USE OF CRUMB RUBBER MODIFIED BITUMEN IN BITUMINOUS WEARING COURSES

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ABSTRACT

Crumb Rubber Modified Bitumen usage is being more popularized and encouraged nowadays because of the advantages over conventional bitumen and economical viability. This article focuses on CRMB usage methods, requirements and results of field studies.

1.0 INTRODUCTION

Usage of bitumen in flexible pavements is a globalised practice nowadays. Behind such extensive usage, the bitumens have come a long way before they were put to proper usage backed by large research and engineering studies. Bitumen was the Roman name for asphalt used as cementing material. As per the current day practice, the names Bitumen and Asphalt apply to the same substance, while the British terminology uses the former one and American terminology uses the later one.

In the earlier days known to history, Asphalt was obtained from lakes and rocks naturally in Mesopotamia (ancient Iraq) and Indus valley. In those times the bitumen was only a caulking material. However, evidences show that bitumen was used for road purposes by using as a cementing material for paving bricks in Indus Valley Civilisation. Usage of bitumen as road construction material was first done in Paris during 1810 by laying of footpaths. But the usage methods were not taken a proper shape until 1835. Asphalt blocks were used for road purposes during 1824 and a pavement for road, using natural rock asphalt was constructed in 1854, both in Paris. With development of Asphalt concrete in United States of America during 1887, it can be presumed that the road construction using bitumen has taken a final shape.

2.0 NEED FOR MODIFICATION

Bitumen is a very complex material. Properties of bitumen depend upon the crude oil from which it was extracted and also the process of manufacture. Durability of bitumen pavement depends upon selection of appropriate grade of bitumen to suit the required climatic conditions and traffic loading. After application as a paving material, the bitumen undergoes the following changes due to High traffic intensity, high axle loads, variation in traffic and seasonal temperature variation.

1) Permanent deformation: The traffic loading exerts a thrust on the pavement. Depending upon the layer characteristics and direction of thrust, the pavement layer undergoes some modifications in shape. This results shoving and rutting, which is a non-recoverable deformation.

2) Low temperature cracking: Bitumen is brittle at very low temperatures and as the temperature grows up, it becomes ductile in the middle range and becomes free flowing at higher temperature. As such, if the regular pavement temperature is much lower than that of at the time of laying, bitumen surfaces develop low temperature cracking.

3) Fatigue cracking: Repeated cycles of temperature drops, generally in the areas with varied range of temperature cause cracking due to thermal fatigue.

4) Aging: When exposed to weather bitumen undergoes oxidation. Oxidation of bitumen results irreversible hardening as the age increases. The process of aging depends upon the temperature as well as the duration at which oxidation takes place.

5) Water Resistivity: When exposed to moisture, the bitumen film, which covers the road aggregate gets displaced and the same is popularly known as stripping.

In the process of improving the qualities of bitumen and make it durable for longer times, several trials and a lot of research has been carried out and the out come was- "Modification of Bitumen".

3.0 MODIFICATION OF BITUMEN

Improving the qualities of bitumen to resist the distress factors by addition of suitable additive is known as modification of bitumen. The modifier, to be effective and for its use to be practicable and economic, it should satisfy the following requirements.

1. Readily available.
2. Resist degradation at asphalt mixing temperatures.
3. Blend with bitumen.
4. Improve resistance to flow at high road temperatures without making the bitumen too viscous at mixing and laying temperatures or too stiff or brittle at low road temperatures.
5. Cost effective.

On blending with bitumen the modifier should exhibit –

1. Maintain its premium properties during storage, application and service.
2. Capable of being processed by conventional equipment.
3. Physically and chemically stable during storage, application and during service.
4. Achieve a coating on spraying viscosity at normal application temperatures.

Several items were found to be good modifiers with different qualities. A list of modifiers is given in Table 1 and benefits achieved by usage of different types of bitumen's are indicated in Table 2.

Table 1: Some additives used to modify bitumen

Type of modifier	Example
Thermoplastic elastomers	Styrene-butadiene-styrene (SBS) Styrene-butadiene-rubber (SBR) Styrene-isoprene-styrene (SIS) Styrene-ethylene-butadiene-styrene(SEBS) Ethylene-propylene-diene terpolymer (EPDM) Isobutene-isoprene copolymer (IIR) Natural rubber Crumb tyre rubber Polybutadiene (PBD) Polyisoprene
Thermoplastic polymers	Ethylene vinyl acetate (EVA) Ethylene methyl acrylate (EMA) Ethylene butyl acrylate (EBA) Atactic polypropylene (APP) Polyethylene(PE) Polypropylene(PP) Polyvinyl chloride (PVC) Polystyrene (PS)
Thermosetting polymers	Epoxy resin Polyurethane resin Acrylic resin Phenolic resin
Chemical modifiers	Organo-metallic compounds Sulphur Lignin
Fibers	Cellulose Alumino-magnesium silicate Glass fiber Asbestos Polyester Polypropylene
Adhesion improvers	Organic amines Amides
Antioxidants	Amines Phenols Organo-zine organo-lead compounds
Natural asphalts	Trinidad Lake Asphalt (TLA) Gilsonite Rock asphalt
Fillers	Carbon black Hydrated lime Lime Fly ash

Table 2: Benefits of different types of modifiers

Modifier	Reduction in Permanent deformation	Reduction in Thermal cracking	Reduction in Fatigue cracking	Less Moisture damage	Slow in Aging process
Elastomers	√	√	√		√
Plastomers	√				
Fillers:					
i) Carbon black	√				√
ii) Lime				√	√
iii) Hydrated lime				√	√
Chemical modifiers	√				
Antioxidants					√
Adhesion improvers				√	√

From the above list it can be seen that elastomers can improve the bitumen qualities better than other types of modifies. The most common and easily available type of elastomer is "crumb tyre rubber."

4.0 CRUMB RUBBER MODIFIED BITUMEN

Automobile tyres are a waste after done with. The waste tyres are an environmental hazard as they are non-biodegradable and burning them leads to weather pollution.

On the other hand the volume of waste tyres is increasing year by year. It is believed that about 15million tonnes of waste tyres are produced globally. As per extensive research done in usage of elastomers in the form of crumb rubber, which is a product of buffed waste tyres, the studies revealed that crumb rubber can be very effectively used to modify the bitumen, which results the following benefits in pavement construction.

- Resistance to rutting, aging and reflective cracking.
- Improved skid resistance
- Increase in pavement life
- Reduction of noise pollution.

Particularly, in the tropical areas where the temperature variation is greater and has quick adverse effect on the performance of bitumen are benefited by the usage of modified bitumen.

The tyres primarily consist of natural rubber, synthetic rubber and carbon black. Generally scrap tyres consist of 50-60% of rubber material and the balance is fiber and steel in the form of radials.

Initially scrap tyres were cut in to small chips and used in place of aggregates in bitumen mixes. After a period of time, it was observed that if the rubber chips and aggregates mixed together for using for paving purposes, they perform better. Further research revealed that if the waste tyre rubber is buffed in to tiny parts and mixed with bitumen and the bitumen prepared thus can work even better. During the detailed studies conducted, it is found that the particle size of c rumb rubber does not affect its hardness. Hence, to break its hardness and to make it compatible with bitumen under controlled temperatures, certain chemicals are to be used so that the modified bituminous material can be a direct substitute to the bitumen. These methods are popularly known as "Dry Process" and "Wet Process".

4.1 Dry Process

The method of incorporating crumb rubber in bitumen mixes consists of using crumb rubber along with mineral aggregates. In this system, hot mix material is prepared by adding about 4% by weight and 4.75mm to powder sized crumb rubber particles to replace some of the aggregates in the mixture. This will generate some reaction between the crumb rubber modifier (CRM) and bitumen. The quantity of fine CRM introduced in to the mix will determine the degree of modification to the bitumen. To achieve desired result, the mixing temperatures are to be limited for the bitumen and CRM, so that CRM can retain its physical shape and rigidity. This method needs no other specific equipment. The Crumb rubber can be proportioned and directly used along with aggregates. The pavements laid thus have exhibited;

- Increased flexibility
- Resistance to studded tyres
- Increased fatigue life
- Reflective crack control, and
- Noise reduction

4.2 Wet Process

Addition of Crumb rubber to the bitumen before mixing the bitumen and aggregates called Wet Process. In this process by addition of Crumb Rubber to bitumen, modified bitumen is produced. In this process finely ground tyres [Buffings] are added to the bitumen in specially made tanks and stirred well at a temperature of 200 °C. The mixing time depends upon various factors and extends up to one hour. In this process, by addition of hydro carbon minerals such as Gilsonite / natural asphalt etc. makes the Crumb Rubber compatible with bitumen and gives desired results. The bitumen modified thus is called Crumb Rubber Modified Bitumen [CRMB] and can be directly used as a substitute to the conventional bitumen and no specific equipment is required either for mixing or for paving.

In India, CRMB is being supplied by various refineries in ready mixed form. The supply is delivered in thermal tankers and the bitumen received at plant site can be used for mix preparation. However, it is advised that repeated heating of CRMB should be avoided to protect the premium properties of the CRMB. Bituminous mixes made with CRMB shows the following improvements in the properties, in comparison to the bituminous mixes made with ordinary bitumen.

- Increase in Marshal Stability
- Increase in Fatigue life.
- Elastic Modulus gets enhanced.
- Improves Water Repellent Properties.
- Improves Skid Resistance.
- Improves Ageing Resistance.

The CRMB usage results the following advantages.

1. Resistance to aging.
2. Resistance to deformation and cracking.
3. Increase in pavement life.
4. Increased skid resistance.
5. Reduction of noise pollution.
6. Reduction in thickness of pavement.

4.3 Specifications

Indian Roads Congress special publication 53 on "Guidelines on use of Polymer on Rubber Bitumen in Road Construction – 2002" permits usage of Crumb Rubber modified bitumen for paving purposes in India. The code specifies the requirements of the modified bitumens. A comparison of plain and rubberized bitumen is as given in the following table.

Table 3: Comparison of Straight run Bitumen and CRMB Properties

	Plain Bitumen as per ISI			Rubberised Bitumen		
Details	80/100	60/70	30/40	CRMB50	CRMB55	CRMB60
Softening Point (R&B) °C, Minimum	35 to 50	40 to 55	55 to 65	50	55	60
Penetration at 25°C, 0.1mm 100g. 5 Sec.	80 to 100	60 to 70	30 to 40	<70	< 60	< 50
Elastic Recovery	<7%	< 7%	<7%	>40%	>35%	> 30%
Flash Point, COC °C, min.				220	220	220
Separation, Difference in Softening Point, R&B, °C, Maximum				4	4	4

Modified bitumens are generally recommended for the heavy traffic road sections and extreme climatic areas hence the selection of type of modified bitumen will be based on climatic and traffic conditions basically. The IRC-53 states that appropriate grade CRMB shall be selected based on selection criteria presented in Table 4.

Table 4: Selection Criteria for Grade of CRMB

Minimum Pavement Temperature °C	Maximum Atmospheric Temperature, °C		
	<35	35 to 45	>45
< - 10	CRMB-50*	CRMB-55	CRMB-55
10 to – 10	CRMB-50	CRMB-55	CRMB-60
> 10	CRMB-55	CRMB-55	CRMB-60

* Not below 15° C

The comparison of mix requirements prepared, using conventional bitumen and modified bitumen are as given in Table 5 presented below.

Table 5: Bituminous Mix Requirements

Sl.No	Properties	Requirement				Method of Test
		SRB	CRMB			
			Hot Climate	Cold Climate	Rainfall	
1	Marshall Stability, (75 blows) at 60 ° C, kg, Minimum	820	1200	1000	1200	ASTM D 1559 – 1979
2	Marshall Flow at 60mm	2-4	2.5-4.0	3.5-5.0	3.0-4.5	ASTM D 1559-1979
3	Marshall Quotient kg/mm	----		2590-500		Stability/ Flow
4	Voids in compacted mix, %	3-5		3.0-5.0		-----
5	Requirement of retained stability after 24hours in water at 60, % Minimum	------	90	95	100	ASTM D:1075-1979
6	Coating with aggregate, %	------	95	95	100	AASHTO T 182

5.0 FIELD STUDIES

National Highways Authority of India has taken up four-lanning work of NH5 between Km.355/0 to Km.434/150 (Chilakaluripet to Vijayawada) of Chennai - Vijayawada section, in Guntur District. In pavement construction, wearing course with bituminous concrete was scheduled to be provided with straight run bitumen of 60/70 grade. While the work is in progress a policy decision was taken to provide the wearing coarse with Crumb Rubber Modified Bitumen of grade55 (CRMB55). This resulted about 50% of bituminous concrete stretches with 60/70 grade bitumen and balance with CRMB55. Hence, there is ample scope for performance comparison of both the grades of bitumen under same weather, traffic and pavement construction conditions. With this background it is proposed to compare the performance of CRMB55 with that of straight run bitumen of 60/70 grade.

10 Nos of test sections were identified with length of each section being 200mts.

The following data was proposed to be collected.

a) Skid Resistance
b) Deflection
c) Roughness
d) Traffic
e) Rut Depth
f) Temperature
g) Moisture Content of sub-grade soils
h) Rain fall data
i) Monthly Mean Temperature
j) Ground Water table

Comparative assessment of performances of both the pavements with CRMB55 and SRB60/70 is proposed to be done using the data collected with reference to the following aspects.

- Strength parameters
- Pavement surface distress
- Riding quality measurements
- Deflection measurements
- Economic Analysis to work out the economic viability of usage of CRMB.

5.1 Strength parameters

Job mix formula for bituminous concrete with CRMB 55 was designed by Marshal Method. Required tests were conducted on bitumen and aggregates and the materials were satisfying the codal requirements. Samples with varying bitumen content from 4.5% to 6% have been prepared and tested and the optimum bitumen content was worked out as 5.04%. Details of properties of the Marshall mix with varying bitumen content are given in the following Table 6.

Table 6: Bituminous Mix Properties

Description	Bitumen content (%)					
	SRB			CRMB 55		
	4.7	5.0	5.3	4.7	5.0	5.3
Compacted Density of Mix (g/cc)	2.437	2.44	2.446	2.53	2.53	2.58
Air Voids in Total Mix(%)	4.8	4.22	3.6	4.1	4.0	2.1
Voids in Mineral Aggregate (%)	15.98	16.13	16.2	15	15	14
Voids Filled with Asphalt (%)	69.95	73.81	78	76	80	96
Marshall Stability (Kgs)	1413	1443	1405	1408	1532	1554
Flow (mm)	2.3	3.13	3.40	2.8	3.1	3.33
Loss of stability	9.3	13.4	14	---	6.7	---

Random samples of working materials from HMP have been collected and tested. The results were comparable with specimen test results.

5.2 Skid Resistance

Skid resistance test was conducted using pendulum type skid meter. The skid resistance was evaluated at each location in the following conditions and the respective values are as presented in Table 7.

Table 7: Skid Resistance Values

	SRB	CRMB
Dry Surface	90 – 100	110 – 120
Wet Surface	65 – 75	80 – 90
Wet & Oily Surface	60 – 75	75 – 85

5.3 Roughness

Roughness test was conducted using standard bump integrator equipment. The roughness for SRB stretches was observed to be in the range of 1900 - 2200 mm/KM while that of CRMB was observed to be in the range of 1300 - 1700 mm/KM.

5.4 Pavement Distress

The pavement has not exhibited any signs of distress such as rutting, shoving and cracking etc during the period of observation.

5.5 Comparison Of Costs

The cost difference of SRB and CRMB is about Rs.2500/MT. Considering the substitution of CRMB in place of SRB and since no other activities are involved raising the costs of bitumen mix and paving, the difference of basic costs of bitumen is the only factor affecting the costs.

Based on average conditions, the cost of Bituminous concrete wearing course is generally Rs.3000/cum. Considering 5% as the bitumen requirement by weight of aggregates, the quantity of bitumen required is about 75kg per cum of mix.

Therefore the cost increase per cubic meter of mix is 75 X Rs.2.50/kg = Rs.187.50, thus making the cost of CRMB mix Rs.3187.50 or Rs.3190/cum.

Considering 40mm thickness of wearing course, the amount required for a 7.0m wide carriageway per KM length is -

CRMB: 1000 X 7.0 X 0.04 X 3190 = 893200
SRB : 1000 X 7.0 X 0.04 X 3000 = 840000
Net increase = 53200 / KM or 6.33 %

As per the results of research, the CRMB wearing courses require renewal time of 1.5 times to that of SRB. If as per IRC standards a section of road way is to be provided with fresh wearing course after four years the surface with CRMB requires it at six years interval. Comparison of the costs for a cycle of 12 years, can be done in following manner.

Period	Amount *	
	SRB	CRMB
Start	8,40,000	8,93,200
4 years	8,40,000	-
6 years	-	8,93,200
8 years	8,40,000	-
12 years	8,40,000	8,93,200
Total Cost	33,60,000	26,79,600

* Price escalation during the period is ignored

Savings : Rs. 6,80,400 in a cycle of 12 years per KM
or 20.25% on total cost of SRB usage.

6.0 CONCLUSIONS

Usage of CRMB in bituminous wearing courses is proved to be economical besides providing various advantages. The main advantages are :-

1. Disposal problem of non bio-degradable waste tyres is solved and weather pollution is controlled.
2. Improved riding quality of roads.
3. Reduction of noise pollution.
4. Increased skid resistance, which results reduction of accidents.
5. Improved bituminous mix characteristics resulting durable pavement.

For Indian climates, the CRMB pavements fit well in view of their suitability and performance.