Use of Crumb Rubber as Partial Replacement of Bitumen in Bituminous Concrete Mix

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Abstract

The aim of the study was to utilize the waste materials i.e., crumb rubber waste for mass scale utilization such as in highway construction in an environmentally safe manner. As a first part of this study, an attempt was made to assess the stabilization of the bitumen containing crumb rubber waste in shredded form by performing basic tests such as Penetration Test, Ductility Test, Softening Point Test, Viscosity Test and Flash & Fire Point Tests. On the basis of the performance of the modified bitumen, the range of optimum percentages of crumb rubber waste Study on effect of crumb rubber modified binder on bituminous concrete mixes will be decided. The dimension of used CR ranges from 0 to 2.36 mm, which is not too coarse for promoting the CR–bitumen interaction and not too fine for facilitating the production of CR. The content of CR was increased gradually from 3 to 5 to examine the effects of CR content on the engineering properties and determine the optimal content in the mixture. Marshall Test has been considered for the purpose of mix design as well as evaluation of paving mixes. The quantity of optimum binder content was determined by Marshall Stability test for samples. The mechanical performance was determined for Marshall Stability, deformation behaviour or flow, as well as for density and void appearances base on prevailing Indian standards specifications.

Keywords: bituminous concrete, Marshall Properties (flow value, stability), optimum bitumen content, crumb rubber waste.

1. Introduction

Crumb rubber is recycled rubber produced from automobiles and truck scraped tires. During the recycling process of this rubber crumb, steel and tire cord (fluff) are removed, and tire rubber are produced with a granular consistency. India has a road network of over 4,689,842 kilometers in 2013, the second largest road network in the world. It has primarily flexible pavement design which constitutes more than 98% of the total road network. India being a very vast country has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. So, to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved. There are many modification processes and additives that are currently used in bitumen modifications such as styrene butadiene Styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA) and crumb rubber modifier (CRM). Crumb rubber is the term usually applied to recycled rubber from automotive and truck scrap tires. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles. From physical and chemical interaction of crumb rubber with conventional bitumen Crumb Rubber Modified Bitumen (CRMB) is made. Its advantages are: Lower susceptibility to daily & seasonal temperature variations, higher resistance to deformation at elevated pavement temperature, better age resistance properties, higher fatigue life of mixes, better adhesion between aggregate & binder, Prevention of cracking & reflective cracking, and overall improved performance in extreme climatic conditions & under heavy traffic condition. Several studies show improved performance of asphalt modified by crumb rubber, resulting in reduced cracking and increased fatigue life, strength, resilience, viscosity and adhesion.

2. Experimental Investigation

The Marshall Stability test was carried out using marshal test and stability flow indicator. The stability (kN), unit weight (gm/cc), percentage of air voids present in the sample, flow value measured in mm, percentage of voids filled with bitumen (VFB) and voids in mineral aggregate (VMA) were evaluated on each sample. Results of all the parameters the sample are mentioned as in table 1 Second point.

Table 1. Parameter Obtained for CRMB mix

Crumb rubber content%	Bitumen Content %	Unit weight (gm/cc)	Air voids %	Voids in Mineral aggregate VMA %	Voids filled by Bitumen VFB %	Stability (KN)	Flow (mm)
3	4.5	2.35	2.89	12.62	77.09	8.884	2.61
	5	2.38	4.8	15.7	69.43	12.984	3.57
	5.5	2.385	3.83	15.8	75.76	11.617	3.84
	6	2.39	2.24	16.26	70.07	9.226	4.03
	6.5	2.40	2.40	16.50	85.45	8.200	4.2
4	4.5	2.28	5.78	15.59	62.92	8.884	2.35
	5	2.305	4.36	15.33	71.56	13.326	3.68
	5.5	2.32	2.93	15.02	80.49	10.592	3.84
	6	2.33	2.10	15.28	86.25	7.859	4.05
	6.5	2.325	1.48	15.66	90.95	7.175	4.10
5	4.5	2.28	4.60	14.32	67.88	9.909	2.65
	5	2.29	3.79	14.59	74.02	14.009	3.75
	5.5	2.295	2.75	14.59	81.15	12.301	3.96
	6	2.30	2.12	15.01	85.88	9.225	4.12
	6.5	2.285	2.14	15.95	86.38	8.542	4.32

Table 2. Marshall Parameter for CRMB at OBC

Sr. No.	Marshall Parameters	Specified Range MORT&H	Obtained values at OBC		
1	Unit Weight	-	3%	4%	5%
2	Air Voids%	3-6	2.38	2.305	2.29
3	VMA	Min. 14	4.8	4.36	3.79
4	VFB	65-75	15.7	15.33	14.59
5	Stability (KN)	Min. 9 KN	69.43	71.59	74.02
6	Flow Value (mm)	2-4	12.984	13.326	14.009

Table 3. Volumetric Properties for Conventional Mix

Sr. No.	% Bitumen Content	Unit weight (gm/cc)	Air voids %	Voids in Mineral aggregate VMA %	Voids filled by Bitumen VFB %	Stability (KN)	Flow (mm)
1	4.5	2.377	6.461	17.627	63.35	7.747	3.1
2	5	2.392	5.598	17.263	67.57	9.386	3.37
3	5.5	2.405	4.622	17.078	72.93	11.142	3.5
4	6	2.393	4.775	17.676	72.98	7.825	4.03
5	6.5	2.367	5.492	18.752	70.71	6.623	4.2

The table:3 shows the summary of volumetric properties of the mix along with stability and flow values of the Conventional Bituminous Concrete Mixes. The maximum stability value is 11.142 KN at 5.5% binder content. The flow values are found between the specified ranges in MORTH for optimum bitumen content is 3.5mm and increases with increase of binder content. Also, at 5.5% Bitumen content mix satisfy entire minimum requirement of MORTH. Estimated OBC for conventional mix is 5.5%.

3. RESULT AND DISCUSSION

The Optimum Binder Content (OBC) for specimens containing 3%, 4% and 5% CRMB was estimated to be 5%. The results of the Marshall Test parameters obtained at OBC value for all the types of samples are shown in Table-7. It was noted that the crumb rubber meets all minimum requirements as per MORTH 2012 Specification m aggregate material in Bituminous Concrete.

A. Unit Weight

For all the samples, the maximum compacted density attained is almost the same (2.42 gm/cc). Moreover, the density increases till its maxima and then decreases for all mixes. 5% CRMB containing mix has higher density than 3% &4% CRMB containing mix at OBC as shown in fig. 1.

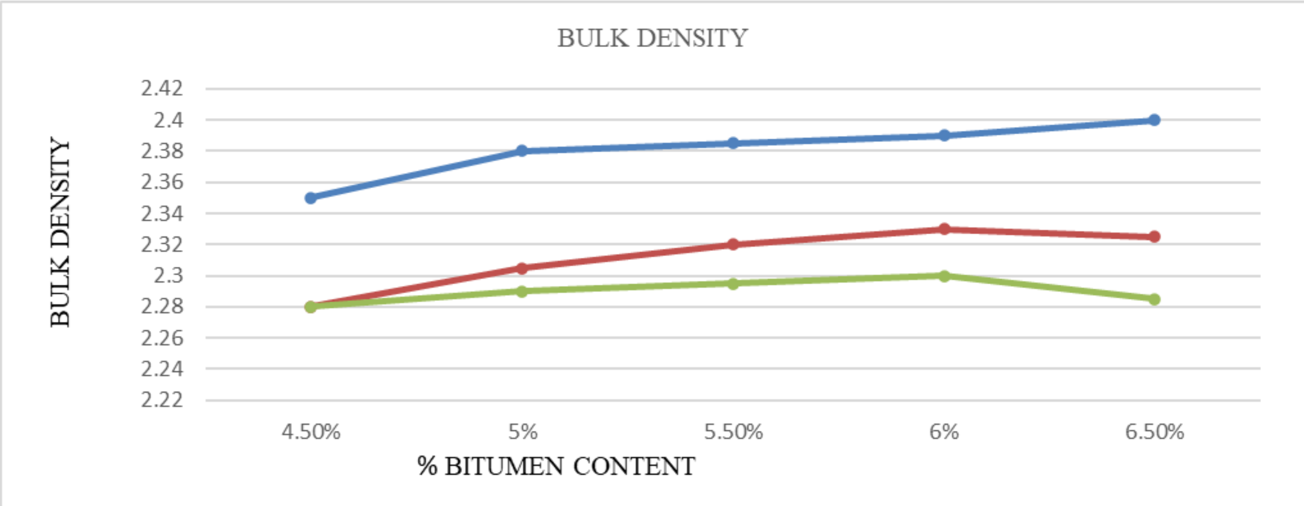

Fig. 1. Graph - % Bitumen Content Vs Bulk Density

B. Air Voids

Table-1 indicates that the percentage of air voids in the mix decreases for all mixes as the bitumen content increases. This is expected since the bitumen will fill the voids in the aggregate matrix. According to MORT&H criteria, voids in the mix must range from 3% to 5%.

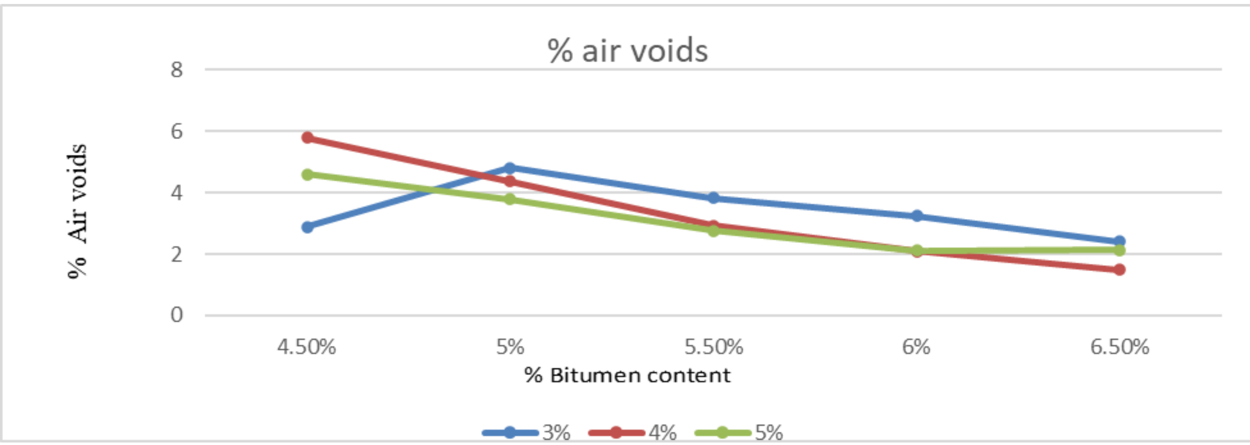

Fig. 2. Graph - % Bitumen Content Vs Air Voids

C. Marshall Stability Value

Marshall Stability values are higher as in case of 5% CRMB containing crumb rubber as compared to 3% and 4% crumb rubber waste containing mix. Fig-3 shows that the stability value increases till the addition of 5% bitumen content in 3%, 4% and 5% CRMB containing mixes respectively and then decreases rapidly.

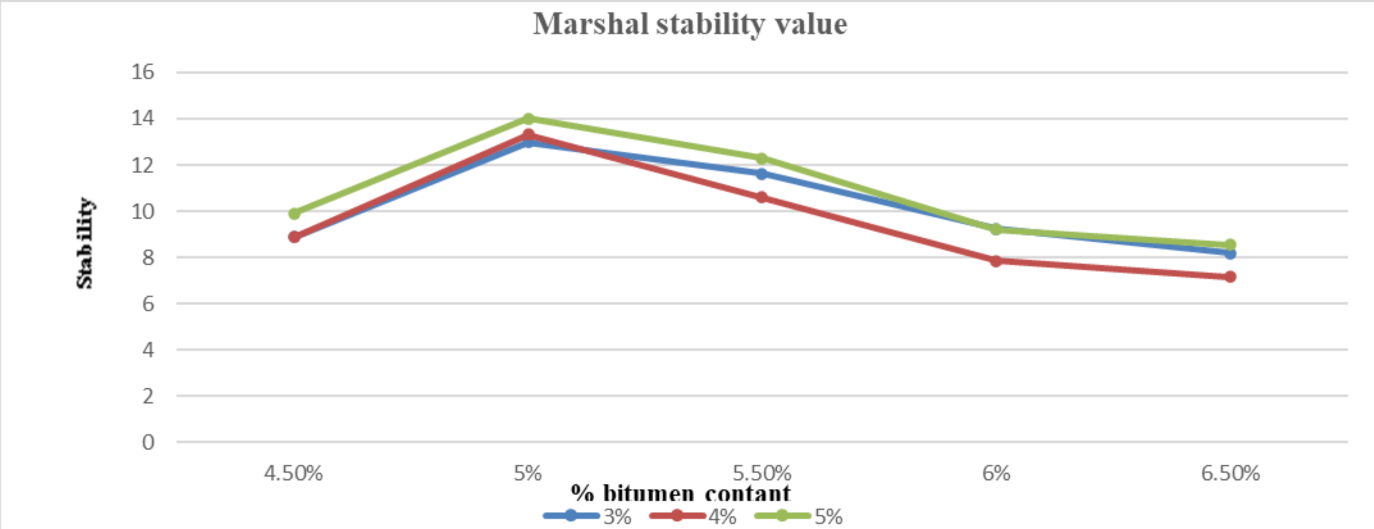

Fig. 3. Graph - % Bitumen Content Vs Stability

D. Flow Values

Flow values for 3%, 4% & 5% CRMB containing mixes are 3.57, 3.68 and 3.75 respectively at OBC (optimum bitumen content). Crumb rubber waste mixes show continuous increase in flow values.
The results obtained shows that crumb rubber waste will deform more under the traffic loads and will have more flexibility. However, 3%, 4% and 5% CRMB as can be used in BC at OBC as shown in Figure 4.

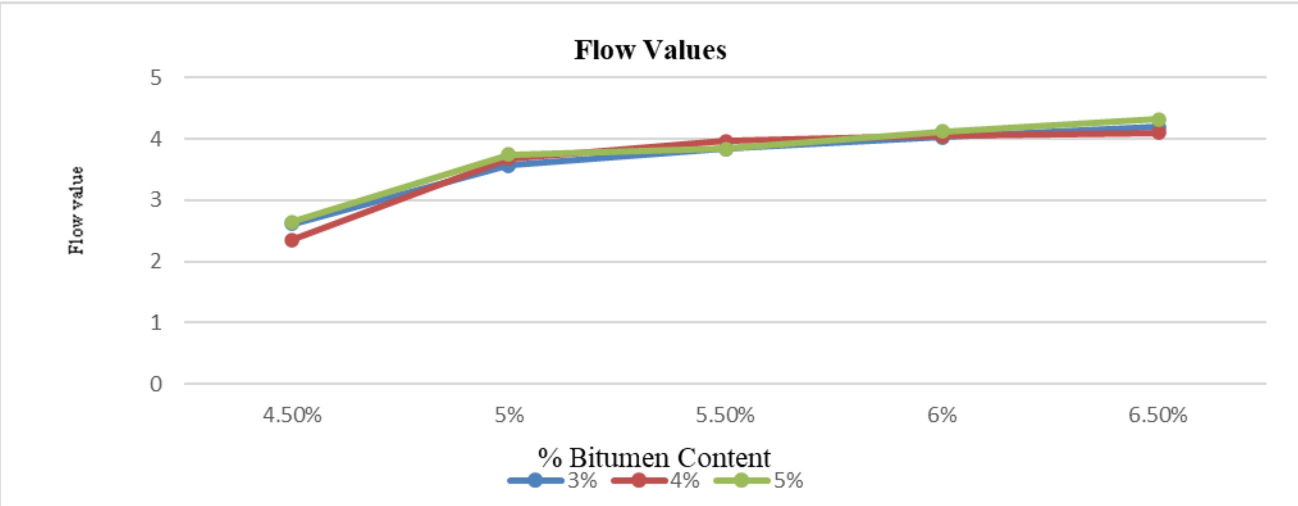

Fig. 4. Graph - % Bitumen Content Vs Flow Value

4. Conclusion

The Marshall tests were conducted on the bituminous mixes containing 3-5% CRMB content. Based on the laboratory experiments and analysis, the following conclusions are drawn.

- It is observed that with the increase in CRMB content from 3% to 5% the stability value increases from 12.984 KN to 14.009 KN at OBC.
- It is observed that conventional mix gives maximum stability about 11.142KN while modified mix gives the maximum stability value about 14.009 KN at OBC.
- Results shows that achieved result for OBC for CRMB Modified mix is 5% and for conventional mixes is 5.5%.
- The flow values for 3 to 5% CRMB mixes are higher than conventional bituminous concrete mixes at OBC which shows that Crumb Rubber containing mix (Modified Mix) will deform more under traffic loads compared to conventional mixes.
- It is observed that 5% Crum Rubber Modified Bituminous Concrete mix gives maximum stability and flow values about to14.009KNand 3.75mm respectively at optimum bitumen content.
- Above result shows that as the amount of Crumb Rubber content increases flow value also increase which indicates that Crumb Rubber containing mixes will deform more under traffic load and gives higher flexibility.
- The patterns obtained in the flow values indicate that Crumb Rubber will deform more under the traffic loads and will have more flexibility.
- The Marshall Properties of CRMB for 3 to 5% Crum Rubber satisfy the limits of MORTH specification and hence can be used in BC as modified binder.
- Crumb Rubber satisfies the entire minimum requirement for modified bituminous concrete mixes as specified in the MORTH.

It was concluded that Crumb Rubber industrial waste can be utilized as a partial replacement for bitumen in bituminous concrete mixes. The utilization of Crumb Rubber in the asphalt concrete mixes may solve the significant disposal problem to save the environment.

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