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Industrial Waste Utilization with Partial Replacement of Bitumen using PMB & CRMB For Flexible Pavement

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ABSTRACT

Waste generated from industries and from various places around us not only contains rubber or plastics but contains lot many harmful pollutants which are hazardous if disposed continuously in open and left to degrade in our environment.

Our project aims to study properties of different materials which may help in utilising the waste as well as improve the quality of roads and make them efficient, stable, durable and long lasting. Some of the materials that we have studied and considered to be tested in the partial replacement of bitumen are PMB & CRMB.

From this research the pavement materials stability and the higher strength with replacing the Optimum content of the CRMB & PMB. For this replacement 2 to 8 percent of Bitumen could replace from the nominal mix of the designing.

Keywords- *CRMB - Crumb Rubber Modified Bitumen , PMB – Polymer Modified Bitumen, PMB (P) - Plastomeric Thermoplastics Based., PMB (E) - Elastomeric Thermoplastics Based., NRMB - Natural Rubber and SBR latex based, CRMB - Crumb Rubber / Treated Crumb, Rubber Based.*

1.0 INTRODUCTION

1.1 GENERAL

Road network is the mode of transportation which serves as the feeder system as it is the nearest to the people. So the roads are to be maintained in good condition. The quality of roads depends on materials used for construction. (Rokade S, 2012[1]). Due to urbanization, industrialization and large increase of populations, accompanied with uplift in the standard of living, road vehicle numbers have increased dramatically which, consequently, has resulted in a lot of end-of-use tires every year. The estimated number of tires manufactured in the world per annum is about 1.5 billon tires. (Bekhiti et al, 2004[2]).

Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of waste tyres and plastic materials in road making in which higher economic returns may be possible. The necessary specifications will be formulated and attempts are to be made to maximize the use of solid wastes in different layers of the road pavement. (Khan et al, 2017[3])

Each year approximately millions of tires are added to stockpiles, landfills or illegal dumps across the United States. The estimated number of accumulated tires is slightly over half a million. The large number of tires accumulated over the years and currently being generated creates a disposal problem in the rural areas. (Bekhiti et al, 2004[2]). Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. Also, cost of extracting good quality of natural material is increasing. (Sarathy et al, 2015[4]).

2.0 ASPHALT PAVEMENT CHARACTERISTICS

- Excellent binding property with aggregates, both cohesive and adhesive in nature.
- Repellant to water.
- Thermoplastic in nature (stiff when cold, liquid when hot) (Mashaan et al, 2012[5])

A common method to improve the quality of bitumen is by modifying the Engineering properties of bitumen by blending with organic synthetic polymers like rubber and plastics. (Mashaan et al, 2012[5])

2.1 PERFORMANCE OF ASPHALT PAVEMENT

Post construction pavement performance studies are to be done for these waste materials for construction of low Volume roads with two major benefits (Raol et al, 2014[6])

(i) It will help clear valuable land of huge dumps of wastes.

(ii) It will also help to preserve the natural reserves of aggregates, thus protecting the environment. Rubber tyres are user friendly but not eco-friendly as they are non-biodegradable generally.

2.2 USE OF WASTE PLASTICS AND WASTE RUBBER

Tiers Worldwide, sustainability is the pressing need of the hour in the construction industry and towards this endues of waste material in road construction is being increasingly encouraged so as to reduce environmental impact. The main aim of this project is to be focus on using the available waste/recycled PMB & CRMB present in abundant which can be used economically and conveniently. The use of these materials as a road construction proves eco-friendly, economical and use of plastic will also give strength in the sub-base course of the pavement. (Priyanka et al, 2013[7])

2.3 WASTE RUBBERS CONSTRUCTION OF BITUMINOUS ROAD

It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive. Therefore the life of the pavement surfacing using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen. (Baraiya et al, 2013[8]).

2.4 OBJECTIVES OF USING CRMB & PMB

The main objectives of the study are,

- To determine the physical properties of aggregates, bitumen, and Crumb rubber.
- To select the optimum percentage of rubber to be mix.
- To study the laboratory investigations of the bitumen concrete mixes with CRMB & PMB.
- Comparative analysis of lab result with crumb rubber and plastic material.
- Cost analysis is to be made with the conventional method.

2.5 CLASSIFICATION OF MODIFIED BITUMEN

The Polymer and Rubber modified bitumen are classified into four types as given below,

(a) Type A – PMB (P) : Plastomeric Thermoplastics Based.
(b) Type B – PMB (E) : Elastomeric Thermoplastics Based.
(c) Type C – NRMB : Natural Rubber and SBR latex based
(d) Type D – CRMB : Crumb Rubber / Treated Crumb Rubber Based

CRMB- Crumb rubber is actually small pieces of waste tyre scrapped from light motor vehicles and whose disposal is a serious menace. The annual available capacity for procured tyres is retreading. (Deshmukh et al[9])

PMB- Plastic is material consisting of any of a wide range of synthetic or semi-synthetic organic compounds that are malleable and so can be molded into solid objects. Kumar et al[10]

Table 1: Basic Properties of PTB & ETB

Requirements of polymer modified bitumen

		Type-A				**Type-B**			
		Plastomeric Thermoplastic based				**Elastomeric Thermoplastic based**			
S. No.	**Designation**	**Grades & Requirements**			**Test Method**	**Grades & Requirements**			**Test Method**
		PMB 120	**PMB 70**	**PMB 40**		**PMB 120**	**PMB 70**	**PMB 40**	
1	Penetration at	90-150	50-	30-	IS 120	90-	50-	30-	IS 120

	25 °C		90	50	3-1978	150	90	50	3-1978
2	Softening point, (R & B), C Min.	50	55	60	IS 1205-1978	50	55	60	IS 1205-1978
3	Elastic recovery of half thread in Ductilometer at 15 °C, % Min.	50	40	30	IS 15462-2004	70	70	70	IS 15462-2004
4	Flash point °C Min.	220	220	220	IS 1209-1978	220	220	220	IS 1209-1978
5	Separation difference in softening point, (R&B) °C Max.	3	3	3	IS 15462-2004	3	3	3	IS 15462-2004
6	**Thin Film Oven Test (TFOT) on residue**								
	a). Reduction in Penetration of residue at 25 °C, Min. % of original	35	35	35	IS 1203 – 1978	35	35	35	IS 1203 – 1978
	b). Increase in softening point, °C Max.	7	6	5	IS 1205 – 1978	7	6	5	IS 1205 – 1978
	c). Elastic recovery of half thread in Ductilometer at 25 °C, % Min.	35	35	35	IS 15462 - 2004	50	50	50	IS 15462 - 2004

Table 2: Basic Properties of NR & CRMB
Requirements of polymer modified bitumen

		Type-C				**Type-D**			
		Natural Rubber based				**Modified Crumb Rubber based**			
S. No.	**Designation**	**Grades & Requirements**			**Test Method**	**Grades & Requirements**			**Test Method**
		PMB 120	**PMB 70**	**PMB 40**		**PMB 120**	**PMB 70**	**PMB 40**	
1	Penetration at 25°C	90 - 150	50 - 90	30 - 50	IS 1203 - 1978	<70	<60	<50	IS 1203 - 1978
2	Softening point, (R & B), C Min.	45	50	55	IS 1205 - 1978	50	55	60	IS 1205 - 1978
3	Elastic recovery of half thread in Ductilometer at 15°C, % Min.	50	40	30	IS 15462 - 2004	50	50	50	IS 15462 - 2004
4	Flash point °C Min.	220	220	220	IS 1209 -	220	220	220	IS 1209 -

					1978				1978
5	Separation difference in softening point, (R&B) °C Max.	4	4	4	IS 15462 - 2004	4	4	4	IS 15462-2004
6	**Thin Film Oven Test (TFOT) on residue**								
	a). Reduction in Penetration of residue at 25°C, Min. % of original	40	40	40	IS 1203 – 1978	40	40	40	IS 1203 – 1978
	b). Increase in softening point, °C Max.	7	6	5	IS 1205 – 1978	7	6	5	IS 1205 – 1978
	c). Elastic recovery of half thread in Ductilometer at 25°C, % Min.	35	25	20	IS 15462 - 2004	35	35	35	IS 15462 - 2004

(Source: BIS, Indian Standard – Polymer and Rubber Modified Bitumen – Specifications, IS:15462-2004, IRC: SP: 53,2002, IS:9381-1979)

3.0 TESTS ON AGGREGATES

Table 3: Tests on Aggregates and its Results

Sl. No.	Laboratory Test	Reference	Inference
1	Crushing test	IS: 2386 part-IV	<10 - Strong Aggregate >35 – Weak Aggregate
2	Abrasion Test	IS: 2386 part IV	<40% - WBM base course <35% - Bituminous Concrete
3	Impact Test	IS: 2386 part IV	<30% - Wearing Coarse <35% - Bituminous Macadam = 40% - WBM
4	Shape Test 1. Flakiness Index 2. Elongation Index	IS: 2386 part-I IS: 2386 part-I	least dimension is <0.6 times their mean size greatest dimension (length) is 1.8 times their mean dimension
5	Specific Gravity and Water Absorption test	IS: 2386 part-III	Specific Gravity: 2.5 to 2.9 Water Absorption: 0.1 to 2%

(Source: IS 2386 Part –I, III and IV)

4.0 TESTS ON BITUMEN

Table 4: Tests on Bitumen and its Results

<table>
<tr><th>Sl. No.</th><th>Laboratory Test</th><th>Reference</th><th>Inference</th></tr>
<tr><td>1</td><td>Penetration Test</td><td>IS: 1203-1978</td><td>Penetration Value: 30/40, 60/70, 80/100 (For Normal Climatic Conditions)
Penetration Value: 180/200 (For colder Conditions)</td></tr>
<tr><td>2</td><td>Ductility Test</td><td>IS: 1208-1978</td><td><table>
<tr><th>penetration grade</th><th>Min. ductility value (cms)</th></tr>
<tr><td>Assam Petroleum A25</td><td>5</td></tr>
<tr><td>A35</td><td>10</td></tr>
<tr><td>A45</td><td>12</td></tr>
<tr><td>A65, A90 and A200</td><td>15</td></tr>
<tr><td>S35</td><td>50</td></tr>
<tr><td>S45, S65 and S90</td><td>75</td></tr>
</table></td></tr>
<tr><td>3</td><td>Softening Point Test</td><td>IS: 1205-1978</td><td>Higher softening point indicates lower temperature susceptibility</td></tr>
<tr><td>4</td><td>Specific</td><td>IS: 1202-</td><td>0.97 to 1.02</td></tr>
</table>

	Gravity Test	1978	
5	Viscosity Test	IS: 1206-1978	Orifice Size – 4 mm: Viscus-25 to 250 Orifice Size – 10 mm: Viscus-10 to 140
6	Flash And Fire Point Test	IS: 1209-1978	minimum value of flash point – 175^{0}C

(Source:IS:1203-1978, IS: 1208-1978, IS: 1205-1978, IS:1202-1978, IS:1206-1978, IS:1209-1978)

5.0 TESTS ON CRMB (CRUMB RUBBER MODIFIED BITUMEN):

Table 5: Tests on CRMB and its Results

Sl. No.	Laboratory Test	Inference
1	Penetration Test	Penetration Value: 60/70
2	Ductility Test	100 cm
3	Softening Point Test	48-50^{0}C
4	Specific Gravity Test	1-1.15
5	Flash And Fire Point Test	minimum value of flash point – 300-325^{0}C

(Source: IRC:SP:53 (First Revision),2002)

6.0 TESTS ON PMB (POLYMER MODIFIED BITUMEN):

Table 6: Tests on PMB and its Results

Sl. No.	Laboratory Test	Inference
1	Penetration Test	Variation in 65 to 70 mm
2	Ductility Test	Variation in 35 to 70 cm
3	Softening Point Test	120-150^{0}C
4	Specific Gravity Test	0.91-1.4
5	Flash And Fire Point Test	minimum value of flash point – 240-320^{0}C

(Source: https://www.nbmcw.com/roads-pavements/930-use-of-waste-plastic-in-construction-of-flexible-pavement.html as on Feb 2009)

7.0 MIX DESIGN METHODOLOGY

EXPERIMENTAL PROGRAM- The Bituminous Concrete mix will be preparing using Marshall Stability Method of bitumen mix design. The BC will be prepare with conventional grades of Bitumen and adding various percentages of PMB and CRMB as mentioned below, Kumar et al, 2015[10]

Table 7: Detail of sample constitution and % Constituents

Sl. No.	Sample Preparation	Sample Constitution	% of Constituent by weight of bitumen
1	Wet Process	Bitumen Mix	
2	Dry Process	Bitumen + PMB	PMB: 3% PMB: 6% PMB: 9%
3	Wet Process	Bitumen + CRMB	CRMB: 8% CRMB: 10% CRMB: 12%

(Source: Kumar et al, 2015[10])

7.1 MARSHALL STABILITY TEST

Before preparing the specimens for Marshall Test, it is required that following steps.

- Material proposed for use the gradation requirements of the project specifications.
- The blend combinations meet the gradation requirements of the project specifications.
- Therefore use in density and voids analysis the pulse specific gravity of all aggregate used in the blend and the specific gravity of asphalt are determined.

(Hari prakash, P et al[13]) After this, the other parameters like Unit Weight (gm/cc), Specific Gravity of mix (Gmm), Air Voids (%), Voids in mineral aggregates (%), Voids filled with bitumen (%), etc. are calculated by derived formulas,

7.2 SPECIMEN PREPARATION

According to IRC:29-1988 1200gm of aggregates and filler is heated to a temperature of 175-190ºC. Bitumen is heated to a temperature of 121-125ºC with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of 154-160ºC . The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of 138-149ºC. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0:5% and repeat the above procedure. Number of trials is predetermined.

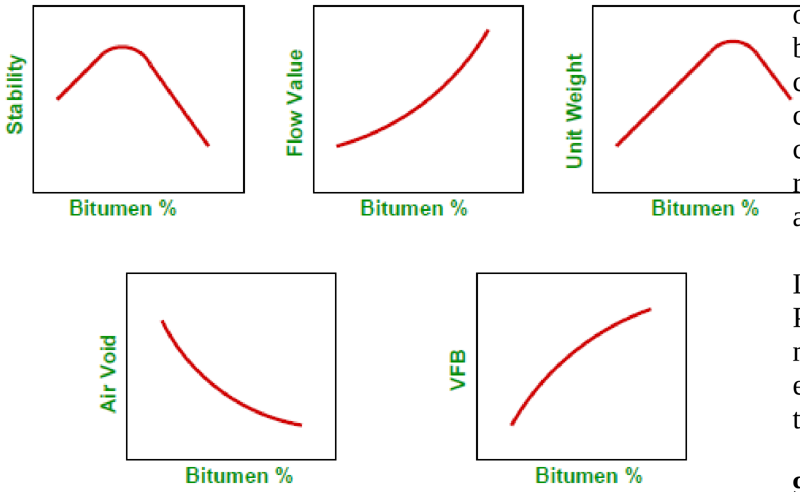

Figure 1: Marshal graphical plots

Table 8: Marshall mix design specification

Sl.No.	Test Property	Specified Value
1	Marshall stability, kg	340 (minimum)
2	Flow value, 0.25 mm units	8 - 17
3	Percent air voids in the mix v_v %	3 - 5
4	Voids filled with bitumen VFB %	75 - 85

(Source: Ministry of Road Transport & Highways, Specifications for Road and Bridge Works, Fourth Revision, Indian Roads Congress)

Then, Plot % of bitumen content on the X-axis and stability in kg on the Y-axis to get maximum Marshall Stability of the bitumen mix. A sample plot is given,

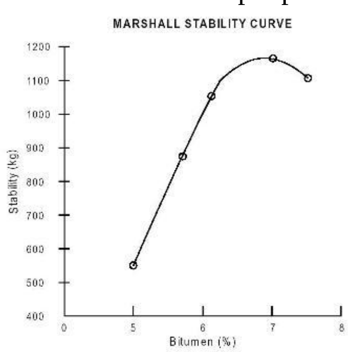

Figure 2: Results of Marshall Stability Test.

8.0 RESULTS AND DISCUSSIONS

The use of Crumb Rubber in Flexible Pavements has a lot of advantages when compared to the disadvantages. The use of Warm mix bitumen has clearly shown that the cost can be significantly bought down by using CRMB & PMB over conventional bitumen pavements has shown that the load carried by CRMB pavements is higher than that of the conventional bituminous pavements and by adding crumb rubber to the bituminous pavements the waste tires which are used as landfill can be significantly bought down.

Likewise CRMB & PMB of Hot Mix Role in Flexible Pavements for a Sustainable Future. The fumes from hot mix asphalt are known to be potential health hazards, especially for the construction workers. Reduced temperature of the mix avoids this health hazard.

9.0 CONCLUSION

It can be seen that the modified bitumen showing better results compared to the normal bitumen. This method contributes for improved disposal of waste tyres and waste plastics. Decrease in penetration point, increases load – bearing capacity of the road. The Marshall Stability value is high hence increases life of the road. While using CRMB & PMB, the melting point of bitumen will be increased. Waste tyre modified bituminous surface of road increases their life period especially the pavement requires low maintenance costs.

REFERENCE

1. Rokade S, Use of Waste Plastic and Waste Rubber Tyres in Flexible Highway Pavements, International Conference on Future Environment and Energy, Vol.28,PP: 105-108, 2012
2. Bekhiti, M., Trouzine, H., and Asroun, A., Properties of Waste Tire Rubber Powder, Engineering, Technology & Applied Science Research, Vol. 4,(04), PP: 669-672, 2014
3. Khan, N., Nafees, A., Hussain, A., Zaidi, G., Osama, M., and Ghaffar, S., Exploring the Properties of Recycled Tyre Rubber for Flexible Asphalt Pavement, Journal of Basic & Applied Sciences, Vol: 13, PP: 335-339, 2017
4. Sarathy, V., Ravindraraj, J., and Kumar, D., Analysis of Properties in Bitumen and Asphalt with Partial Replacement of Rubber Tyres, International Journal Of Innovative Research & Development, Vol:4 (05), PP: 172-176, 2015

5. Mashaan, N., Ali, AH., Karim, MR., and Abdelaziz, M, An overview of crumb rubber modified asphalt, International Journal of the Physical Sciences, Vol. 7(2), PP. 166 - 170, 2012.
6. Raol, H., Parmar, A., Patel, D., and Jayswal, J., Effect Of The Use Of Crumb Rubber In Conventional Bitumen On The Marshall Stability Value, International Journal of Research in Engineering and Technology, Vol: 03 (01), PP:209-2013, 2014.
7. Priyanka, M., Ganesh, PD., and Bhosale, S.M., Laboratory Evaluation of Usage of Waste Tyre Rubber in Bituminous Concrete, International Journal of Scientific and Research Publications, Vol: 3 (09), PP: 01-07,2013
8. Baraiya, D., Use of Waste Rubber Tyres in Construction of Bituminous Road – An Overview, International Journal of Application or Innovation in Engineering & Management, Vol: 02 (07), PP: 108-110, 2013
9. Deshmukh, H., and Kshirsagar, Y., Utilization of Rubber Waste in Construction of Flexible Pavement, International Journal of Advance Research and Development, Vol:02 (07), PP: 70-77, 2017.
10. KUMAR, CP., and SHASHISHANKAR, Study of Crumb rubber for the partial replacement for bitumen or as an alternative material for bitumen, Applied Sciences, Engineering & Technology, Vol: 04,PP: 01-05, 2015
11. Prasad, R., and Sowmya, NJ., Bituminous Modification with Waste Plastic and Crumb Rubber, IOSR Journal of Mechanical and Civil Engineering, Vol: 12 (03), PP: 108-115,2015.
12. Chhabra, RS., and Marik, S, A Review Literature On The Use Of Waste Plastics And Waste Rubber Tyres In Pavement, International Journal Of Core Engineering & Management, Vol: 01 (01), PP: 01-05,2015
13. Hari prakash, P., and Tamilselvan, B., Experimental Study On Partial Replacement Of Bitumen By Recycled Rubber From Tyre On Asphalt Pavement, International Journal of Advanced Research in Basic Engineering Sciences and Technology, Vol: 03 (24), PP: 514-518, 2017
14. Aziz, A., Rahman, T., Hainin, R., and Bakar, A., Alternative Binders For Flexible Pavement, ARPN Journal of Engineering and Applied Sciences, Vol: 11 (20), PP: 11868-11871, 2016
15. Altieb, A., Aziz, A., Kassim, B., and Jibrin, B., A Short Review On Using Crumb Rubber As Modification Of Bitumen Binder, Jurnal Teknologi , Vol: 78 (03) PP: 29-36, 2016
16. Dnyneshwar, C., Mahesh, A., Nandikeshwar, J., Pravin, K., Sagar, P., and Waychal, PP., Construction of Flexible Road Pavement by using Waste Rubber Tyre, International Engineering Research Journal, Vol:02 (03) PP: 01-05, 2015.
17. Farina, A., Zanett, M., Santagata, E., Blengini, G., and Lanotte, M., Life Cycle Assessment Of Road Pavements Containing Crumb Rubber From End of Life Tires, Land and Infrastructure Engineering, Vol: 24, PP: 119-132, 2014.
18. Roy, A., Waste Rubber Bitumen Modifier, International Journal of Engineering Research and General Science, Vol: 03 (05), PP109-119, 2015
19. BIS, Indian Standard – Polymer and Rubber Modified Bitumen – Specifications, IS:15462-2004, IRC: SP: 53,2002, IS:9381-1979
20. Indian Road Congress :SP:53 (First Revision),2002.