Effect of Adding Waste Tires Rubber to Asphalt Mix

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Abstract

Properties of pavement performance are affected by the bitumen binder properties. With the continuously increased consumption, a large amount of waste rubber materials is generated annually in the world. The main objective of this paper is to study the change in asphalt mixture properties after adding tires rubber. In this paper, some important properties of asphalt mix, including stability and flow are investigated. The original sample is prepared without adding rubber for (4.5%, 5%, and 5.5% bitumen). Other samples are prepared by adding rubber to bitumen in wet process with 5%, 10%, and 20% by bitumen weight. The results showed that the properties of rubber–asphalt mixture are improved in comparison with normal asphalt pavement. It is concluded that the use of tires rubber in asphalt pavement is desirable. The suitable amount of added rubber was found to be 10% by bitumen weight.

Keywords:

Asphalt performance, bitumen, rubber, waste tires, and stability.

1- Introduction

Properties of pavement performance are affected by the bitumen binder properties. The need to modify conventional bitumen rises due to high maintenance cost of the highway systems. Bitumen modification can be made at different stages of its usage, from binder production to asphalt pavement production and can be made by using different modifiers. 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.

The use of industrial additives in bitumen mixes will increase the construction cost. However, the use of alternative materials, such as waste tires crumb rubber is less costly and eco-friendly, and is expected to enhance the bitumen properties (Mashaan, 2012). This enhancement appeared in increasing asphalt resistance to pavement distress such as rutting, fatigue cracking, and low-temperature cracking (Shu and Huang, 2014).

2- Rubber Asphalt

Adding rubber to asphalt has similar benefits to adding additives to concrete. The additives materials helped the engineers to improve the asphalt for some special required specifications. Rubber asphalt is produced either by wet process: rubber is melted in the liquid asphalt binder before mixing, or by dry process: rubber replaced by a portion of fine aggregate during mixing (Huang et al. 2007). Rubber pavement association found that using tire rubber in open-graded mixture binder could decrease tire noise by approximately 50% (Zhu and Carlson, 2001).

Crumb rubber is used to minimize the damage of pavement such as resistance to rutting and fatigue cracking (Ali, 2013). Crumb rubber is derived from used vehicles tires and it is used for a wide variety of industrial applications (Clark et al. 1993). Heitzman (1992) indicated that the asphalt–rubber interaction involves two opposite mechanisms that occur simultaneously: particle swelling and dissolution. The absorption resulting in rubber particles swelling two to three times their original volume (Abdelrahman and Carpenter, 1999). Several studies reported higher construction cost of rubber asphalt pavements when compared to conventional ones (Huang B, 2002/ Amirkhanian, 2001).

3- Experimental Work

Various lab tests were conducted on aggregate including sieve analysis, specific gravity, and Los-Angeles tests. Specific gravity test results are shown in Table 1 below. While the wear percentage of aggregate after 500 revolutions in Los-Angeles test is 21.3%.

Table (1): Specific Gravity and Absorption of Aggregate

Status	Value
BULK SP. GRAVITY (DRY BASIS)	2.85
BULK SP. GRAVITY (SSD BASIS)	3.00
APPARENT SPECIFIC GRAVITY	3.34
ABSORPTION	5.15%

On the other hand, penetration test was conducted on the used bitumen. And 70/80 bitumen penetration grade was obtained. Properties of pure bitumen are shown in Table 2.

Table (2): Conventional Properties of Bitumen

Item	Value
Penetration (0.1mm)	78.1
Softening point (ºC)	52.3
Flashing point (ºC)	291
Specific gravity	1.02

The original sample is prepared without adding rubber for (4.5%, 5%, and 5.5% bitumen) the weights in grams (gm) are shown in Table 3.

Table (3): Original Sample Preparation for Different Bitumen Percentage

AGG. SIZE	3/4"	3/8"	05"	BITUMEN	TOTAL
Weight (gm)	229.2	343.0	573.0	54	1200
% Weight	19.1%	28.58%	47.75%	**4.5%**	100%
Weight (gm)	228.0	342.0	570.0	60	1200
% Weight	19%	28.5%	47.5%	**5%**	100%
Weight (gm)	226.8	340.2	567.0	66	1200
% Weight	18.9%	28.35%	47.25%	**5.5%**	100%

In the factory, the wires are dragged from waste tires, and the rubber is cut into small pieces. The crumb rubber is melt in bitumen at 170◦C and mixed with aggregate. 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 at temperature of 145◦C. After that, another nine samples are prepared by mixing crumb rubber with bitumen in wet process with 5, 10, and 20% of rubber from bitumen weight as in table 4.

Table (4): Crumb Rubber Mixing Weights

BITUMEN+ RUBBER 95% + 5%	BITUMEN+ RUBBER 90%+10%	BITUMEN+ RUBBER 80%+20%
4.5%	**4.5%**	**4.5%**
51.3 - 2.7	48.6 - 5.4	43.2 - 10.8
5%	**5%**	**5%**
57.0 - 3.0	54.0 - 6.0	48.0 - 12.0
5.5%	**5.5%**	**5.5%**
62.7 - 3.3	59.4 - 6.6	52.8 - 13.2

4- Results and Discussion

The main objective of this paper was to study the change in asphalt mixture properties after adding crumb rubber. Using Marshall Test, stability and flow of the prepared samples were recorded. Results are shown in table 5 and fig 1 and 2.

Table (5): Stability and Flow Results

BITUMEN	RUBBER% BITUMEN%	**4.5%**	**5%**	**5.5%**
Stability (kg)	No rubber	1335.6	1293.2	1280.48
Flow (0.01inch)		15	16	16
Stability	5%	424	614.8	805.6
Flow		14	16	18
Stability	10%	1314.4	1462.8	1568.8
Flow		14	15	16
Stability	20%	551.2	669.9	572.4
Flow		17	19	22

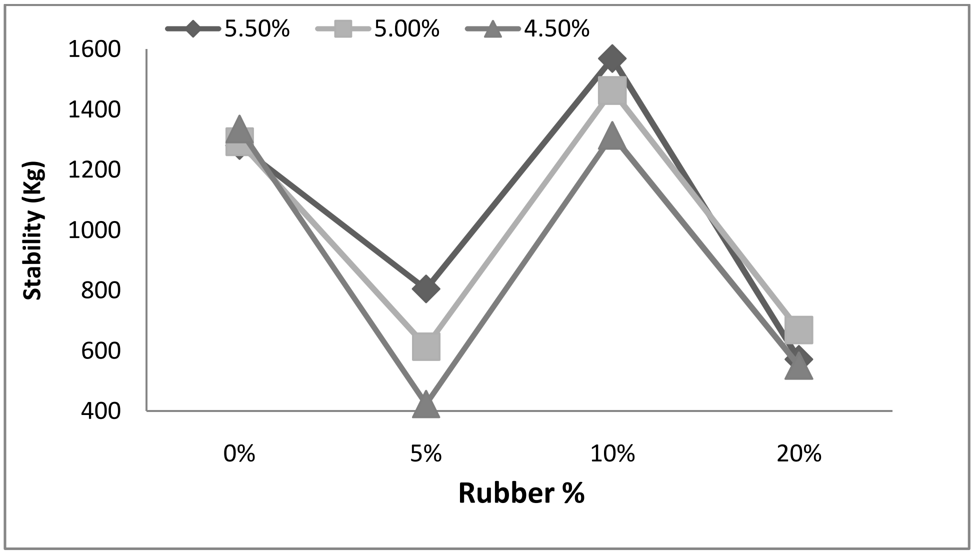

Figure (1): Relation between stability and rubber at different bitumen percentage

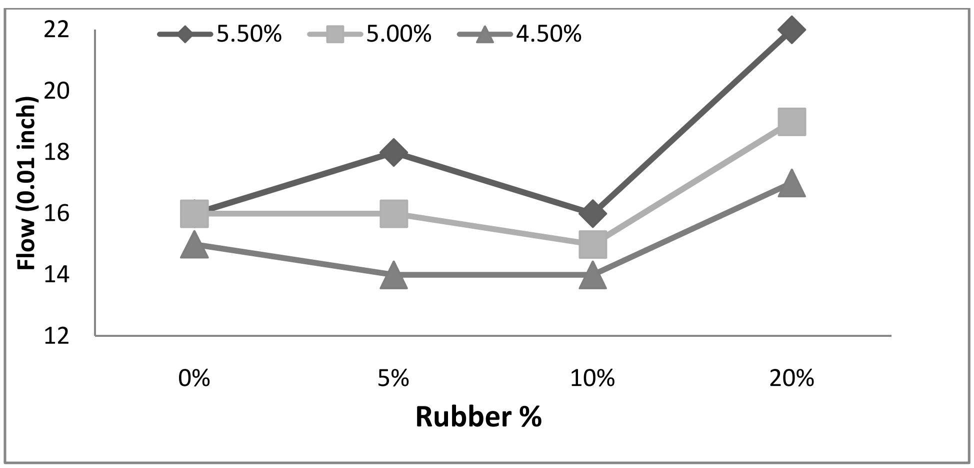

Figure (2): Relation between flow and rubber at different bitumen percentage

The average stability increased with rubber addition up to 10%, and decreases at higher percentages. At low percentage of bitumen, average stability of asphalt without rubber is low compared to asphalt with 10% rubber. The results showed that the flow value increases with an increase in the bitumen content. The flow value of asphalt without rubber is lower in comparison with the asphalt with 5%, and 20% rubber but higher than 10% rubber. The average values of Marshall Test parameters with different rubber percentage were summarized in Table 6 below.

Table (6): Average Stability and Flow Results

Type	0% Rubber	5% Rubber	10% Rubber	20% Rubber
Stability (Kg)	1303.10	614.80	1448.67	597.83
Flow (0.01inch)	15.67	16.00	15.00	19.67

Comparing the results of stability and flow for rubber-asphalt mix with conventional mix showed that there is an improvement in stability at 10% rubber especially at bitumen percentage of 5% or more. Typical Marshall Test design criteria for stability and flow at different traffic density are shown in table 7 below.

Table (7) Typical Marshall Design Stability and Flow Criteria

Mix Criteria	Light Traffic (< 104 ESALs)		Medium Traffic (104 – 106 ESALs)		Heavy Traffic (> 106 ESALs)	
	Min.	Max.	Min.	Max.	Min.	Max.
Compaction: number of blows on each end of the sample	35		50		75	
Minimum Stability (KN)	2.27		3.40		6.80	
Flow (0.25 mm)	8	20	8	18	8	16

(Asphalt Institute, 1997).

The above standards indicated that minimum stability of Marshal Test at heavy traffic (75blows) is 680 Kg, and flow between 2 to 4 mm. All test values consistence with the specifications limits.

5- Conclusion

Stability and flow were improved by adding rubber to the asphalt pavement. The appropriate percentage was 10% from bitumen weight. Standards indicated that minimum stability of Marshal Test at heavy traffic (75blows) is 680 Kg. and maximum flow is 4mm. The 10% of added rubber match with the above standards.

The finding of this study agreed with other international studies. The study of Mashaan et al. (2013) indicated that replacing 12% of bitumen weight by rubber will give higher asphalt stability. Concerning the cost, several studies showed the high cost of rubber asphalt. But it is more accurate to consider the design life cost of pavement not the initial construction cost. Hicks and Epps (2000) concluded that asphalt rubber pavement could be more cost effective than conventional pavement.

In this research article number of bitumen and asphalt samples was examined on laboratory tests. The conclusions are summarized as follows.

1- Waste tires rubber can be used in asphalt pavement with optimum replacement ratio of 10% by weight of total aggregates.
2- The average stability for 10% rubber modified mixture was higher than the control mixture. Therefore, a significant improvement occurred in the Marshall properties of asphalt concrete mixtures using a melted rubber modifier.
3- All test values are consistent with the specifications limits.
4- The results of this study apply only to the type of rubber that was used.
5- Other sources of rubber may produce different results.

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