Use of Waste Tire Rubber as an Additive to Asphalt Mixture

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ABSTRACT

Properties of pavement performance are effected by the bitumen properties with increased continuously consumption, large amount of waste rubber materials is generated annually in the world. The main objective of this study is to study the change in asphalt properties and asphalt mixture properties after adding tire rubber. Fine crumb rubber size 30 # (0.6 mm) was selected. The original sample is prepared without adding rubber for (4.5%, 5%, %6 ,%5.5 , and 6.5% of bitumen). Other samples are prepared by adding the crumb rubber to the bitumen mixture in wet process with 3%, 6% %9 and 12% by bitumen weight. Results showed that, increasing the rubber ratio would significantly affect the properties of the bitumen mixture. Where the values of penetration and softening point will decrease as the percentage of waste tire rubber materials are increased. Generally, this will result in an improvement in asphalt properties when it is compared to the reference asphalt sample (Un-treated asphalt).

Keywords: Asphalt mixture, crumb rubber, penetration, softening point, waste materials.

1. Introduction

In recent years, with the rapid development of road transportation, the mileage of asphalt pavement grows fast. However, due to the increase of the traffic volume, especially the influence of overloaded traffic, an early damage of the asphalt pavement occurs frequently. This is generally caused by several factors, such as the material’s properties, construction method, construction quality, traffic volume and loads, the unsuitable design method of asphalt mixture is also considered as main reason causing the early damage of asphalt mixture. Therefore, how to improve the performance of asphalt mixture and prolong the service life of pavement becomes an important research direction of the road building materials [1]. Also, despite the great benefit of using the waste material as an additive to enhance the properties of asphalt pavement, using additives to the asphalt mixture is not sufficiently investigated in Libya. The use of industrial additives in bitumen mixes will increase the construction cost. However, the use of alternative materials, [2] Waste rubber tire is an ideal asphalt modifier, [1] waste tires crumb rubber is less costly and ecofriendly, and is expected to enhance the bitumen properties. This enhancement appeared in increasing asphalt resistance to pavement distress such as rutting, fatigue cracking, and low-temperature cracking [2]. It's shown in some research papers that adding rubber particles into asphalt can significantly improve the performance of asphalt and its mixture, such as enhancing durability of pavement, increasing the toughness and elasticity recovery of asphalt, improving the aging resistance and anti-rutting ability, and reducing the pavement noise etc [1]. The properties of rubberized bitumen binders at a wide range of temperatures are highly dependent on the chemistry of the bitumen binder, the crumb rubber content, size and texture of rubber particle and the blending conditions [3]. The main purpose of this paper is to investigate whether the addition of crumb rubber produced from waste car tires improving the properties of asphalt mixture or not.

2. Materials and Methods

Bitumen specifications vary to meet the consuming needs and they are based on different tests. Asphalt is a composition of a bituminous binder with mineral aggregates, sand and filler, and approximately 4-7% bitumen. [2] Modified asphalt binder materials, paving products can be made with crumb rubber by several mixing or blending process including dry process. In the dry process crumb rubber blend with hot aggregate before incorporate with asphalt binder, and wet process the crumb rubber blend with asphalt binder before incorporate with aggregate. [4]

For this paper work aggregate, bitumen and crumb of scrap tire shown in figure 2 were used. Different properties of bitumen and aggregate have been tested. Then prepare different mixes of bitumen and crumb of waste tire rubber with varying proportions by using wet process. The percentage weight of crumb tire rubber replace for percentage weight of bitumen taken for test. The feasibility of different mixes of bitumen and crumb tire rubber with varying proportions with aggregate has been tested. The mixture method used different concentrations of crumb rubber were prepared by first heating the asphalt to 160°C, upon reaching 160°C, a weight amount of rubber were slowly added to the original bitumen will mixing at 160°C by using manually blending for blending time 20 minute.

Particle size distribution of aggregate & filler used in the mixture compared to the specifications are illustrated in Table 1 and figure 1.

Table 1: *Admixture aggregates types*

Opening (mm)	11% (3/4-4)	5% (1/2-8)	34% (1/2-30)	45% Fine	5% Filler	Final Gradate	Specification [5]
25	10.96	5	34	45	5	99.96	100 (1)
19	10.26	5	34	45	5	99.26	97 – 100 (1)
12.5	0.9	4.78	33.14	45	5	88.82	76 – 88 (5)
9.5	0.21	4.67	31.42	45	5	86.3	- - - - - -
4.75	0.05	0.13	15.12	45	5	65.3	49 – 59 (7)
2.36	0.04	0.01	2.07	35.58	5	42.7	36 – 45 (5)
0.6	0.04	0.01	0.28	11.34	5	16.65	20 – 28 (4)
0.3	0.04	0.01	0.23	8.04	4.97	13.28	13 – 21 (3)
0.075	0.03	0.01	0.07	2.83	3.51	6.45	7 – 3 (2)

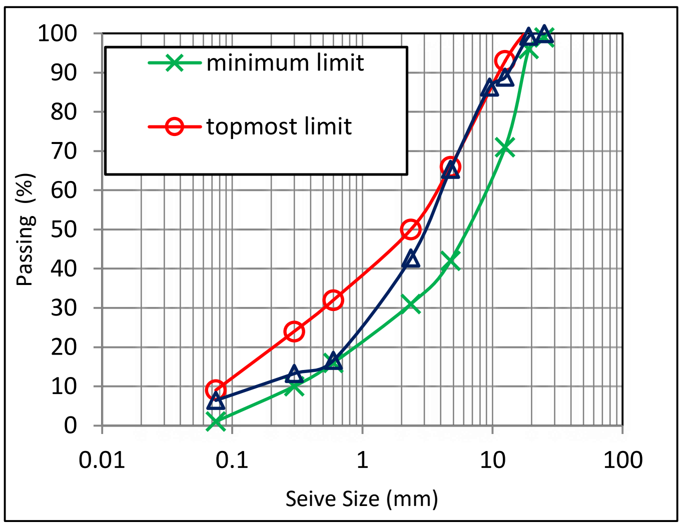


Figure 1. Grain size distribution curves

Figure 2. Crumb Rubber

Table 2: *Results of Los Angeles &Specific gravity tests*

Sr. No	Aggregate tests [5]	Test results obtained				
1	Los Angeles abrasions value %	25.6				
	Sieved size mm	(3/4-4)	(1/2-8)	(1/2-30)	fine	filler
2	Bulk SP Gr.(Gsb)	2.534	2.54	2.532	2.589	-
3	Bulk SP Gr.(S.S.D).Gse	2.576	2.59	2.587	2.65	-
4	Apparent SP.Gr.(Gsq)	2.645	2.674	2.679	2.757	2.528
5	Water absorption %	1.659	1.968	2.161	2.355	-

Table 3: *Specific gravity for total aggregate*

Bulk SP Gr.(Gsb)	Bulk SP Gr.(S.S.D).Gse	Apparent SP.Gr.(Gsq)
2.558	*2.701*	*2.611*

Table 4: *properties of the asphalt without rubber content*

Penetration Test, 0.1mmx25°C	Softening Point Test, °C	Flash and Fire Point, °C	Specific gravity
65.67	48.5	Flash degree 250,Fire degree 257	1.051

For maintaining consistency of the CRM throughout the entire study, one batch of crumb rubber obtained from one local source was solely used. In this study, fine crumb rubber size 30 # (0.6 mm) was selected in order to reduce segregation. The results sieve analysis test of crumb rubber is illustrated in Table 5.

Table 5: *Granular combination of recycle (CR) according to specification AASHTO T27-11*

Sieve size	WT. retained gm	%retained	%Passing
2.36mm(N8)	0	0	100
0.6 mm(N30)	129.45	53.34	46.66
0.3 mm(N50)	69.85	28.88	17.78
0.15mm(N100)	30.3	12.53	5.25
0.075mm(N200)	9.45	3.9	1.35
Pass	2.75	1.13	0.22

Marshall Stability test has been prepared for bituminous mix design. For this research project, the size of aggregate used as follows:

There are steps involving for producing the modified asphalt mixture Collecting of aggregate, bitumen and crumb of scrape tire. Then different properties of bitumen and aggregate have been tested. The sample is prepared with and without adding rubber for (4.5, 5, 5.5, 6, 6.5) % of asphalt and total weight for mixture 1180g as explained in Table 6. Samples are prepared by adding rubber to asphalt at 160% in wet process (3, 6, 9) %

rubber by asphalt weight for (4.5, 5, 5.5, 6, 6.5) % of asphalt which were adding to mixture. The aggregate was placed in oven at 170°C for 4 hours. All materials mixes were manually mixing on flame. Then it was placed in oven at 170°C for 4 hours. The mixture was then compacted at temperature of 160±5°C. All samples were subjected to 75 blows of compaction by Marshall Hammer on each side of specimen, another 45 samples are prepared by mixing crumb rubber with asphalt.

Table 6: *Mix Proportion*

asphalt %	**4.5**	**5**	**5.5**	**6**	**6.5**
(3/4-4) gm	124	123.31	122.7	122	121.4
(1/2-8) gm	56.35	56.05	55.755	55.46	55.165
(1/2-30) gm	383.18	381.14	379.13	377.13	375.12
Fine gm	507.15	504.45	501.8	499.14	496.5
Filler gm	56.35	56.05	55.755	55.46	55.165
Total aggregate gm	1127	1121	1115.1	1109.2	1103.3
asphalt gm	53.1	59	64.9	70.8	76.7

3. Results and Discussion

The main objective of this paper was to study the change in asphalt properties & asphalt mixture properties after adding crumb rubber.

Table 7: *Properties of bitumen by varying % of rubber*

Properties	**60/70 grade bitumen**	**Bitumen with rubber content %**				**Method of testing**
		3	**6**	**9**	**12**	
Penetration Test,0.1mmx25°C	65.7	49.1	43.7	40.2	37.8	standard ASTM D2397
Softening Point Test, °C	48.5	50	50.5	51.85	52.25	standard ASTM D-36
Flash and Fire Point, °C	250,257	248,255	246,253	236,239	_	standard AASHTO T-48
Specific gravity	1.052	1.052	1.054	1.061	_	standard ASTM D-7

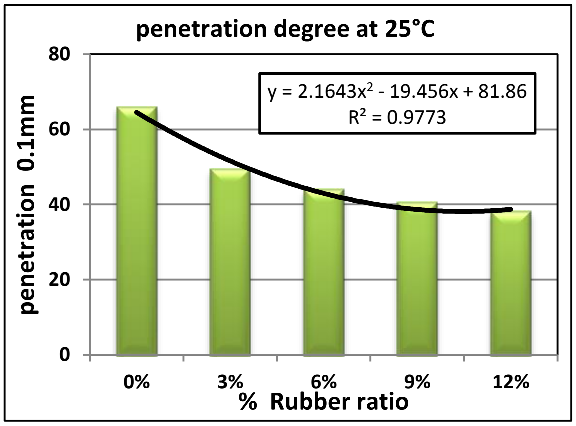


Figure 3. Penetration degree vs. rubber ratios

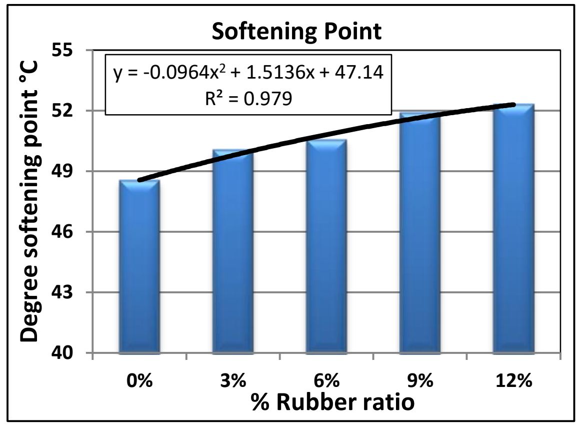
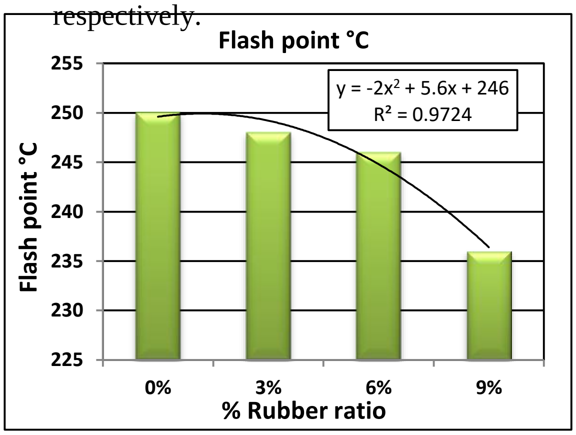


Figure 4. Softening point vs. rubber ratios

Figure 3 shows the effect of crumb rubber concentration on penetration. The penetration decreased as the amount of rubber increases up to 12%. The crumb rubber content has a strong effect on reducing the penetration value by increasing the stiffness of crumb rubber bitumen binder. The results of crumb rubber content (3, 6, 9) % correspondent to specification in Libya. [5] The average reduction in penetration value of modified binder was between 25 and 42 % for crumb rubber content ranging between 3 and 12% respectively. This increase in rubber content lead to enhanced the particle size of the rubber. This was due to the increase in rubber mass through the interaction and swelling of the rubber into the bitumen during the blending process, which led to the decrease in the penetration of rubberized bitumen. Thus, indicate that the rubberized bitumen binder will be less susceptible to high temperature change and more resistance to rutting. Figure 4 clarify softening point degree increased with the increase in rubber ratio. This means asphalt becomes more ruthlessness where it is risen softening point by ratios (3, 4, 6.9, 8.9) % with the rubber ratios (3, 6, 9, 12) % respectively.



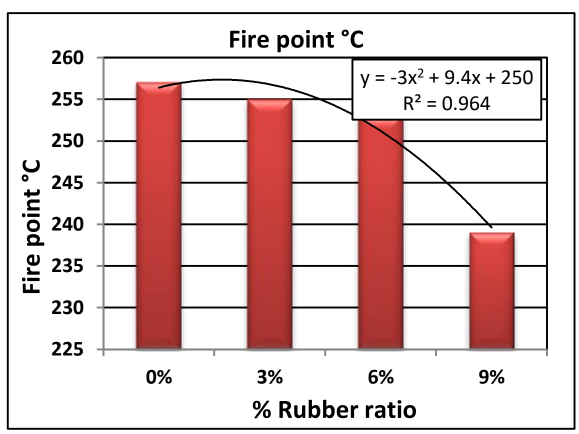


Figure 5. Flash point vs. rubber ratios

Figure 6. Fire point vs. rubber ratios

This was due to the differences between rubber an

it is obvious that the flash point degree and fire point degree will decrease as the asphalt modified with additive .Despite, this reduction in the values of both factors, the asphalt will be within AASHTO specification. Therefore, investigations in this point were not considered in the previous studies. Figure 7 shows the results of specific gravity would slightly increase as the percentage of crumb rubber additive is increased by (3, 6 and 9) %. Where, it will increase by about 1% as the percentage of crumb rubber increases from 0 to 9%. However, although the change in the value of specific gravity, it will remain within the ASTM specifications (1.01-1.06).

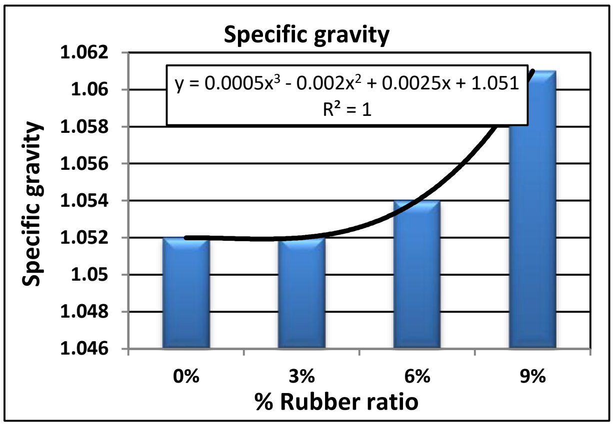


Figure 7. Values of specific gravity vs. rubber ratios

Effect of CRM on the asphalt mixture.

Marshall stability test

Number of tests has been conducted to specify the characteristics of asphalt mixture. Marshall Test was adopted to obtain these different characteristics (i.e stability, flow, Marshall density, voids ratio, voids filled with asphalt). Table (8) shows the Marshal Test results, where it is clear that, all test values shown in the table are consistent with the specifications limits.

Figures (8, 9, 10, 11 and 12) of curves test results are corresponding for graphs Marshall. The stability values of unmodified asphalt mixtures that asphalt ratios (4.5, 5, 6, 6.5) are not corresponding with the specifications, but asphalt ratio 5.5% and optimum asphalt content are identical with the specifications. The stability values for modified asphalt mixtures which modified by rubber ratios (3, 6, 9) and all asphalt content (4.5, 5, 5.5, 6, 6.5) % are correspond to specifications. Marshall properties for unmodified asphalt mixture such as flow values of all modified asphalt mixtures and unmodified that have (4.5, 5, 5.5, 6, 6.5) % asphalt and (3, 6, 9) % rubber ratios are within the specifications.

Table 8: *Results of Marshall test*

Asphalt %	%of rubber	Wt. of ample (gm)		Bulk specific gravity	% air voids (Vv)	VMA	VFB	Marshall stability (Kg)	Flow value (mm)
		Air	Water						
4.5	0	1172.5	662.67	2.3	5.185	14.142	63.357	572.361	2.5
5		1171.5	662.67	2.302	4.429	14.495	69.451	578.109	2.6
5.5		1150.5	648	2.29	4.314	15.417	72.039	625.922	2.7
6		1160.5	650.33	2.275	4.292	16.409	73.887	864.289	2.8
6.5		1152.17	644	2.267	3.96	17.12	76.989	622.177	2.85
4.5	3	1167.17	657.25	2.289	5.627	14.542	61.478	1123.472	2.4
5		1174.47	663.9	2.3	4.513	14.57	69.038	1480.544	2.5
5.5		1168.27	659.27	2.296	4.064	15.196	73.827	1175.726	2.65
6		1170.07	659.6	2.292	3.559	15.768	77.529	1106.054	2.7
6.5		1170.3	659.27	2.29	2.99	16.283	82.101	862.199	2.8
4.5	6	1153	644	2.266	6.614	15.42	57.434	1537.676	2.2
5		1165	655.33	2.286	5.136	15.109	66.032	1558.926	2.3
5.5		1160.17	652.83	2.287	4.452	15.519	71.377	1530.708	2.3
6		1163.33	653.83	2.283	3.957	16.095	75.416	1507.368	2.7
6.5		1157.83	656.5	2.282	3.362	16.581	79.726	1250.973	2.7
4.5	9	1168	653.67	2.271	6.456	15.219	57.576	984.1264	2.2
5		1163	656.17	2.295	4.841	14.781	67.247	1095.951	2.2
5.5		1166.67	659.83	2.302	3.9	14.961	73.931	1325.522	2.3
6		1162.67	656.17	2.296	3.529	15.646	77.442	1144.374	2.35
6.5		1156	650.67	2.288	3.226	16.383	80.311	1093.861	2.7

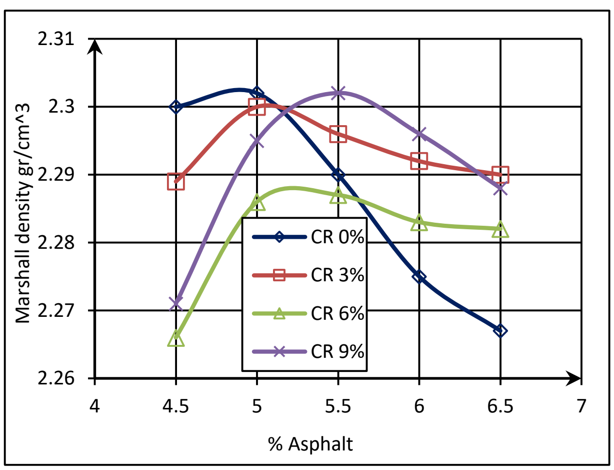


Figure 8. Marshall Density vs. asphalt content

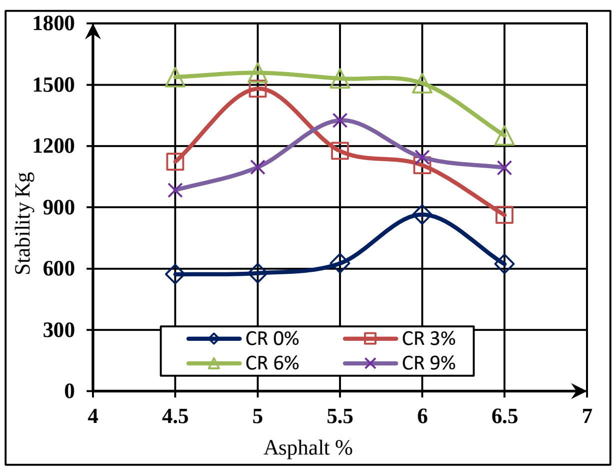


Figure 9. Marshall Stability vs. asphalt content

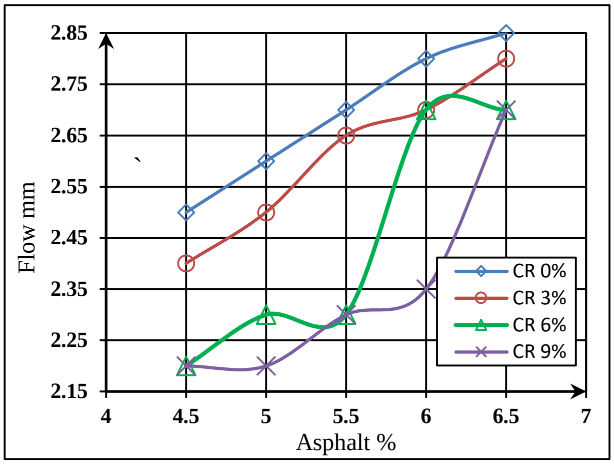


Figure 10. Flow results vs. asphalt content

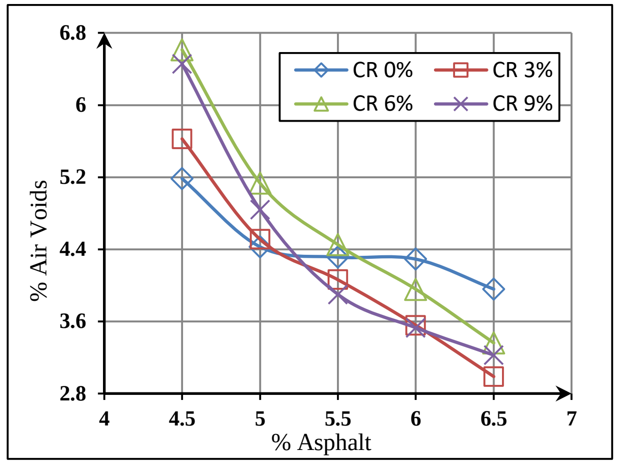


Figure 11. Air Voids vs. asphalt content

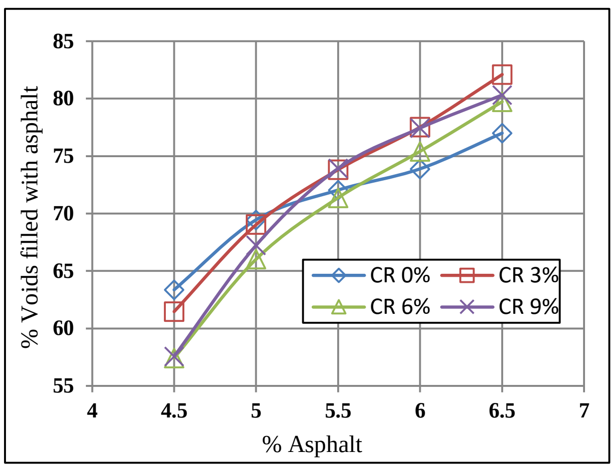


Figure 12. Voids filled with asphalt vs. asphalt

The comparison between results asphalt unmodified and modified by rubber respecting ideal asphalt ratio and stability and flow to ideal asphalt ratio are explained the results in Table 9. Inference for Table 9 decrease optimum asphalt content of modified asphalt mixture, decrease in modified mixture by compare with mixture unmodified (11.85, -5.22, - 6.082) for rubber ratios (3, 6, 9) % respectively. Stability values increased for modified mixture in compare with mixture unmodified, increased for stability in all modified mixtures, increased percentage in stability values in compare with mixture unmodified (81.25, 87.39, 62.385) % to rubber ratios (3, 6, 9) % respectively to all ideal asphalt ratio in mixture, increased in stability for 3%, 6% rubber then leaser at 9% rubber.

Table 9: *Values of stability and flow corresponding to ideal asphalt ratio*

Asphalt mixture	Ideal ratio to asphalt %	Stability Kg	Flow mm
used asphalt 60-70 not modify	5.82	816.28	2.775
used asphalt modify by rubber ratio 3%	5.13	1479.544	2.51
used asphalt modify by rubber ratio 6%	5.516	1529.708	2.4
used asphalt modify by rubber ratio 9%	5.466	1325.522	2.22

Flow values in modified mixture decreases in compare with mixture unmodified for ideal values to asphalt in all mixture, percentage change for flow (-9.549, -13.513,-20) % according to the rubber ratio (3, 6, 9) % respectively.

Therefore demanding for used rubber ratio 6% for modified mixture because given higher stability and good flow in compare with another modified mixture and unmodified.

4. Conclusions

Stability values of all modified asphalt significantly increased in a comparison to values of unmodified mixtures at all asphalt ratio (4.5, 5, 5.5, 6, 6.5) %. Furthermore, the highest value of stability will be presented at 6% of crumb rubber for all asphalt ratios. Decrease flow values in all modified mixture by comparing with flow values for unmodified mixture for all asphalt ratio. Modified asphalt mixture by 9% and 6% of CR gives highest percentage of reduction in flow at asphalt percentages of (4.5, 5.5, 6.5) %. Decreasing for penetration degree and increased softening point for modified asphalt by rubber in comparison with asphalt unmodified, decrease for penetration degree and increased in softening point correspondent with increased for additive rubber ratio. Modified asphalt mixture by recycle rubber of cars tire improved the stability values and reduces the flow values this given longer life for asphalt mixture. Asphalt rubber paving programs are key components to acceptable and successful waste tire management programs.

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