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LABORATORY EVALUATION OF ITS TEST ON ASPHALT MODIFIED WITH VARIOUS RANGES OF CRUMB RUBBER

Asmaa Abdulmaged MAMHUSSEINI[1+]
Barham Jalal NAREEMAN[2]

[1,2]*Department of Civil Engineering, Ishik University, Sulaimani, Iraq*
[1]*Email: asmaa.abdulmajeed@ishik.edu.iq Tel: 009647507472705*
[2]*Email: pencweni89@gmail.com Tel: 009647807963771*

(+ Corresponding author)

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ABSTRACT

The rubber which is generated from scrap tyres (tires), identified by crumb or powdered rubber. Day after day, discarded or scrap tyres create huge environmental problems. As long as the scrap tyres are regarded as a non-decade material those disrupt the clean environment. Using this rubber in pavement and asphalt has become a great interest and proposal for researchers for overcome this issue in recent years. Researchers and engineers discovered another way to improve asphalt concrete, by adding crumb rubber (CR) into asphalt concrete. This is done by two methods; first method rubber placed in bitumen and completely or partially reacted with bitumen, this will become binder modifier (wet process). Second method replacing this rubber with fine aggregates which are not dissolved completely with bitumen (dry process). In this study crumb rubber is added into mixture initially by substituting rubber with amount of fine aggregate. Thereafter laboratory tests; penetration, ductility, softening point, elastic recovery and moisture susceptibility test were conducted. These tests were performed, investigated and compared to evaluate the effect of indirect tensile strength (ITS) on asphalt concrete modified with several ranges of crumb rubber. It has been shown that (0%) is control sample, while (2, 4, 6, 8 and 10) are percent of rubber by the total weight of aggregate. One of the critical issues in asphalt pavement is moisture damage. The existence of moisture play a great role in reducing the stiffness of the asphalt mix as well as makes the chance for stripping of the asphalt from the aggregate. This study evaluates the strength loss by comparing two methods of ITS test, which are conditioned (tested in saturated state) and unconditioned (tested in dry state) samples. Marshall Mix method was applied for preparation of total 24 samples for both states of ITS. The results show that for conditioned samples 6% of CR gives the highest value of tensile strength, (892) Kpa. While in unconditioned samples, 10% of CR gives even higher value of strength, compared to conditioned and control sample, (933) Kpa. According to AASHTO T 283-14, the tensile strength ratio (TSR) results of all samples are within the standards, using the minimum value of 80%. For asphalt modified with (2, 4, 6, 8 and 10) % of CR, the TSR values are (95.3, 97.7, 97.4, 93.6 and 90.9) % respectively. Moreover the results are discussed in detail in this study. As summary, the optimal dose of CR is 4% which gives better performance for penetration, softening point, elastic recovery and tensile strength ratio.

Contribution/Originality: This study contributes in the existing literature, to investigate the binding medium between concrete asphalt with crumb rubbe. This study uses new methodology which is called Wet Process, mixing crumb rubber with asphalt prior to the aggregate. This study originates new formula to improve asphalt and

asphalt concrete. This study is one of very few studies which have investigated tensile strength ratio (TSR) by using Indirect Tensile Strength Test, and elastic recovery for conventional mixture.

1. INTRODUCTION

Rubberized asphalt binder involves the mixture of normal asphalt binder with crumb rubber resulting from vehicles and automobile tires. With the rapid increase in development of the vehicle industry and factory, the number of individual that possess a car is growing and increasing each year. This huge amount of scrap and unwanted tires are indications for facing and dealing with a serious problem nowadays and in future [1]. Old tires actually do not decay and are permanent environmental matter. Unfortunately, tires are intended to be firm and are characterized by their chemical, biological, and physical resistance, which make them difficult to resolve [2]. Referring to the total weight of tires, there are three main components of tires: 22% almost synthetic fiber, 18% steel wire, and 60% rubber. As well as there are two procedures for pulverizing scrapping tires into crumb rubber: the ambient or cryogenic grinding procedures are used [3].

Recycling and repurposing are two thinkable approaches for disposing discarded tires. Yearly almost 80% of scrap tires have been recycled or repurposed, since 2003 Rangaraju [1] . There are various techniques to reuse these scrap tires, most common method is to apply in civil engineering applications [4]. Numerous investigations have studied the performance of asphalt mixtures that use crumb rubber obtained from squander tires. Studies have found adding crumb rubber into asphalt mixture has many advantages, reutilizing the rubber of scrap tire facilitate the pressure on atmosphere and enhance the performance of asphalt. Due to this, the performance of pavements depend on bituminous mixture, external and environmental factors such as heavier loads, higher traffic volume, higher tire pressure and climate circumstances like high or low temperature [5]. In addition, there is another serious distress in pavements which is moisture damage in bituminous mixtures. Moisture may harm and damage asphalt concrete by three behaviors. Initially, the loss of cohesion of the asphalt layers which is caused by merging the moisture with asphalt. Secondly, the reason behind the bond failure at the asphalt aggregate interface is water. Lastly, the effect of moisture in the asphalt concrete may result in disintegration of the aggregate in the concrete. These defects in concrete are known as stripping. Stripping in asphalt pavements can lead to early destruction of the pavement structure [6].

Crumb rubber is antistripping agent. Assists the flexible pavement to improve the binder stability at high temperature, crack resistance at low temperatures and fatigue resistance [1]. Regardless of its many advantages, hot mixed asphalt that contain crumb from waste tires are infrequently recycled in some countries [2]. Iraq is an example, possibly because of the lack of researches that focuses its benefits in Iraq circumstance.

The scope of this study is to determine the tensile strength ratio (TSR) and elastic recovery for conventional mixture then compare them with crumb rubber modified asphalt (CRMA) with different percentages of rubber. Also the laboratory evaluation focuses on asphalt mixture tests for instance; penetration, ductility and softening point. In addition, Marshall Mix design was conducted to determine Optimum Bitumen Content (OBC) which was 5.2% of the total weight of the aggregate. 4% is the optimal CR content which was added to the mixture as additive.

2. MATERIALS AND EXPERIMENT PREPARATIONS

2.1. Aggregate

The aggregates used in the tests were from the type of lime aggregate and they are of various sizes from the biggest size 38 mm to smallest size of 0.075 mm. Gradation of aggregate used in this test is according to GDH of Turkish Highway Construction Specification Standards for use in surface course pavements. The physical properties of aggregate are summarized in Table 1.

Table-1. Physical properties of aggregate used in this study

Properties	Test Results	Standards
Specific Gravity of coarse aggregate, 25°C, gr/cm^3	2.672	ASTM C127-07
Water Absorption of coarse aggregate, %	1.343	ASTM C127-07
Specific Gravity of fine aggregate, 25°C, gr/cm^3	2.674	ASTM C128-07a
Water Absorption of fine aggregate, %	0.606	ASTM C128-07a
Specific Gravity of filler, 25°C, gr/cm^3	2.75	ASTM C128-07a
Los Angeles test, %	26.12	ASTM C535-09
NaSo4 Soundness, %	4.05	ASTM C 88

2.2. Bitumen

The bitumen type used here was the PGB 50/70 which is a standard Penetration Grade Bitumen (PGB). Commonly used as a paving grade of bitumen, this is proper for road constructions mostly for wearing courses as well as for manufacturing of asphalt pavements with greater and better properties. The properties of neat bitumen are shown in Table 3.

2.3. Crumb Rubber

The CR used in this research is 100% of Turkish sources it is taken from (Akyüz İnovasyon ve Geri Dönüşüm Teknolojileri San.Ve Tic.A.Ş) in Istanbul city, Turkey. Its trademark is registered as CRM 300. It's also called fine crumb rubber because by making sieve analysis, particles retains on sieve no. 0.125 mm and 0.075 mm respectively.

Table-2. Sieve Analysis for crumb rubber

Sieve Size (mm)	25	19	12.5	9.5	4.8	2	1	0.25	0.125	0.075	filler
Retained (gm)	0	0	0	0	0	0	0	0	245	56.5	2.5

Fig-1. Sieve analysis for CR

Fig-2. Crumb Rubber

Table-3. Properties of neat bitumen with crumb rubber modified asphalt

Properties	Values						Standards
	0%	2%	4%	6%	8%	10%	
Penetrat□on at 25˚C, 1/10 mm	69.1	62.3	59.8	53.3	51.9	50.7	EN 1426
Ductility at 25°C, cm	100	26.5	23.5	19.8	18.9	18.5	ASTM D 113
Softening Point, °C	51.3	50.5	53	53.5	55.5	57.8	EN1□27
Elastic Recovery , % (25°C)	13	15.2	35	37.8	38.6	41	□STM D 6084

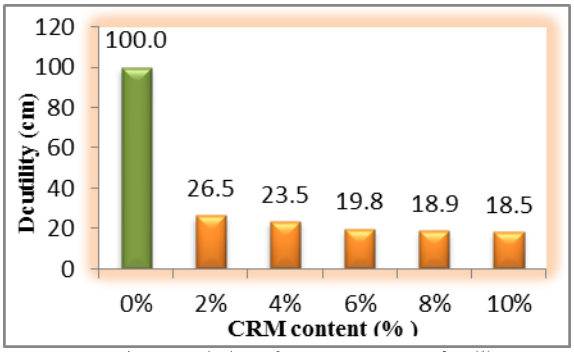


Fig-3. Variation of CRM content vs. ductility

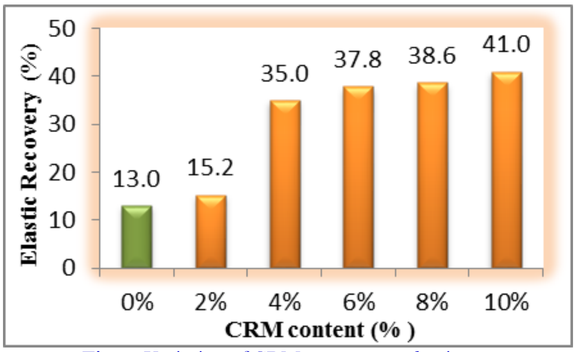


Fig-4. Variation of CRM content vs. elastic recovery

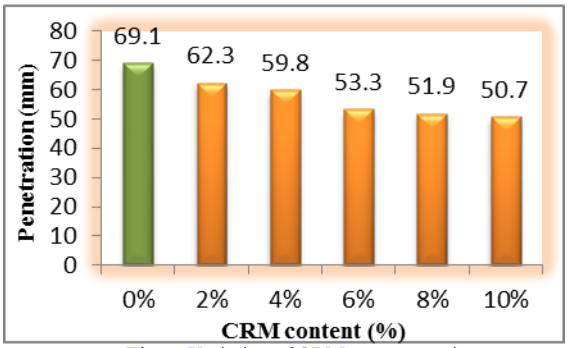


Fig-5. Variation of CRM vs. penetration

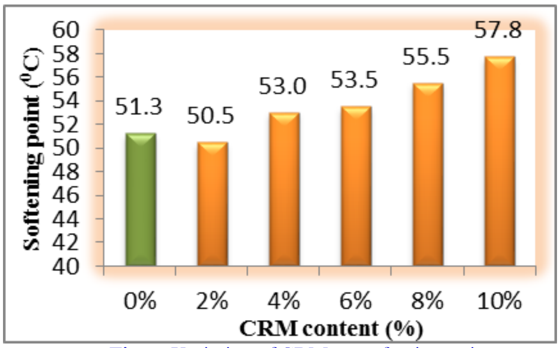


Fig-6. Variation of CRM vs. softening point

2.4. Mix Design Method

Marshall Design Method was used to prepare the samples for I.T.S. which was conducted according to ASTM D 6931 standard. Specimens were left to cool in a controlled temperature cabinet at 25°C for at least 3 hours. For pavement engineers, the tensile properties are of great interest for bituminous mixtures, because of the problems related to cracking [6].

24 specimens were prepared for each additive (0-2-4-6-8-10) %; they divided into two groups (12 specimens each). The first 12 samples were submerged in a water bath at 60˚C, for 24 hours (conditioned sample). The samples are then removed from the water bath and kept at a temperature of 25˚C for a period of 2 hours. Other set of samples (unconditioned sample) were kept at a temperature of 25˚C for a period of 2 hours without submerging in a water bath. Then these samples were mounted on the conventional Marshall testing apparatus and loaded at a deformation rate of 51mm/min and the failure load is recorded at each case. Then the tensile strength of conditioned as well as unconditioned specimen for each additive stabilized mixture is determined. The following is the detail for Marshall Preparation.

3. RESULTS AND DISCUSSIONS

3.1. Indirect Tensile Strength

The ITS of bituminous blends is performed by loading a cylindrical specimen laterally by vertical diametric plane at a specified rate of deformation.

Two types of HMA samples are subjected to a moisture susceptibility test (usually called as Indirect Tensile Strength test (ITS). One type is used as a control (unconditioned) by leave it in room temperature at 25 ºC. The other type is conditioned by saturating with water, soaking in water for 24 hours. Tensile Strength Ratio (TSR) is defined as the ratio of the average tensile strength of the conditioned samples over the average tensile strength of the unconditioned (control) samples.

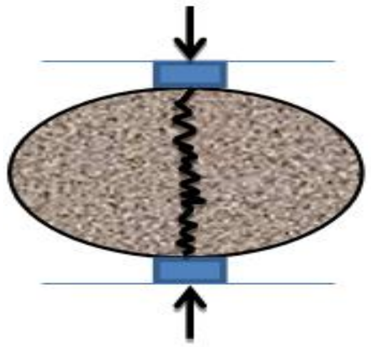


Fig-7. Loads acting vertically on compacted specimen

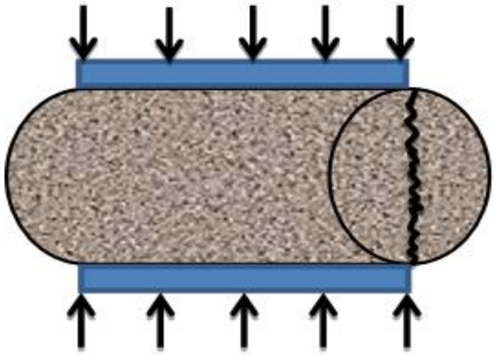
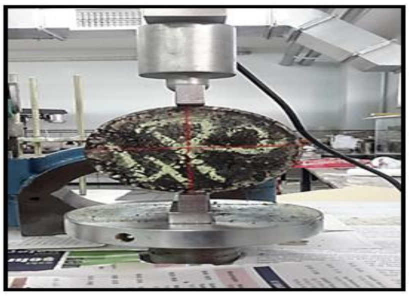


Fig-8. Schematic represents ITS test

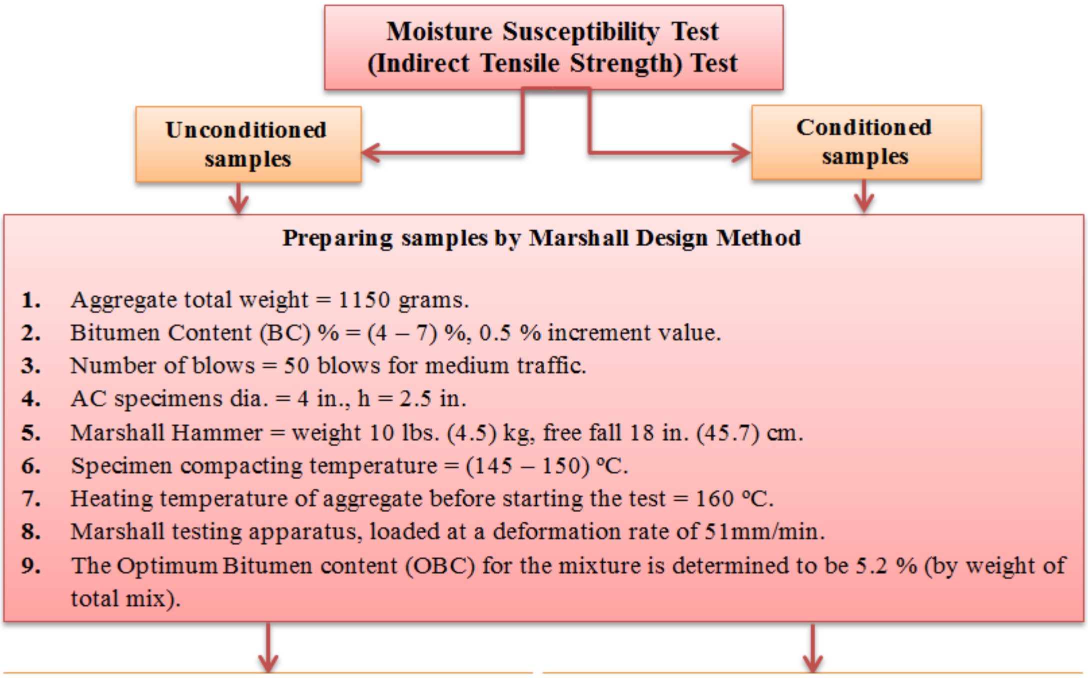
Samples prepared by Marshall Mix Design

Samples placed in distilled water



Sample during ITS test

Fig-9. Indirect Tensile Test



Preparing samples for ITS test (wet state)

1. Twelve Marshall samples were prepared and compacted with Marshall Hammer.
2. Samples were left to a room temperature for some hours between (3-4) hours to cool.
3. Samples were placed and were left in a water bath in which the container is prefilled with water until the sample is covered by 1 inch (25 mm) of water.
4. The bulk specific gravity (G_{mb}) and the SSD mass were calculated and determined for comparing the volume of absorbed water.
5. The degree of saturation is determined by comparing volume of absorbed water with volume of air voids (V_a).
6. Indirect tensile test is run on each sample by placing the sample between the two bearing plates in the testing machine and applying the load at a constant rate of 2 in / min (50 mm/min).
7. The tensile strength values are recorded.

Preparing samples for ITS test (dry state)

1. Twelve Marshall samples were prepared and compacted with Marshall hammer.
2. The bulk specific gravity (G_{mb}) and the SSD mass were calculated and determined for comparing the volume of absorbed water.
3. The degree of saturation is determined by comparing volume of absorbed water with volume of air voids (V_a).
4. Indirect tensile test is run on each sample by placing the sample between the two bearing plates in the testing machine and applying the load at a constant rate of 2 inches/minute (50 mm/min).
5. The tensile strength values are recorded.

3.2. Indirect Tensile Strength for Conditioned Samples

The results for ITS of conditioned samples, inverses with dry stated samples, as shown in table 4. By adding (2, 4, 6)% of CR to the bitumen binder, the strength increases and reaches the maximum value by adding 6% of CR as compared to control mix. But a sudden decrease can be seen by adding 8% and 10% of CR by 857.722 kpa to 847.997 kpa respectively.

Table-4. Indirect tensile strength results for conditioned samples

No		h1 (mm)	h2 (mm)	h3 (mm)	hav (mm)	Wair (gr)	Wwater (gr)	Gmm	Gmb	Va	P Load (kN)	P Load (N)	Tensile Strength (MPa)	Tensile Strength (kPa)
1	C1	61.68	61.70	61.78	61.72	1194.9	698.1	2.405	2.484	3.2	8.692	8692	0.882	882.428
2	C2	62.17	62.19	62.21	62.19	1196.6	699.8	2.409	2.484	3.0	8.563	8563	0.863	862.762
					61.96	**1195.8**	**699.0**	**2.407**	**2.484**	**3.1**	**8.628**	**8628**	**0.873**	**872.595**
3	2R1	62.30	62.26	62.30	62.29	1192.6	695.8	2.401	2.485	3.4	8.567	8567	0.862	861.825
4	2R2	62.62	62.69	62.53	62.61	1191.6	696.3	2.406	2.485	3.2	8.546	8546	0.855	855.227
					62.45	**1192.1**	**696.1**	**2.403**	**2.485**	**3.3**	**8.557**	**8557**	**0.859**	**858.526**
5	4R1	62.40	62.37	62.35	62.37	1194.4	698.3	2.408	2.486	3.2	8.746	8746	0.879	878.610
6	4R2	62.49	62.36	62.47	62.44	1197.0	700.8	2.412	2.486	3.0	8.771	8771	0.880	880.180
					62.41	**1195.7**	**699.6**	**2.410**	**2.486**	**3.1**	**8.759**	**8759**	**0.879**	**879.395**
7	6R1	62.96	61.95	62.96	62.62	1195.9	697.3	2.399	2.486	3.5	8.762	8762	0.877	876.703
8	6R2	62.10	62.02	62.04	62.05	1197.0	700.8	2.412	2.486	3.0	8.987	8987	0.907	907.476
					62.34	**1196.5**	**699.1**	**2.405**	**2.486**	**3.2**	**8.875**	**8875**	**0.892**	**892.089**
9	8R1	62.27	62.42	62.34	62.34	1186.3	690.8	2.394	2.487	3.7	8.352	8352	0.839	839.433
10	8R2	62.74	62.84	62.76	62.78	1192.1	694.4	2.395	2.487	3.7	8.777	8777	0.876	876.012
					62.56	**1189.2**	**692.6**	**2.395**	**2.487**	**3.7**	**8.565**	**8565**	**0.858**	**857.722**
11	10R1	63.13	63.11	63.16	63.13	1200.5	697.4	2.386	2.488	4.1	8.863	8863	0.880	879.645
12	10R2	63.31	63.42	63.24	63.32	1198.5	695.7	2.384	2.488	4.2	8.250	8250	0.816	816.348
					63.23	**1199.5**	**696.6**	**2.385**	**2.488**	**4.1**	**8.557**	**8557**	**0.848**	**847.997**

Table-5. Average ITS test results for conditioned state

CR %	H_{av} (mm)	W_{air} (gr)	W_w (gr)	G_{mm}	G_{mb}	V_a	P (kN)	Tensile Strength (Mpa)	Tensile Strength (Kpa)
0	61.96	1195.8	699.0	2.407	2.484	3.1	8.628	0.863	**872.595**
2	62.45	1192.1	696.1	2.403	2.485	3.3	8.557	0.859	**858.526**
4	62.41	1195.7	699.6	2.410	2.486	3.1	8.759	0.879	**879.395**
6	62.34	1196.5	699.1	2.405	2.486	3.2	8.875	0.892	**892.089**
8	62.56	1189.2	692.6	2.395	2.487	3.7	8.565	0.858	**857.722**
10	63.23	1199.5	696.6	2.385	2.488	4.1	8.557	0.848	**847.997**

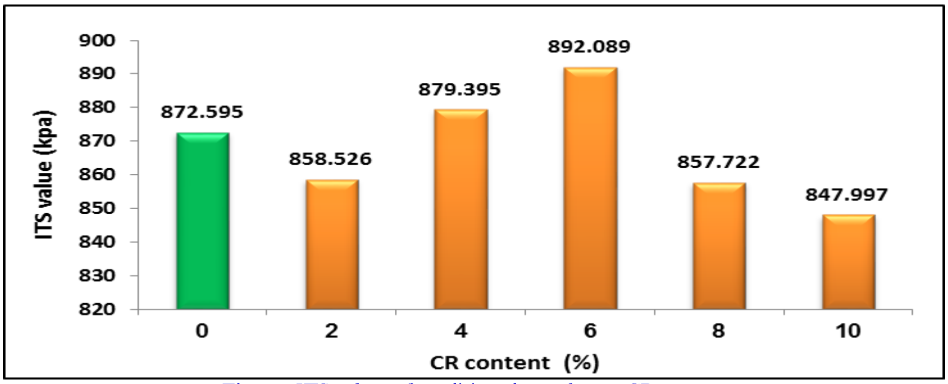


Fig-10. ITS values of conditioned samples vs. CR content

3.4. Indirect Tensile Strength for Unconditioned Samples

ITS of Unconditioned samples decreases by adding (2, 4 and 6) % of CR as compared to control mix which has greater value of 912.531 KPa, as shown in Table 5. But there is a sudden increase by adding 8% and 10% of CR by 916.350 kpa and 933.390 kpa respectively can be seen. At last a concaved up curve will be achieved.

Table-5. Indirect tensile strength results for unconditioned samples

CR %	H_{av} (mm)	W_{air} (gr)	W_w (gr)	G_{mm}	G_{mb}	V_a	P (kn)	Tensile Strength (MPa)	Tensile Strength (KPa)
0	62.00	1190.0	696.6	2.412	2.484	2.9	9.031	**0.913**	**912.531**
2	62.22	1196.6	700.4	2.411	2.485	3.0	8.947	**0.901**	**900.998**
4	62.38	1196.5	700.1	2.410	2.486	3.0	9.138	**0.918**	**906.144**
6	62.57	1196.0	698.8	2.405	2.486	3.2	8.801	**0.881**	**881.356**
8	62.75	1193.8	694.6	2.392	2.487	3.8	9.177	**0.916**	**916.350**
10	63.10	1199.4	696.9	2.387	2.488	4.1	9.399	**0.933**	**933.390**

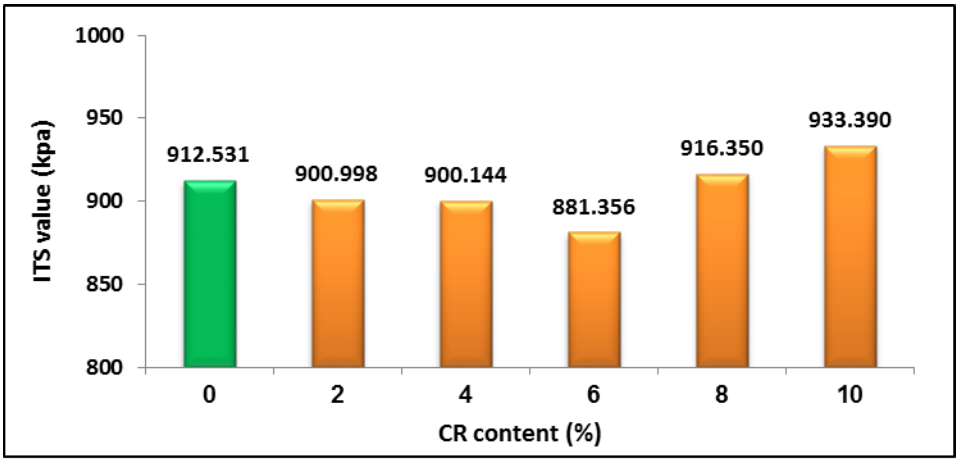


Fig-11. ITS values of unconditioned samples vs. CR content

3.5. Tensile Strength Ratio

Tensile Strength Ratio (TSR) is the last step for this test can be found by calculating tensile strength ratio (TSR) before and after conditioning. In Fig 12. TSR value results are shown and a half concaved down curve is achieved. There is a very important point should be discussed which is moisture damage; it is the result of moisture interaction with the asphalt binder - aggregate adhesion within a HMA mixture.

The ITS test is a performance test which is often used to evaluate the moisture susceptibility of a bituminous mixture. Tensile strength ratio (TSR) is a measure of water sensitivity. It is the ratio of the tensile strength of water conditioned specimen, (ITS wet, 60°C, and 24 h) to the tensile strength of unconditioned specimen (ITS dry) which is expressed as a percentage. A higher TSR value typically indicates that the mixture will perform well with a good resistance to moisture damage. The higher the TSR value, the lesser will be the strength reduction by the water soaking condition, or the more water-resistant it will be [6].

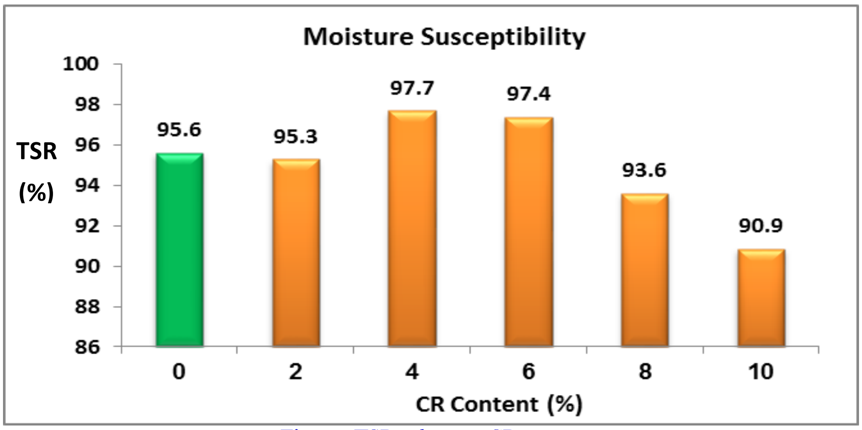


Fig-12. TSR values vs. CR content

Table-6. Tensile strength ratio results

CR (%)	Dry State (Unconditioned)	Wet state (Conditioned)	Tensile Strength Ratio (TSR) (%)
0	912.531	872.595	95.6
2	900.998	858.526	95.3
4	900.144	879.395	97.7
6	895.356	872.089	97.4
8	916.350	857.722	93.6
10	933.390	847.997	90.9

$$TSR = \frac{S1}{S2} * 100$$ Where:

- TSR = Tensile strength ratio
- S_1 = Average tensile strength of unconditioned samples
- S_2 = Average tensile strength of conditioned samples

4. CONCLUSION

Based on the results in this laboratory evaluation, the conclusions of this study are summarized as the following:

1. Crumb rubber is proposed by many scholars as asphalt additive, moreover the results are within the standard requirements.
2. By increasing the addition amount of CR to asphalt, penetration, ductility, softening point and elastic recovery values will change. Compared to the control mix sample 0%, penetration and ductility values decrease by increasing the amount of CR. Meanwhile softening point and elastic recovery will increase as shown in table 3. Most significant improvement noticed in this study is higher elastic recovery values.

From the addition of 10% of CR to the asphalt binder, the elastic recovery value gave highest value of 41% as compared to conventional sample 0% which was 13%.

3. ITS of Unconditioned samples decreases by adding 2%, 4% and 6% of CR modifier as compared to control mix which has value 912.531 kpa, 900.998 kpa, 900.144 kpa and 881.356 kpa respectively. But there is a sudden increase by adding 8% and 10% of CR by 916.350 kpa and 933.390 kpa respectively. ITS of Conditioned samples, as it inverses with unconditioned samples, by adding the amount 2%, 4%, 6% of CR to the bitumen binder it increases the tensile strength value up to 6% as compared to the control mix, from 913.252 kpa to 858.526 kpa, 879.395 kpa and 892.089 kpa respectively. But a sudden decrease can be seen by adding 8% and 10% of CR by 857.722 kpa and 847.997 kpa respectively.
4. As summary the scope of this study is to determine the tensile strength ratio (TSR) and elastic recovery for conventional mixture. Later step is to compare them with crumb rubber modified asphalt (CRMA) with different percentages of rubber. Also the laboratory evaluation focuses on asphalt mixture tests for instance; penetration, ductility and softening point. In addition, Marshall Mix design was conducted to determine Optimum Bitumen Content (OBC) which was 5.2% of the total weight of the aggregate. 4% is the optimal CR content which was added to the mixture as additive.

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Contributors/Acknowledgement: Both authors contributed equally to the conception and design of the study.

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