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Utilization of Rubber Waste in Road Infrastructure–A Case Study

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Abstract—*With the Worldwide technology up gradation and industrialization, the number of vehicles is increasing at an alarming rate. Every passing day, more vehicles are increasing on the road surface causing a lot of pressure on the road infrastructure. Consequently, a lot of tyre waste is being generated causing a disposal problem. Thus the problem of disposal of used tyres can only be solved by recycling. Generally the recycling of waste tyres is possible by converting it into crumb rubber which is obtained by grinding waste tyre rubber into small pieces of different sizes. This paper highlights the utilization of rubber waste in road infrastructure development by performing experimental investigations on physical properties of aggregates and binder for Bituminous Concrete. Different mix design parameters were evaluated by using Marshall Stability method for Bituminous Concrete using Crumb Rubber Modified Bitumen (CRMB). The properties of conventional bituminous mixes and crumb rubber modified bituminous mixes were compared for the specimens prepared at Optimum Binder Content (OBC) for the Bituminous Concrete (BC). The addition of crumb rubber modified bitumen has been found to increase the strength of the mix thus paving the way for utilization of rubber (a waste material) for Road Infrastructure Development.*

Keywords: *Bituminous Concrete (BC), Marshall Stability Method, Optimum Binder Content (OBC), Crumb Rubber Modified Bitumen (CRMB).*

1. INTRODUCTION

Bituminous mixes are most commonly used in India for road construction. The roads are expected to perform better as they are experiencing increased volume of traffic, increased loads and increased variations in daily or seasonal temperature over what has been experienced in the past. Due to increased loads and high temperature differential which are typical for Indian condition the conventional bitumen fails to give longer life for pavements. Addition of modifiers into conventional bitumen results in the improvement of execution qualities of bituminous mixes used in road construction. The utilization of industrial additives in bitumen mixes will increase the construction cost. So the utilization of recycled material is one of the methods to reduce the construction cost of road construction, such as waste tyres crumb rubber is less costly and eco-friendly, and is relied upon to improve the bitumen properties. Crumb rubber is utilized to minimize the damage of pavement such as resistance to rutting and fatigue cracking. Crumb rubber is obtained from utilized vehicles tyres and it is utilized for a wide assortment of industrial applications.

An ideal bituminous mix is relied upon to bring about a mix which is sufficiently strong, durable and resistive to fatigue and pavement deformation and in the meantime environment friendly and economical. For a given aggregate gradation, the optimum binder content is assessed by fulfilling various mix design parameters. Fillers play an essential part in engineering properties of bituminous paving mixes. Crumb Rubber Modified Bitumen is a special category of bitumen which is prepared for enhancing the properties by mixing with crumb rubber and special type of additives to make the material resistant to temperature variations, weathering and high traffic loads.

2. MATERIALS AND METHODS

- **Aggregates**

The coarse aggregates of varying size are sieved by passing through 26.5 mm and retained on a 2.36 mm sieve while fine aggregate should comprise 100% of fine crushed sand passing the 2.36 mm sieve and retained on 0.075mm sieve.

- **Mineral fillers**

Mineral fillers have substantial influence over the properties mix design. Filler should comprise of finally divided mineral such as rock dust or hydrated lime. The utilization of hydrated lime is encouraged because of its very good anti-stripping and anti-oxidant properties. Fillers used are lime and sand in bituminous mix specimen.

- **Bitumen (VG30)**

Bitumen is the by-product of petroleum and its grading depends upon its penetration value and viscosity grade for different climatic factor and nature of duty. It is utilized to build additional heavy duty bitumen pavement that need to persevere through considerable substantial traffic loads.

- **Rubber modified bitumen**

Crumb rubber Modified Bitumen (CRMB 55) is prepared by using waste tyre rubber. It is a unique kind of worth included bitumen where the properties of are enhanced by mixing with crumb rubber and special additives as per the provisions of IRC: SP: 53-2002 and IS 15462: 2004. CRMB 55 is prescribed for moderate climatic regions.

- **Marshall method of mix design**

Marshall Stability test of a mix is characterized as maximum load carried by a compacted specimen at a standard test temperature at 60ºC. The flow value is the deformation the Marshall Test specimen under goes during the loading up to the maximum load in 0.01mm units. The Marshall Stability test is relevant for hot mix design using bitumen and aggregate with maximum size of 26.5 mm.

3. RESULTS AND DISCUSSIONS

Physical properties of aggregates, bitumen and crumb rubber modified bitumen

A. Test Results of Aggregates for Bituminous Concrete as per specification is shown in Table 1.

Table 1: Test Results of Aggregates for Bituminous Concrete

Test	Test results	MORT&H (V[th] Revision)
Aggregate Impact value (%)	19.82	Max 24%
Grain size analysis (%)	3.0	Max 5 % passing 0.075 mm IS-Sieve
Los Angeles abrasion value (%)	23.62	Max 30%
Flakiness and Elongation index (%)	21.2	Max 30%
Water absorption (%)	0.37	Max 2%
Stripping Value (%)	99.7	Min. Retained Coating 95 %
Aggregate Specific Gravity		Min 2.5
• Coarse Aggregates	2.67	
• Fine Aggregates	2.6	
• Filler	2.3	

B. Test results of Bitumen (VG30) as per Indian Standard is shown in Table 2.

Table 2: Test Results of Bitumen

Test	Test Results	Requirement as per IS73:2006
Penetration at 25ºC, 100g, 5 seconds, 0.1 mm	66	50-70
Softening point (R&B), ºC	52	47-57
Ductility test @ 27ºC, cm	87	Min 75
Flash point, ºC	273	Min 220
Fire point, ºC	292	Min 220
Specific gravity	1.02	Min 0.99

C. Physical properties of Crumb Rubber Modified Bitumen (CRMB 55) as per specifications are shown in Table 3.

Table 3: Test Results of CRMB 55

Test	Test results	Requirement as per IS:15462-2004
Penetration at 25ºC, 100g, 5 seconds, 0.1 mm	52	Max 60
Softening point (R&B), ºC	51	Min 55
Flash point, ºC	256	Min 220
Fire point, ºC	275	Min 220
Elastic recovery of half thread in Ductilometer at 15°C, percent, minimum	55	Min 50
Elastic recovery of half thread in Ductilometer at 25°C, percent, minimum	43	Min 35

D. Combined gradation of the sample as per MoRT&H

Table 4: Combined gradation of the sample

I.S Sieve Designation	%age passing required	%age passing blend
26.5mm	100	100
20 mm	79 -100	89.5
13.2 mm	59-79	74.41
9.5 mm	52-72	63.6
4.75 mm	35-55	38.12
2.36 mm	28-44	29.8
1.18 mm	20-34	22.8
0.6mm	15-27	20.33
0.3mm	10-20	14.9
0.15mm	4-13	4.68
0.075mm	2-8	1.75

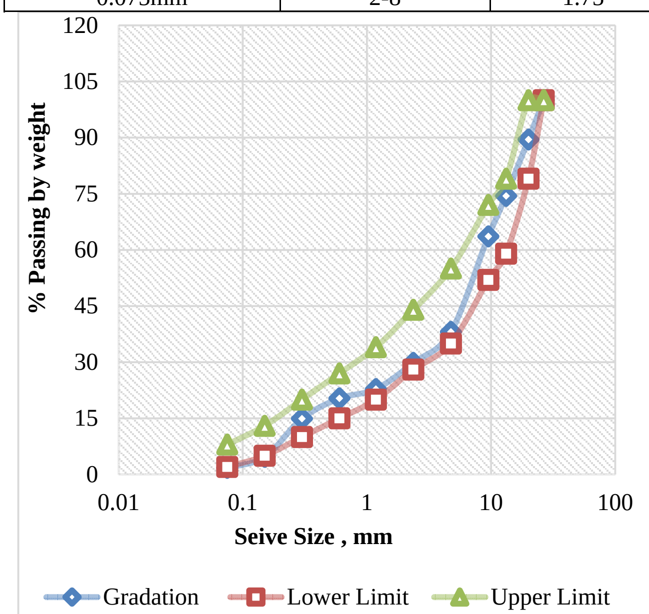

Fig 1: Gradation curve of aggregates

4. ANALYSIS OF DATA

Marshall Properties

Marshall Properties of bituminous concrete mix (Grading-I) specimens are prepared by adding 4.5 %, 5 %, 5.5 %, 6 %, and 6.5 % of Bitumen. The optimum binder content is found to be 5.65 %. At OBC by replacing bitumen with CRMB at varying percentage of +1.0%, +0.5%, -0.5%, -1.0%, -1.5% and -2.0% are presented below Table 5.

Table 5: Marshall properties of rubber modified bituminous concrete mix at OBC (5.65%)

CRMB content (%)	Flow,(mm)	Bulk density, (g/cc)	Total air voids, (%) Va	Voids filled with bitumen, (%) VFB	Voids in mineral aggregate, (%) VMA	Marshall stability, (kN)
+1.0	5.2	2.6	3.3	68.3	18.6	12.5
+0.5	4.5	2.5	4.2	74.2	17.8	13.6
-0.5	3.8	2.4	3.9	77.6	17.2	15.4
-1.0	4.0	2.5	4.3	79.4	17.5	16.7
-1.5	4.3	2.7	4.1	83.2	17.7	18.7
-2.0	5.1	2.4	3.7	78.5	17.9	15.8

F. The Marshall Stability values at different percentage of Rubber Modified Bitumen are shown in Fig. 2 to 7.

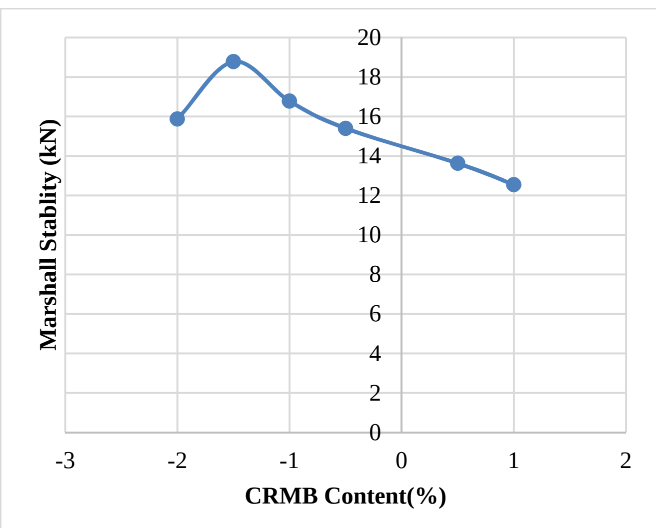

Fig 2. Marshall Stability v/s CRMB Content

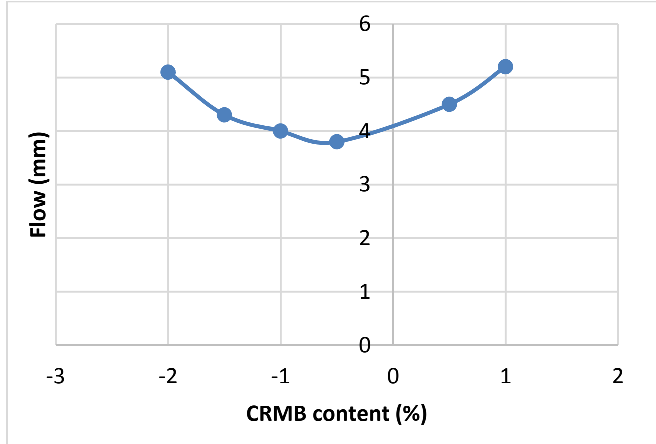

Fig 3. Flow v/s CRMB Content

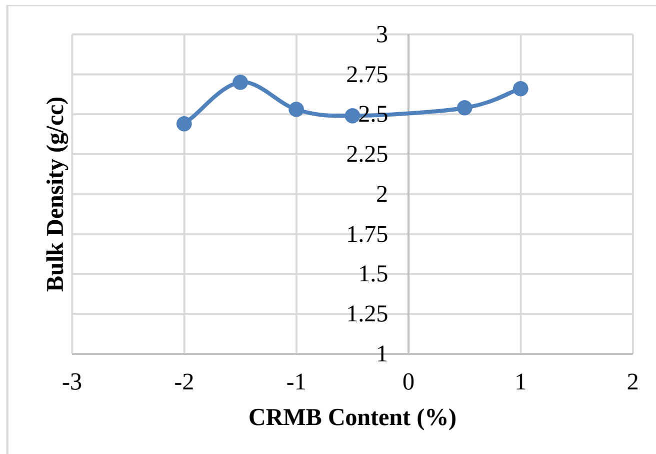

Fig 4. Bulk Density v/s CRMB Content

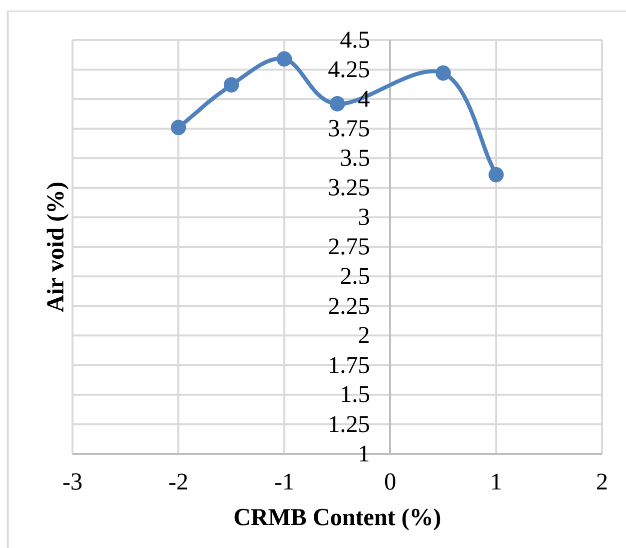

Fig 5. Air Void v/s CRMB Content

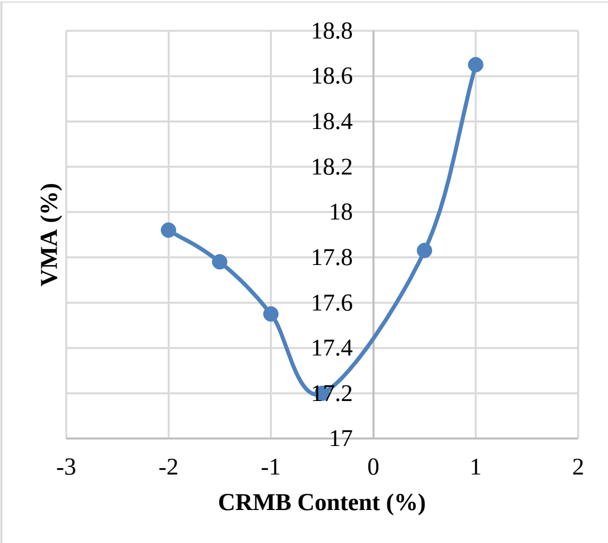

Fig 6. VMA v/s CRMB Content

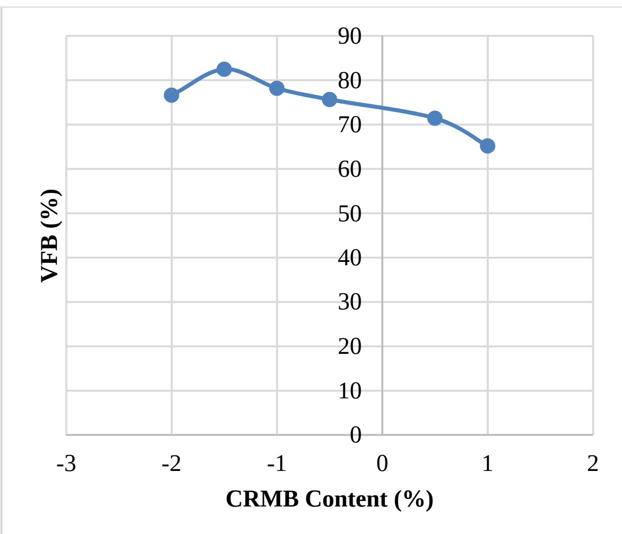

Fig 7. VFB v/s CRMB Content

Summary of results

The result obtained for the Marshall properties of rubber modified bituminous mix at optimum binder content (5.65%) by replacing bitumen with CRMB are discussed in the following points.

Optimum binder content

The optimum binder content for rubber modified bituminous concrete mix (Grading-I) with CRMB is found to be -1.5%. This means that by replacing 1.5% of bitumen content with CRMB at OBC (5.65%) of conventional bitumen concrete mix.

Marshall Stability value

The Marshall Stability value for conventional bituminous concrete mix and rubber modified bituminous concrete mix at OBC are 16.75 kN and 18.78 kN respectively.

It is observed from Fig. 2 that the Marshall stability value increase from +1.0% to -1.5% and then decreases rapidly for -2.0% by replacement of bitumen with CRMB. The stability value for rubber modified bituminous concrete (Grading-I) mix is increased by 10.8% as compared to conventional bituminous concrete mix at OBC.

Marshall Flow value

The flow value for conventional bituminous concrete mix and rubber modified bituminous concrete mix at OBC are 4.2 mm and 4.3 mm respectively.

It is observed from Fig. 3 that the flow value decreases from +1.0% to -0.5% and then increases from -1.0% to -1.5% by replacement of bitumen with CRMB. The flow value for rubber modified bituminous concrete (Grading-I) mix is increased by 2.3% as compared to conventional bituminous concrete mix at OBC.

Bulk density

The bulk density for conventional bituminous concrete mix and rubber modified bituminous concrete mix at OBC are 2.55 mm and 2.7 mm respectively.

It is observed from Fig. 4 that the bulk density decreases from +1.0% to -0.5% and then increases rapidly from -1.0% to -1.5% after that it decreases at -2.0% by replacement of bitumen with CRMB.

The flow value for rubber modified bituminous concrete (Grading-I) mix is increased by 5.56% as compared to conventional bituminous concrete mix at OBC.

Percentage air voids

The percentage air void value for conventional bituminous concrete mix and rubber modified bituminous concrete mix at OBC is 4.6% and 3.7% respectively.

It is observed from Fig. 5 that the percentage air void value increases from +1.0% to +0.5%, decreases from +0.5% to -0.5%and rapidly increases up to -1.0% after that it decreases at -2.0% by replacement of bitumen with CRMB. The flow value for rubber modified bituminous concrete (Grading-I) mix is decreased by 19.6% as compared to conventional bituminous concrete mix at OBC.

Voids in mineral aggregate (VMA)

The voids in mineral aggregate (VMA) for conventional bituminous concrete mix and rubber modified bituminous concrete mix at OBC are 16.2% and 17.78% respectively.

It is observed from Fig. 6 that the VMA decreases rapidly from +1.0% to -0.5% and then increases rapidly from -1.0% to -2.0% by replacement of bitumen with CRMB. The VMA for rubber modified bituminous concrete (Grading-I) mix is increased by 8.89% as compared to conventional bituminous concrete mix at OBC.

Voids filled with bitumen (VFB)

The voids filled with bitumen (VFB) for conventional bituminous concrete mix and rubber modified bituminous concrete mix at OBC are 77.35% and 83.20% respectively.

It is observed from Fig. 7 that the VFB increases from +1.0% to -1.5% and then decreases at -2.0% by replacement of bitumen with CRMB. The VFB for rubber modified bituminous concrete (Grading-I) mix is increased by 7% as compared to conventional bituminous concrete mix at OBC.

G. Properties of Conventional Bitumen mix at Optimum Binder Content (OBC) and comparison with MoRT&H Specification are shown in Table 5.

Table 5: Properties of Conventional mix at Optimum Binder Content

Properties	Values obtained at OBC	Required as per MORT&H specification, Clause 509
Marshall Stability (kN)	16.75	Min 9.0
Flow (mm)	4.2	2-4
Bulk density, (g/cc)	2.55	-
Air voids (%) Va	4.6	3-6
Voids in mineral aggregate (%) VMA	16.2	Min 14.5
Voids filled with bitumen (%) VFB	77.35	65-75

H. Properties of CRMB mix at Optimum Binder Content (OBC) and comparison with IRC: SP: 53 specifications are shown in Table 6.

Table 6: Properties of Rubber Modified mix at Optimum Binder Content

Properties	Rubber Modified mix at OBC	Required as per IRC:SP:53 specification
Marshall Stability (kN)	18.78	Min 12.0
Flow (mm)	4.3	2.5-4.0
Bulk density, (g/cc)	2.71	-
Air voids (%) Va	3.7	3-5
Voids in mineral aggregate (%) VMA	17.78	Min 12
Voids filled with bitumen (%) VFB	83.20	65-78

Comparisons of mixes

Comparison of Conventional Bituminous Concrete Mix & Crumb Rubber Modified Bituminous Concrete Mix is shown in Table 7.

Table 7: Comparison of conventional mix & rubber modified mix

Properties	Conventional mix	Rubber Modified mix (CRMB)
Marshall stability (kN)	16.75	18.78
Flow (mm)	4.2	4.3
Bulk density, (g/cc)	2.55	2.71
Air voids (%) Va	4.6	3.7
Voids in mineral aggregate (%) VMA	16.2	17.78
Voids filled with bitumen (%) VFB	77.35	83.20

5. CONCLUSION

Coating of crumb rubber modified bitumen on aggregate enhances properties of the mix. Inter-molecular bonding between bitumen and crumb rubber coated aggregate enhance strength and thus upgrades the quality of bituminous concrete mixes. Noteworthy enhancement are observed in the performance parameters in Marshall Stability, flow value, voids in total mix and voids filled with bitumen of bituminous concrete mixes. The substantial increase in Marshall stability value using crumb rubber modified bitumen by replacing -1.5% of bitumen and also increase in Flow value, Bulk density, Voids filled with Bitumen , Voids filled with aggregate but decrease in the Air voids at optimum binder content. Thus, the crumb rubber modified bituminous concrete mixes are expected to be more durable, less susceptible to moisture in actual field condition.

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