen mixture at 30˚C and loads. It is conducted by applying a static load to a specimen using OBC and then measuring the maximum load. This test used to determine the permanent deformation of asphalt concrete without crumb rubber and asphalt concrete with three types of crumb rubber is done using UTM (Universal Testing Machine) to obtain a strong push by the unit KN, and then a strong press is made to the calculation unit Kpa. The unconfined compression test is by far the most popular method of shear testing because it is one of the fastest and cheapest methods of measuring shear strength. The results of the unconfined compressive strength test are given in Table 9 and Figure 6.

Table.9: Results of Unconfined Compressive Strength Test at OBC at 30℃

Crumb Rubber	Load Kpa at 30 ^{0}C	OBC
0	5220.707633	6.400
2.5	4097.285707	6.475
5	3234.877943	6.450
7.5	2619.054288	6.375

This relationship between the UCS and the CR is shown in Figure 6.

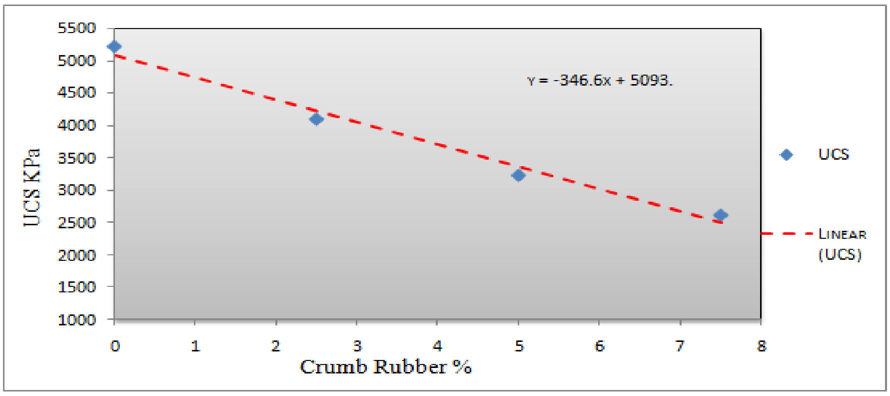

Fig 7: Results of UCS Each and AC Modified Without and With CR at 30˚C

G. Indirect Tensile Strength Modulus (ITSM)

According to EN 12697-26 and to EN 12697-23, and static indirect tensile strength tests in particular, data from static tests have been processed to obtain stiffness measurements through the application of Hondros' theory or graphically from the stress–strain curve. Although based on empirical derivation, this relationship would enable the laboratories that are not equipped with a proper machine for dynamic modulus tests to estimate the stiffness properties of the bituminous material by exclusively performing simple static tests. The experimental program included static and dynamic indirect tensile tests at 10, 20, and 30 C on three asphalt concretes, different for binder type and compacted to two air voids contents. Results proved that good correlations ITSM tests were performed on samples of thin normal and modified AC using UMMATTA [7]. Tests were conducted at a temperature of 40ºC, and the results can be seen in Table 10 and Figure 7 (see also Appendix D).position.

Table.10: Indirect Tensile Strength Modulus test at 40^{O}C

CR %	ITSM (MPa) at 40 ^{0}C			Average (MPa)
0%	633	705	669	669
2.5%	613	586	599.5	599.5
5%	636	349	356	356
7.5%	194	234	214	214

Three samples were tested for each unmodified and modified mixture. To obtain a stiffness modulus for a mixture, each sample was tested in three different conditions, and the average value was adopted. The stiffness modulus of the mixtures is shown in Table 10, Figure 8.

This relationship between the ITSM and the CR is shown in Figure 8

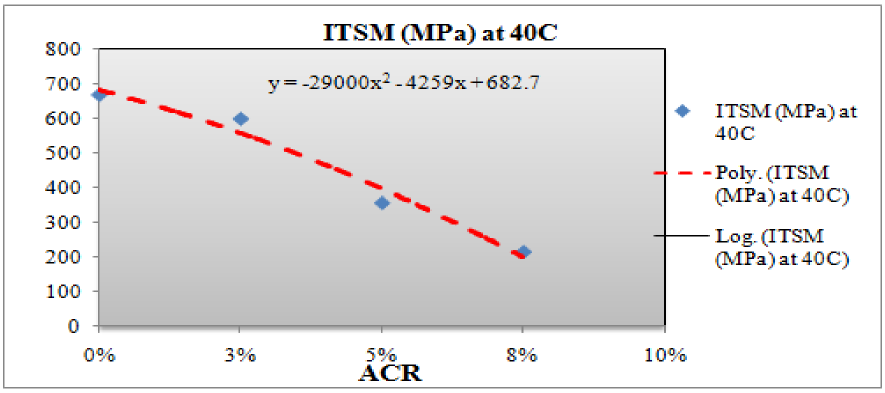

Fig 8: Results of ITSM Each and AC Modified Without and With CR

4. Conclution

- Increasing the proportion of crumb rubber has the ability to reduce the stability values due to the spacing between the blocks within the mixture and hence the softness of the asphalt increases.
- Increasing the proportion of crumbled rubber contributes in a direct relationship with the flow values of the asphalt mixtures until it reaches the appropriate proportion for the required flows.
- The results of the VFWA test confirmed that it has a positive response to increasing the values of the crumb rubber ratios of asphalt mixtures.
- The voids in the asphalt mixture increase directly with the increase in the proportion of crumb rubber in the mixture. That is, the lower the permeability of the mixture, the higher the porosity and vice versa. The presence of many voids in the mixture (high porosity) will provide passages through the mixture for the entry of harmful air and water. Low porosity may lead to leakage, as excess bitumen leaks from the mixture to the surface.

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