Waste Rubber Bitumen Modifier

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Abstract— A lot of research has been conducted to find alternative material in pavement construction that acts as additive or modifier which could improve the performance of its properties. Bitumen is sensitive to temperature and rate of loading. Thus, bitumen modification has become trigger factors to improve the hot mix asphalt (HMA) properties. This dissertation presents a study of laboratory evaluation on the performance of hot mix asphalt (HMA) using rubber waste as an additive. In this study, rubber waste is referred as a free fine rubber particle made by size reduction from byproduct of rubber tire making industry.

The tests conducted were bitumen ductility, softening point and Marshall Mix design test. In this study, an attempt was made to evaluate the relationships between Ductility, Softening Point of the bitumen with the amount of rubber waste in bitumen. Meanwhile, Marshall Test was done to evaluate the suitability of rubber waste as bitumen modifier. After, conducting these tests on various sample of bitumen this was found that the property of bitumen varies consecutively with the application of rubber on the bitumen.

Keywords— Bitumen, Hot Mix Asphalt (HMA), Rubber Waste, Ductility Test, Softening Point Test, Marshall Mix Design, Marshall Test, Bitumen Modification, Asphalt Concrete (AC).

INTRODUCTION

Conventional bituminous materials performed their function satisfactorily in most of the pavements. However, existing highway systems have been dealing with increased traffic volume, higher axle load and tire pressure and extreme environmental impacts. The situation is evident for the last three decades, that the pavement has been facing more demands than before resulting in the need for an enhancement in the properties of bituminous materials.

The study conducts focus on the application of rubber waste as modifier in bitumen and asphaltic concrete. Therefore, the laboratory test is concentrates on bitumen tests and Marshall. In order to investigate the effects of rubber waste on HMA properties, the scope of the study was included preparation of Marshall samples with bitumen grade of 40/50 bitumen content without additive were 4%, 4.5%, 5.0%, 5.5% and 6.0% as control samples. The Marshall Test was conducted to determine optimum bitumen content and properties.

Besides that, content of rubber waste used were 4%, 8%, 12% and 16% of the optimum bitumen content weight into the mixture. The optimum waste content will be determined using Marshall Method. The result on the density, stability, flow, voids in total mix, voids filled bitumen and stiffness from the modified sample and control sample were compared and analyze.

This study is conduct to study the effect used of waste material in bituminous mixture. Rubber waste product used to improve the bitumen used in mixture and increase the strength of the pavement due to its rubbery characteristic. Besides that, the performance of the bituminous mixture need to improved due to the changes in the weather and increased in traffic loading.

Waste product is cheaper and can be obtained directly from the factory where these waste products are not reused by the factory. In directly, it will minimize construction cost. Reused waste product can ideally reduced pollution problem due to disposal aspect. The commercial value of waste material will increase if it was found suitable to be used in highway construction.

MATERIALS

Aggregate, Bitumen Grade 40/50, Waste Rubber Tyres.

METHODOLOGY

In order to evaluate the quality of rubber waste on road asphalt, laboratory experiments have to be done to identify the performance of the modified asphalt with rubber waste compared to the unmodified asphalt. All the laboratory experiment is based on the standard specification on ASTM and AASHTO.

The objective of Marshall Mix Design (ASTM D 1559) is to determine the optimum aggregate and bitumen mixture to ensure the mixture is durable, stable, sufficient void ratio, flexural, economic and quality.

Testing on bitumen have to be carried out is Ductility Test and Softening Point Test in order to ensure it performs well on the specification. Both tests were carried out to test whether the modified binder was appropriate. Ductility Test is the consistency test to determine the material stiffness meanwhile Softening Point Test is the consistency test to determine the temperature where the phase change occur in bitumen.

This study used the Marshall method, and the type of mixes that was designed is DBM. Contents of elastomeric base waste used in the mixes were 4%, 8%, 12% and 16% from the optimum bitumen content used in DBM. Minimum three specimens for each of the mix were prepared the optimum waste content.

EXPERIMENTAL WORK AND ANALYSIS

Through the laboratory work has been conducted, the result and data can be used to determine the properties of HMA. Data analysis was done according to Marshall Test and all result should be compared. The comparison of HMA properties were observed in terms of density, stability, flow, stiffness, VTM, VMA and VFB. This is to ensure that suitability of the industrial waste used as a modifier to conventional bitumen.

SIEVE ANALYSIS AND AGGREGATE DISTRIBUTION

All aggregates were sieved to sizes as stated according to specification. Hot mix asphalt mixture specifications require aggregate particles to be within a certain range of sizes and for each size of particle to be present in a certain proportion. In this study, DBM was used and the calculation was based on the median between upper and lower limit of the gradation. Table 1 shows the result of sieve analysis calculation for DBM Marshall Sample.

Table 1:- Sieve Analysis

Sieve size	Wt. Of aggregate retained (kg)	% wt. Retained	Cumulative % Retained	% wt. of aggregate passing
24 mm	0	0	0	100
20 mm	0.482	9.64	9.64	90.36
16 mm	0.521	10.42	20.06	79.94
12 mm	0.437	8.74	28.80	71.20
10 mm	0.624	12.48	41.28	58.72
6.3 mm	0.598	11.96	53.24	46.76
2.36 mm	0.360	7.20	60.44	39.56
1.18 mm	0.648	12.96	73.40	26.60
425 µm	0.297	5.94	79.34	20.66
150 µm	0.348	6.96	86.30	13.70
75 µm	0.291	5.82	92.12	7.88
Filler	0.394	7.88	100	0

SPECIFIC GRAVITY AND WATER ABSORPTION OF AGGREGATE

As the sample for testing specific gravity of aggregate is based on DBM, the coarse sizes are in the range of 5 - 20mm. Table 2 shows the full result of the specific gravity and water absorption of coarse aggregate.

Table 2:- Specific Gravity and Water Absorption of Coarse aggregate

Coarse Aggregate	Label	Sample 1	Sample 2
Weight of Oven Dry Aggregate (gm)	A	628.0	587.0
Weight of Saturated Surface Dry Aggregate (gm)	B	637.0	602.0
Weight of Aggregate in Water (gm)	C	404.0	384.0
Apparent Specific Gravity, (SG)	SG = A / (B – C)	2.70	2.69
Average	2.695		
Water Absorption (%)	(B – A) / A * 100	1.4	2.6
Average	2		

The specific gravity testing for fine aggregate also utilizes the gradation of DBM. The sizes of aggregates tested ranges from 0.075mm to 2.36mm. The full results of the test conducted are shown in Table 3.

Table 3:- Specific Gravity and Water Absorption of Fine aggregate

Fine Aggregate	Label	Sample 1	Sample 2
Pycnometer Weight + Water (gm)	A	838.8	828.8
Pycnometer Weight + Water + Aggregate (gm)	B	1121.0	1133.3
Weight of Oven Dry Material (gm)	C	492.8	491.6
Weight of Saturated Surface Dry Aggregate (gm)	D	500	500
Apparent Specific Gravity (SG)	SG = C / (A + D – B)	2.268	2.515
Average	2.392		
Water Absorption (%)	(D – C) / C * 100	1.46	1.71
Average	1.585		

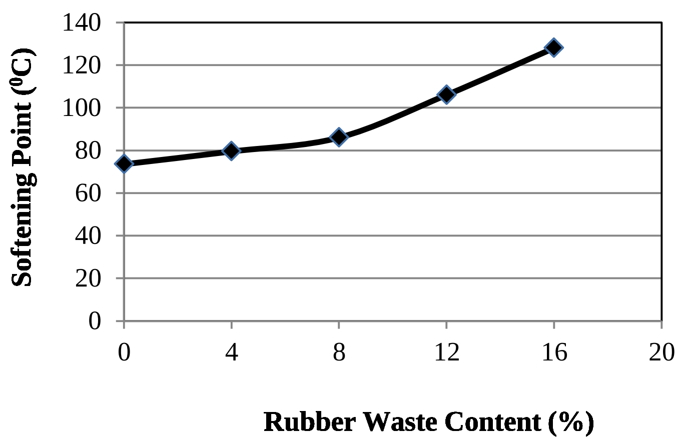
SOFTENING POINT TEST

Softening Point Tests were done for normal bitumen and modified bitumen with 4%, 8%, 12% and 16% of rubber waste content. The result was shown in Table 4. From the plotted graph, the softening point for normal bitumen was 83.5°C.

The relationship between the rubber waste added and the softening point of the bitumen are almost linear as shown in Graph 1. Softening Point increased with the increased amount of the waste added. This showed that, the bitumen become less susceptible to temperature changes as content of rubber waste increased.

Table 4:- Softening Point

Rubber Content (% by Weight of Optimum Bitumen Content)	Reading(^{0}C)		SP(^{0}C)
	Ball A	Ball B	
0	72	75	73.5
4	80	79	79.5
8	85	87	86
12	102	110	106
16	130	126	128



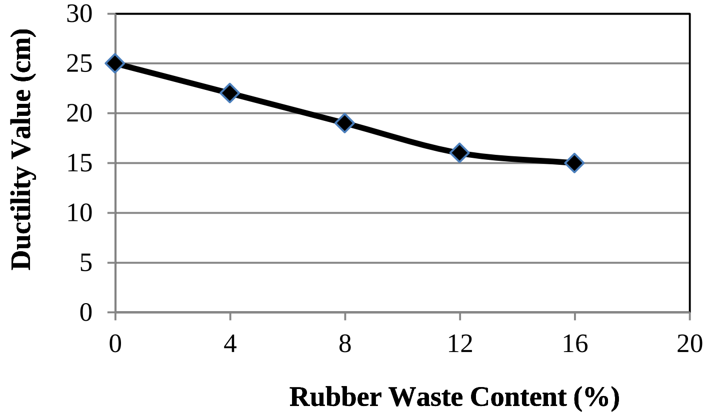
Graph 1:- Softening Point versus Rubber Waste Content

BITUMEN DUCTILITY TEST

Ductility test were done for normal bitumen and modified bitumen with 4%, 8%, 12%, and 16% of rubber waste content. The result was shown in Table 5. The ductility value decrease as the rubber content increase as shown in Graph 2. The result shows that the rubber waste added will harden the bitumen. The bitumen becomes more viscous and harder, which would be useful to obtain stiffer bitumen asphalt.

Table 5:- Ductility Test

(%) Rubber Waste	Sample Reading (cm)			Average
	Reading 1	Reading 2	Reading 3	
0	25	24	27	25
4	21	23	23	22
8	18	19	20	19
12	14	16	17	16
16	13	15	16	15



Graph 2:- Ductility Value versus Rubber Waste Content

MARSHALL TEST ANALYSIS

OPTIMUM BITUMEN CONTENT

Optimum bitumen content for AC was determined by using bitumen content of 4%, 4.5%, 5%, 5.5% and 6% according to the specification. Data obtained were analysis using Marshall Properties. The result of Marshall Test for AC was shown in Table 6.

Table 6:- Marshall Test Result

Bitumen Content (%)	Unit Weight (Kg/cm^3)	Stability (Kg)	Flow (mm)	VTM (%)	VMA (%)	VFB (%)	Stiffness (Kg/mm)
4	2.279	1123.1	2.11	12.6	21.45	41.26	532.27
4.5	2.26	1130.22	2.70	12.21	22.04	44.6	418.6
5	2.211	1202	3.14	10.33	20.965	50.728	382.80
5.5	2.202	1281.55	3.98	10.65	22.246	52.126	322
6	2.182	935.69	5.09	9.924	22.404	55.70	183.83

From the Table 6 it is clear that the specimen which has 5.5% bitumen content have maximum stability. So, we used 5.5% bitumen content as optimum bitumen content.

RUBBER WASTE ADDED IN AC MIXTURE

After control sample and optimum bitumen content were obtained, Marshall Test with modified bitumen was conducted. The rubber waste content used in the AC mixtures were 4%, 8%, 12% and 16% by the weight of OBC. Table 7 shows the test result obtained for various content of waste added.

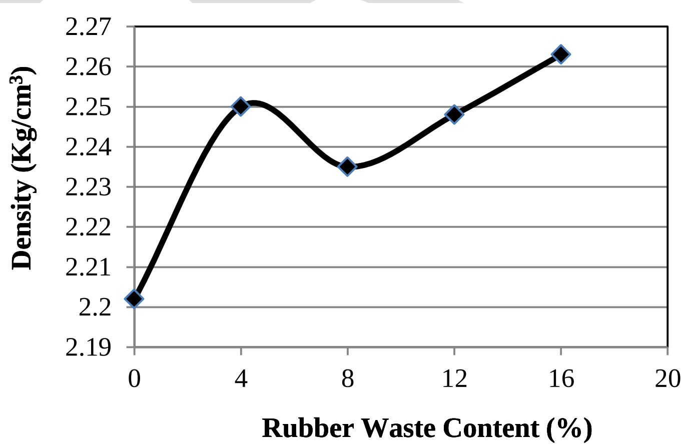
Table 7:- Marshall Test Result for Modified Bitumen Mixture

Rubber Waste Content (%)	Unit Weight (Kg/cm^3)	Stability (Kg)	Flow (mm)	VTM (%)	VMA (%)	VFB (%)	Stiffness (Kg/mm)
4	2.2503	2031	2.7	12.29	23.603	47.93	752.22
8	2.2347	2042.67	2.1	11.01	21.757	49.396	972.70
12	2.2482	1712.33	2.823	11.242	21.614	47.987	606.564
16	2.263	1405	3.28	11.533	21.531	46.4354	428.354

DENSITY ANALYSIS

Specific gravity of cooled compacted sample was determined according ASTM D 2762 after being cooled at room temperature. Graph 3 shows the density versus bitumen content for modified bitumen. The graph shows that the maximum density for modified bitumen was when rubber waste added at 12% and 16%. The graph pattern shows that the density value increase as the rubber waste content added increasing.

The rubber has higher value of density as compare to the normal bitumen. So, when the percentage of rubber is increase the density increase. The effectiveness of compaction reduced due to the addition of rubber waste into bitumen, the area for bitumen coating become increased since the optimum bitumen content was reduced by increased the percentage of rubber waste amount added into the mixture as replacement.



Graph 3:- Effect of Rubber Waste on Mixture Density

STABILITY ANALYSIS

Graph 4 shows the relationship between stability and waste content. The graph shows that the stability value decreases gradually with increasing the percentage of rubber waste content added. As we know, the stability of mixtures depends on bitumen cohesion. Cohesion results from the bonding ability of bitumen and the cohesion increase with increasing bitumen content. However if the stability is too high, it will causes significance effect on mixture. Excess bitumen will cause instability problem. Too high stability value produces a pavement mixture that is too stiff and less durable.

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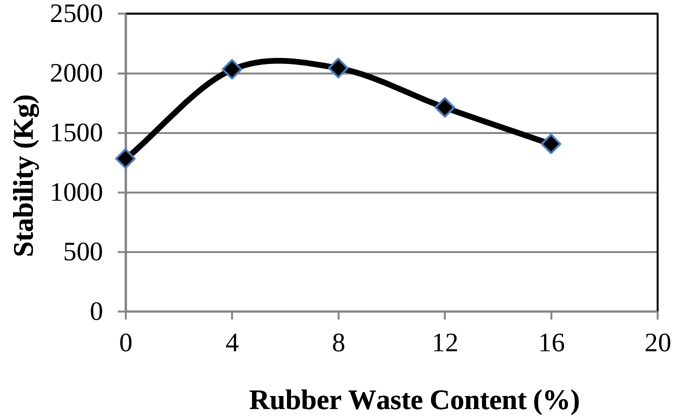
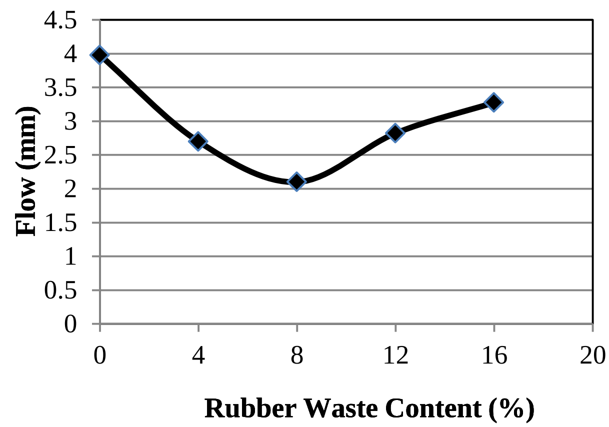


Graph 4:- Effect of Rubber Waste on Mixture Stability

FLOW ANALYSIS

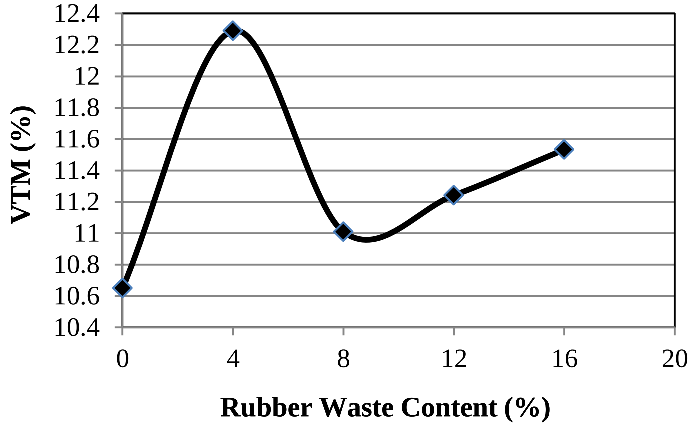
Graph 5 shows the relationship between flow and rubber waste content. Flow was related to the flexibility of the mix. High value of flow shows high flexibility.



Graph 5:- Effect of Rubber Waste on Mixture Flow

VOIDS IN TOTAL MIX ANALYSIS

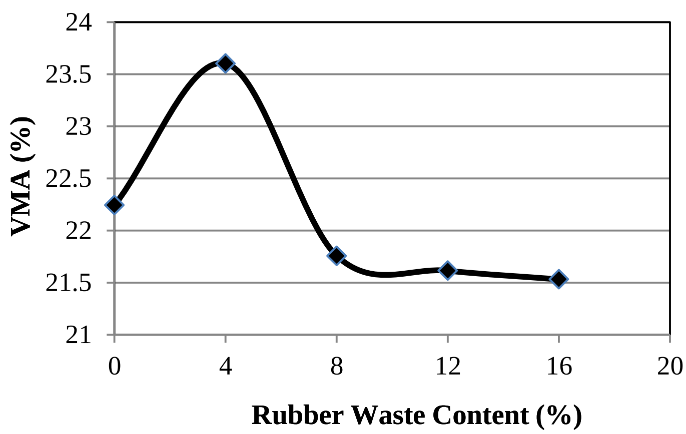
From the Marshall test that has been done, the trend of the voids in total mix obtained was decreased until a minimum value is reached and increased after that. The voids in total mix were highly related to the compaction has been done. Graph 6 shows that the samples were under compacted. Higher compaction will caused the small particles filled between aggregate and reduce the voids in the mix. When the waste was added, the waste was not fully melted and under compaction caused by the particles not proper filled between aggregate and increased the voids. When the waste content added above 12%, the waste was not fully melted because of the bitumen content was reduced.



Graph 6:- Effect of Rubber Waste on Mixture VTM

VOIDS IN MINERAL AGGREGATE ANALYSIS

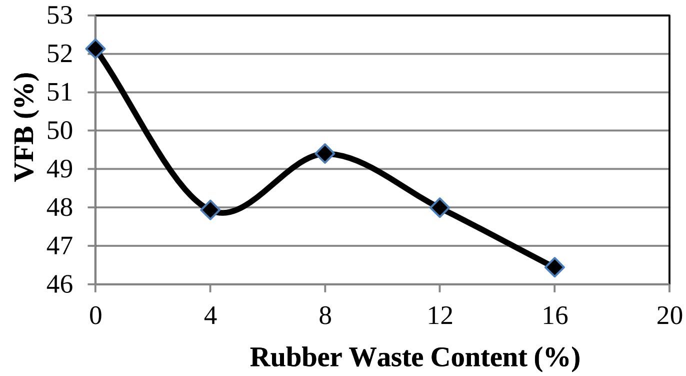
Voids in mineral aggregate are a part of the voids in total mix. Voids in mineral aggregate are the voids which are present in the aggregate mix and which is not filled by the bitumen filler. Graph 7 shows the graph of the voids in mineral aggregate are greatly affected by proportion of waste rubber added.



Graph 7:- Effect of Rubber Waste on Mixture VMA

VOIDS FILLED WITH BITUMEN ANALYSIS

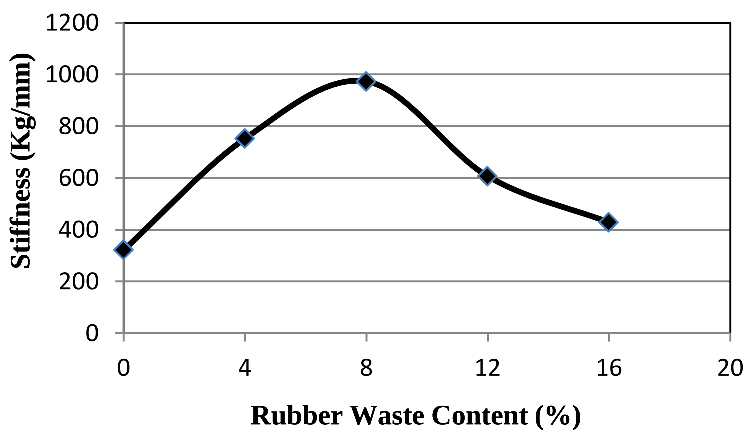
Voids filled with bitumen are related to the voids in total mix and density and Graph 8 shows the graph of VFB versus modified bitumen using rubber waste from the test has been done. The percent of air voids filled with bitumen was decreased. Due to the addition of rubber waste into bitumen, the bitumen content become decreased and caused the bitumen not properly filled the voids and affected the bonding between aggregate. This will make the pavement mixture easy to allow air and water permeates. If the bitumen content exceeds the optimum value, it will produce the mix that prone to bleed. The highest voids filled bitumen was 49.396% at 8% waste added.



Graph 8:- Effect of Rubber Waste on Mixture VFB

STIFFNESS ANALYSIS

Stiffness of the mixture is important to limit the occurrence of rutting. Higher stiffness value shows that the mixture can take the load without changing in shape. Graph 9 shows the graph of stiffness versus modified bitumen. The stiffness value decreases with increasing percent of rubber waste added. This mean, in term of rut resistance, the asphaltic concrete with higher percent of rubber waste will has deeper rut depth.



Graph 9:- Effect of Rubber Waste on Stiffness

CONCLUSION

From the comparison shown in Table 8, there are some parameters of the sample with rubber waste added that meet the specification which are stability and stiffness. The optimum waste content is 8%.

Table 8:- Comparison of Marshall Parameter between Control Sample and Modified Sample

Marshall Properties	Control Sample	Rubber Waste Content			
		4%	8%	12%	16%
Stability	1281.55	2031	2042.67	1712.33	1405
Flow	3.98	2.7	2.1	2.823	3.277
Density	2.202	2.25	2.235	2.248	2.263
VTM	10.65	12.29	11.01	11.242	11.533
VMA	22.246	23.603	21.757	21.614	21.531
VFB	52.126	47.93	49.396	47.987	46.4354
Stiffness	322	752.22	972.70	606.564	428.354

The stability of the samples was decreased with the increasing of waste content. The percentage of VTM of modified mix is higher than normal mix. The density of the mix was increase with the increase of rubber waste content. The optimum value of voids filled bitumen was 49.396% at the waste content of 8%. When the waste was added more than 12%, it caused the flow to increase. Rubber waste is suitable to be used as bitumen modifier in order to improve the bitumen properties with the right amount of replacement. Replacement rubber waste as bitumen modifier in the asphaltic concrete mixture increase the adhesion between the aggregate particles, durability and possibility to minimize the deformation of road wearing course.

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