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No. RW/NH-34041/86/90-S&R(Vol. II) ***Dated, the 21st April, 1999***

To

The Secretaries/Chief Engineers of States/Union Territories, Public Works Departments, (dealing with National Highways and Other Centrally Sponsored Schemes); Chairman, National Highways Authority of India; Director General Border Roads

Subject : Use of rubber and polymer. modified bitumen in road works

It has been a general experience that flexible pavements with bituminous surfacing develop pre-mature distress inter-alia due to factors, like, traffic intensity, overloading. climatic conditions, etc. The accelerated deterioration of flexible pavement burdens the scarce maintenance budget which in turn affects the available resources for new corridors. This situation has led to development of improved pavement materials and techniques in road construction.

2. The technology for use of modified bitumen in construction and maintenance of road is now a fairly established practice. The technology has been trial tested under Ministry's sponsored research scheme (R-54) by CRRI and also through R&D works undertaken by other research institutions of the country.

3. Considering its improved performance, it is suggested that use of rubber/polymer modified bitumen may be introduced in surfacing course of Pre-mix Carpet, M.S.S., Semi-Dense Bituminous Carpet and Bituminous

1-Amended vide circular dated 17.01.2000 & 13.06.2002

Concrete, as the case may be on the heavily trafficked section of National Highway and performance of the same compared with that of work with conventional bitumen. A report on the feedback may please be sent to the Ministry six monthly for the complete life cycle of the renewal for that specific km. In order to have a proper comparison, a continuous stretch of at least 5 km be considered for renewal. with modified bitumen. It has been decided that the State Chief Engineers shall use it in at least 10 per cent length of periodical renewal programme starting from 1999-2000 in each State. The additional cost towards use of modified bitumen (about 15 to 25 per cent of overall cost for each km) may be met from funds for periodical renewal placed with the State Government by suitably adjusting the overall length of renewal programme. In case of original works the additional cost may be included in project estimates of Annual Plan. The stretches where the treatment is to be adopted during the current year may be identified in consultation with the Regional Officer.

4. Guidelines on use of rubber and polymer modified bitumen in road works are separately under finalization by Flexible Pavement Committee of Indian Roads Congress. However, based on interim report received from CRRI on study, guidelines on rubber and polymer modified bitumen in surface course during the current year have been prepared by the Ministry. A copy of the same is enclosed for adoption during execution.

5. This may please be brought to the notice of all concerned officers in your organization/department.

[Enclosure to Ministry's Circular No.RW/NH-34041/86/90-S&R (Vol. II) dated 21st April, 1999]

GUIDELINES FOR THE USE OF RUBBER AND POLYMER MODIFIED BIUTMEN IN ROAD WORKS

1. INTRODUCTION

Flexible pavements with bituminous surfacings are widely used in India. The high traffic intensity in terms of commercial vehicles and the serious overloading of trucks have been responsible for early development of distress symptoms, like, undulations, rutting, cracking, deformations and pot-holing of pavements. A factor which causes further concern in India is the high range of temperature in most parts of the country. Under these conditions, pavements tend to become soft in summer and brittle in winter. Investigations in countries abroad have revealed that the properties of bitumen and bituminous mixtures can be modified by incorporation of certain additives. These additives are known as modifiers and the bitumen treated with modifiers is known as modified bitumen. The use of modified bitumen is now a fairly established practice in some countries abroad. In India also, limited studies have been encouraging. The technology has been trial tested by C.R.R.I., HRS, Chennai, GERI under research schemes sponsored by the Ministry and R&D works undertaken by other Research Institutions of the country. The guidelines contained here are based on international and available Indian experience. These guidelines are tentative and if required, the same shall be modified on the basis of feedback received from the users.

2. ADVANTAGES OF BITUMEN MODIFIERS

With a careful selection of modifiers, it is expected that the properties of bitumen and bituminous mixtures will get considerably improved. Life of the periodical maintenance and overlays gets enhanced by about 1.5 times resulting in reduced frequency of maintenance renewals. The choice will, thus, ultimately be based on the life-cycle-costing of the construction using conventional bitumen and modified bitumen.

The advantages of modified bitumen are :

- Lower susceptibility to temperature variations
- Higher resistance to deformations/wear and tear
- Better adhesion between aggregates and binder
- Increase in fatigue life
- Resistance in reflective cracking

3. TYPES OF ADDITIVES FOR BITUMEN MODIFICATION

A variety of additives are used for modification of bitumen. The degree of modification depends on type of polymer and rubber, its dose and nature of the bitumen. The classification of modifiers and their optimum dose level is indicated in Table 1.

Table 1. Types of Bitumen Modification

	Type of modifiers	Example	Dose level. % by –wt.. of bitumen
1.	**Plastics** • Thermoplastics • Thermosets	Polyethlene (PE) Ethylene Vinyl acetate (EVA)	2-4 3-5
2.	**Elastomers** • Natural rubber • Synthetic elastomers	Dry rubber content Styrene butadiene copolymer (SBR) Styrene butadiene Styrene block copolymer (SBS)	2-4 3-5
3.	Reclaimed rubbers	Tyre Crumb Powder	10-12
4.	Fibres	Polyester, Polypropylene	2-5

4. APPLICATIONS OF MODIFIED BITUMEN IN CONSTRUCTION AND MAINTENANCE OF PAVEMENTS

The use of modified bitumen needs to be encouraged for special applications. The suggested area of applications are:

(i) stress absorbing membranes (SAM) for sealing of cracks. .
(ii) stress absorbing membranes interlayer (SAMI) for delaying reflection cracks
(iii) surface dressing for roads high traffic
(iv) surfacing, such as, PC, SDBC, BC at National Highways and Expressways

5. REQUIREMENT OF ADDITIVES FOR BITUMEN MODIFICATION

When used as bitumen modifier, selected polymer/rubber alone or blend of polymers should :

- be compatible with bitumen
- be blended with bitumen so that it disperses thoroughly with bitumen prior to use
- improve the temperature susceptibility of bitumen
- resist degradation at bitumen mixing temperature
- be capable of being processed by conventional mixing plants and laying machinery
- produce coating viscosity at application temperature
- maintain premium properties during storage, application and in service
- be cost-effective considering life cycle cost

6. PROPERTIES AND TEST METHOD FOR MODIFIED BITUMEN

The properties of materials and modified binder shall be as indicated in Tables 2, 3, 4 and 5

Table 2. Requirement of Crumb Rubber Modified Bitumen

S. No.	Characteristic	Grade % Requirement of CRMB			Method of Test
		CRMB 50	CRMB 55	CRMB 60	
1.	Penetration at 25°C 0.1 mm	70-90	50-70	30-50	IS:1203 – 1 978
2.	Softening Point °C	45-55	50-60	55-65	IS : 1205-1978
3.	Elastic recovery % at 15°C	Min. 40	Min. 35	Min. 30	ASTMD : 5840-96
4. 5.	Penetration of residue after TFOT, % Increase in softening point of residue after TFOT, °C	Min. 60 Max. 5	Min. 60 Max. 5	Min. 60 Max. 5	IS : 1203-1978 IS : 1205-1978
6.	Elastic recovery of residue after TFOT, %	Max. 25	Max. 20	Max. 15	ASTMD: 5840-96

Table 3. Requirement of Crumb Rubber Powder

Sl. No.	Characteristics	Requirement
	Particle Size	0.15 mm to 0.60 mm
1.	Quantity	9.12 per cent
2	Ash content	Max. 5 per cent
3	Initial decomposition temperature	Above 200°C

Table 4. Requirements of Elastomer (SBS or Natural Rubber Modified Binders)

Sl. No.	Characteristic	Grade and Requirements		Method of Test
		PMB 70	PMB 40	
1.	Penetration, 20°C, 0.1 mm	50-90	30-50	IS : 1203 - 1978
2.	Penetration, 4°C 0.1 mm	30-40	20-35	IS : 1203 - 1978
3.	Softening point (R&B), °C	45-65	66-90	IS : 1205 - 1978
4.	Viscosity, 135°C, Poise	Max. 2000	Max. 2000	IS : 1206 - 1978
5.	Ductility at 27°C, cm	+ 50	+ 40	IS : 1208-1978
6.	Flush Point, COC, °C	220 Min.	220 Min.	IS : 1209 - 1978
7.	Elastic recovery, % at 15°C	+ 60	+ 60	ASTM D-5840-96 Sumary at Appendix -I
8.	Tests on residue after thin film oven test at 163°C, 5 hours			IS : 9392-1982
	★ Weight loss %	Max. 1.0	Max. 1.0	IS : 9382-1982
	★ Penetration at 25°C, %	Min. 60	Min. 60	IS : 1203-1978
	★ Increase in softening point, °C	Max. 6	Max. 7	IS : 1205 - 1978
	★ Elastic recovery, % at 15°C	Min. 40	Min. 40	ASTM D-5840-96
9.	Penetration ratio, %	Min. 35	Min. 40	IS : 1203-1978
10.	Fraass Breaking point, °C	Max. –16	Max. 14	IS : 9381-1978
11.	Separation, difference in softening point, °C	Max.3.0	Max. 3.0	ASTM D 5976-96 Summary at Appendix -II

Table 5. Requirements of Polymer Thermoplastics Based Modified Binders :

Sl No.	Characteristic	Grande and Requirements		Method of Test
		PMB 70	PMB 40	
1.	Penetration, 25°C, 0.1 mm	50-90	30-50	IS : 1203 - 1978
2.	Penetration, 4°C 0.1 mm	30-40	20-35	IS : 1203 - 1978
3.	Softening point (R&B), °C	48 to 58	59 to 68	IS : 1205 - 1978
4.	Frass breaking point, °C	Max. -12	Max. -12	IS : 9381 - 1978
5.	Ductility at 27°C, cm	Min. 40	Min. 40	IS : 1208-1978
6.	Flush Point, COC, °C	Min. 220	Min. 220	IS : 1209 - 1978
7.	Elastic recovery, of half thread ductilometer at 15°C %	Min. 40	Min. 40	ASTM D-5976-96
8.	Viscosity at 150°C, poise	5-10	6-15	IS : 1206-1978
9.	Separation, Difference in softening point, °C	Max. 3	Max. 3	ASTM 5976-96
10.	After thin film oven test at 163°C, for 315 minutes, loss in weight,%	Max. 1.0	Max. 1.0	IS : 9382-1982
	• Increase in softening point °C	Max. 6	Max. 5	IS : 1205-1978
	• Reduction in penetation %	Max. 35	Max. 30	IS : 9382-1982
	• Elastic recovery of half thread in ductilometer at 15°C	Min. 35	Min. 35	ASTMD 5976-96

7. SELECTION CRITERIA FOR MODIFIED BINDERS FOR DIFFERENT APPLICATION

CRMB 50 and PMB 70 for cold climate Zone.

CRMB 55, CRMB 60 and PMB 40 for high temperature Zone.

8. REQUIREMENTS OF POLYMER AND RUBBER MODIFIED MIXES

Extensive laboratory and field studies have established better resistance of rubber/polymer modified mixes to deformation, fatigue cracking, stripping and ageing. Mixes can be designed by Marshall method of mix design. The suggested design criteria are given in Table 6

Table 6. Requirements of PMB Mixes

Description	DBM	SBC	BC
Marshall stability at 60° C, kg	820 (min.)	1050 (min.)	1200 (min.)
Marshall flow, mm	2.4 to 3.6	2.5 to 4.0	3.0 to 4.5
Marshall quotient, kg/mm	300	400	400
Air voids in mix	3-5	3-5	3-5
Binder content by weight of mix, %	4.5 (min.)	4.5 (min.)	5.0 (min.)
Loss of stability of mix after immersion in water 60° C, 24 hours % Retained Stability.	75 (min.)	80 (min.)	85 (min.)

9. HANDLING OF MODIFIED BINDERS AND MIXES AT SITE

During laying of various test stretches the experience has shown that a good circulation system is needed to ensure that modified bitumen retains its premium properties. Temperature of mixing and rolling should be slightly higher than conventional bituminous mixes. Requirement of temperature at different stages is given in Table 7.

Table 7. Requirement of Temperature

Stage	**Temerature, ^{0}C**
Binder at mixing	170 - 180
Mix at plant	145 - 155
Mix at site	120 - 140
Rolling at site	110 - 135

The hot mix construction using modified bitumen should be done when atmospheric temperature is above 15°C.

10. BLENDING OF MODIFIER WITH BITUMEN

Modifiers, like, EVA, PE and crumb rubber based products can be easily blended with the molten bitumen at 140°C to 160°C using a suitable mechanical stirrer at site. The blending time is 20 to 40 minutes, as recommended by the manufacturers.

Natural rubber can be blended with bitumen at 140°C to 160°C in a boiler equipped with paddle or shear type stirrer. Blending is usually continued for a period of 2 hours.

SBS type modifiers are blended with shear type agitators. Bitumen is heated to a temperature of 160°C when the modifier is added and the stirring is continued for 90 to 120 minutes. The blending can be done in a central plant or in the refinery.

11. SPECIFICATIONS AND CONSTRUCTION METHODOLOGY

The specifications and construction methodology for various items of work using modified bitumen are generally the same as those with ordinary bitumen, except for any special considerations which the manufacturer may indicate.

12. COST BENEFIT ANALYSIS

Life cycle costing is an economic evaluation technique in which all significant cost for construction and maintenance of roads are considered in terms of discounted cost over the period of time that the facility is required. Considering 1.5 times increase in life of overlay as proved by field trials, frequency of overlaying can be minimised. Comparing cost of 60/70 bitumen with modified bitumen, the latter would be about 50 per cent expensive at an independent blending unit and about 30 per cent expensive at refinery. Since, other component of the cost of construction would be same, the overall increase in cost of overlaying will be about 15 to 25 per cent higher. For design life of 12 years, three renewals of 60/70 bitumen mix would be required while using modified bitumen, only two renewals are sufficient for periodic maintenance. Incorporating cost of construction and 2 per cent escalation per year, the computation of routine maintenance expenditure would be as per typical calculation given in Table 6. It is evident from data given in Table 8 that routine maintenance cost can be reduced to about 22 to 30 per cent. If cost of interest, safety and road user is taken in account, the saving may be substantial.

Table 8. Cost Benefit Analysis of Using Modified Bitumen (Unit 1000 m²)

Traffic intensity	No. of overlays required		Cost of (Rs.)1st Overlay		Cost of (Rs.) 2nd Overaly		Cost of (Rs) 3rd Overaly		Total (Rs.)	
	60/70	SBS Mod	60/70	SBS Mod	60/70	SBS Mod	60/70	SBS Mod	60/70	SBS Mod
> 4500 (40 mm 8°C)	3	2	93487	112560	103217	126760	110642	-	307346	239320
1500-4500 (25 mm SDBC)	3	2	58316	69550	64386	78324	69693	-	192395	147874
>1500 (20 mm OGPC)	3	2	43946	52455	48520	59061	52519	-	144985	111516

Appendix-I

Summary of Elastic Recovery Test

2.1. *Scope :* The elastic recovery of a polymer-modified bitumen is evaluated by the percentage of recoverable strain measured after elongation. Unless otherwise specified, the têst shall be made at a temperature of 25 ± 0.50 C (77 ± 0.90°F) and with a speed of 5 cm/min ± 5 per cent.

2.2. *Referenced Documents*-Test Method IS:1208 and Specification E-1.

2.3. *Apparatus*

2.2.3.1. *Mould,* similar in design to that described for use in the ductility test, Test Method IS:1208, Fig. 1, except that the sides of the mould assembly, parts a and a', shall have straight sides producing test specimen with a cross-sectional area of 1cm².

2.2.3.2. *Water Bath,* maintained at the specified test temperature, varying not more than 0.1°C (0.18°F) from this temperature. The volume of water shall not be less than : 10 litres and the specimen shall be immersed to a depth of not less than 10 cm and shall be supported on a perforated shelf not less than 5 cm from the bottom of the bath.

2.2.3.3. *Testing Machine,* for pulling the briquet of bituminous material apart. Any apparatus may be used that is so constructed that the specimens will be immersed completed in the water as specified while the two clips are pulled at par at a uniform speed without undue vibration.

2.2.3.4. *Thermometer*-An ASTM or 63°C or 63°F thermometer shall be used.

2.2.3.5. *Scissors*-Any type of conventional scissors capable of cutting polymer-modified asphalt at the test temperature.

2.2.4. *Procedure*

2.2.4.1. Prepare the test specimens and conditions as prescribed in Test Method IS:1208.

2.2.4.2. Elongate the test specimen at the specified rate to a deformation of 20 ± 0.25 cm.

2.2.4.3. Immediately, cut the test specimen into two halves at the midpoint using the scissors. Keep the test specimen in the water bath in an undisturbed condition for 1 h.

2.2.4.4. After the 1 h time period, move the elongated half of the test specimen back into position near the fixed half of the test specimen so the two pieces of polymer-modified bitumen just touch. Record the length of the recombined specimen as X.

2.2.5. *Report-* Calculate the percent recovery by the following procedure :

$$\text{recovery, \%} = \frac{10 - X}{10} \times 100$$

2.2.6. Precision and Bias - The precision and bias of the elastic recovery test has not been determined ASTM subcommittee D 4.44 is developing a test method.

Appendix-II

Summary of Separation Test

3.1. *Scope* - The separation of polymer and asphalt during hot storage is evaluated by comparing the ring by ball softening point of the top and bottom portions from a conditioned, sealed tube of polymer - modified asphalt. The conditioning consists of placing a sealed tube polymer - modified asphalt in a vertical position at 163±5°C (325 ± 10°F) in an oven for a 48 - h period.

3.2. *Referenced Documents* - Test Method D 36 at Specification E II.

3.3. *Apparatus*

3.3.1. *Aluminium Tubes*[6] : 25.4-mm (1 in.) diameter by 139.7 mm (5.5 in.) length blind aluminium tubes used to bold the test sample during the conditioning.

3.3.2. *Oven:* capable of maintaining 163 ± 5°C (325 ± 10°F).

3.3.3. *Freezer*: capable of maintaining –6.7 ± 5°C (20 ± 10°F).

3.3.4. *Rack*: capable of supporting the aluminium tubes in a vertical position in the oven and freezer.

3.3.5. *Spatula and Hammer:* The spatula must be rigid and sharp to allow cutting of the tube containing the sample when at a low temperature.

3.4. *Procedure*

3.4.1. Place the empty tube with the sealed end down in the rack

3.4.2. Carefully heat the sample until sufficiently fluid to pour. Care should be taken to avoid localized overheating. Strain the melted sample through a No. 50 sieve conforming to Specification E-II. After through stirring, pour 50.0 g into the vertically held tube. Fold the excess tube over two times and crimp and seal.

3.4.3. Place the rack containing the sealed tubes in a 163 ± 5°C (325 ± 10°F) oven. Allow the tubes to stand undisturbed in the oven for a period of 48 ± 1R. At the end of the heating period, remove the rack from the oven, immediately place in the freezer at –6.7 ± 5°C (20 ± 10°F), taking care to keep the tubes in a vertrical position at all times. Leave the tubes in the freezer for a minimum of 4 h to solidify the sample completely.

3.4.4. Upon removing the tube from the freezer, place the tube on a flat surface. Cut the tube into three equal length portions with the spatula and hammer. Discard the center portion and place the top and bottom portion of the tube into separate beakers. Place the beakers in a 163 ± 5°C (325 ± 10°F) oven until sufficiently fluid to remove the pieces of aluminium tube.

3.4.5. After a thorough stirring, pour the top and bottom samples into appropriately marked rings for the ring and ball softening point test. Prepare the rings and apparatus as described in Test Method D 36.

3.4.6. The top and bottom samples from the same tube should be tested at the same time in the softening point test.

Report: Report the difference in °C or °F of the softening point between the top and bottom portions.