Performance Evaluation of Pavement Characteristics Using Styrene Butadiene Rubber (SBR) Latex as Bitumen Substitute

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Abstract **Abstract**: Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and variations in temperatures have shown some limitations of conventional bitumen performance. Flexible pavements can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over sub-grade. Bituminous surfacing develops distress symptoms like cracking, rutting, raveling, undulations, shoving etc, are been reported in flexible pavements. Bitumen modified with Styrene Butadiene Rubber (SBR) which is one of the most effective polymer additive offers a combination performance related to physical properties of the bitumen. SBR is an elastomer which is an important sort of synthetic rubber whose molecule structure primarily consists of organic compound Styrene and Butadiene chain. It plays an active role in improving the visco-elastic properties bitumen and also changes rheological behavior of bitumen by increasing the resistance of mixture against permanent deformations. This paper presents the experimental study on modification of Bitumen by the replacement of bitumen by SBR latex at 0, 3, 5, 7, 9% by the weight of bitumen. Various tests on bitumen like penetration test, softening point, viscosity test and ductility test are conducted on addition of SBR latex with bitumen and results are compared. Marshall Stability test is the one of the important test conducted to decide the performance of the bituminous mix. So, Marshall Stability test is conducted for various percentages of SBR latex and optimum % is determined. The properties of the mix evaluated by Marshall test are stability, flow, air voids (Va), volume of mineral aggregates (VMA) and void filled with bitumen (VFB). From this test optimum content of SBR to be added to bitumen is obtained. SBR latex is an easily available product and also economical.

Keywords: Bitumen, SBR latex, Marshal Stability test, visco-elastic.

1.INTRODUCTION

In India Bitumen is widely used for construction of flexible pavements since long time. But their actual duration of working is 5-10 years only instead of their design period, because they undergo repairs and rehabilitation of pavements needs additional cost which will directly increases the construction cost of pavements. The main reasons of this quick deterioration of Pavements are the conditions of adverse climatic factors and heavy traffic loads. These leads to development of distress symptoms like cracking, rutting, undulations, ravelling of bituminous surfacing.

Bitumen as a visco-elastic material plays a prominent role in determining many aspects of road performance. Various types of crude sources and refining process lead to extreme complexity in bitumen chemistry and rheology. This rheological behaviour of bitumen varies depending on the loading time and temperature. A Bituminous mixture needs to be flexible enough at low service temperatures to prevent pavement cracking and to be stiff enough at high service temperatures to prevent rutting. Flexible pavements containing conventional bitumen do not always perform as expected. In improving the properties of bitumen several types of modifications are done by addition of polymers, synthetic rubber, natural rubber and some chemicals. From the previous studies it has been revealed that properties of bitumen mix can be improved to meet the growing requirements of pavement with incorporation of certain polymers. Bitumen modified with polymer offers a combination of performance related benefits as they improve the physical properties of bitumen without changing the chemical nature of it. Two types of polymers are generally used in bitumen for road construction: Plastomers and Elastomers. Basically, plastomers increase the viscosity and stiffness of bitumen and elastomers also improve the elastic behaviour of bitumen. Plastomers like Polyethylene, Polypropylene etc., Elastomers like Styrene Butadiene Rubber, Styrene Butadiene Styrene are generally used. These polymers usually influence bitumen by creating an Inter-connecting matrix of polymer through bitumen. It is this matrix of long chain molecules of added polymer that modifies the physical properties of bitumen. This additive increase the elasticity, decrease the brittle point and increases the softening point of bitumen. This results in greater stiffness of bitumen mix at higher temperatures and high flexibility at low temperatures.

In this case, study on the properties of bitumen on addition of SBR latex is made. In general SBR latex is used as an abrasion resistant replacement for natural rubber. It can be produced by free-radical solution polymerization or by emulsion polymerization either warm at 300C to 600C (hot rubber) or at cold temperatures near 00C (cold rubber). SBR is comprised of 75% butadiene (CH2=CH-CH=CH2) and 25% of styrene (CH2=CHC6H5). On polymerization process the styrene and butadiene repeating units are arranged in a random manner along a polymer chain. A large amount of SBR is produced in latex form as a rubbery adhesive for use in applications such as carpet backing, water proofing, flooring, cable insulation etc,.

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SBR is one of the cheaper synthetic elastomers that sometimes used as a substitute for Natural Rubber. The addition of styrene lowers the price contributes to good wear and bonding properties. The addition of SBR also improves the strength, abrasion resistance and blend properties of poly-butadiene. The fatigue resistance and low temperature properties of SBR are inferior to Natural Rubber but its heat-aging and abrasion resistance are better.

Blending bitumen with any modifiers is termed as modified bitumen. PMB offers a combination of performance related benefits. From previous studies it is noted that:

- PMB offers stronger roads with increased Marshall stability value
- Better resistance towards rain water and water stagnation.
- No stripping and no potholes.
- Increase binding and better bonding of the mix

The physical properties of bitumen are improved without changing its chemical nature. Further these polymers improve fatigue resistance, increase the performance in extreme climatic conditions and under heavy traffic conditions. So, to enhance the resistance to wear and tear of the bituminous roads we can modify them by many modifiers and this paper deals with the study of properties of bitumen added with SBR latex.

2.METHODOLOGY

This chapter describes the materials used, the preparation of the test specimens and the test procedures.

2.2 MATERIALS REQUIRED

2.2.1 COARSE AGGREGATE:

Coarse aggregate shall be crushed material retained on 2.36 mm sieve and shall be crushed stone, crushed slag. It shall be clean, strong, durable, fairly cubical shape & free from disintegrated pieces, organic or other deleterious material. The aggregate shall be hygroscopic and low porosity.

Aggregate most of which is retained on 4.75-mm IS Sieve and containing only so much finer material as permitted.

2.2 FINE AGGREGATE:

Fine aggregate shall be the fraction passing through 2.36 mm sieve and retained on 0.075 mm sieve consisting of crusher run screenings, natural sand or mixture of both. It shall be clean, hard, durable, uncoated, dry & free from any flaky pieces and organic matter.
Aggregate most of which passes 4.75-mm IS Sieve and contains only so much coarser material as permitted.

2.2.3 FILLER MATERIAL

The filler material chosen in this project is stone dust. The main function of filler is to fill the voids between coarse aggregate and fine aggregate and increases the density of the mix. Stone dust is by- product of crushing stone. It has ability to form strong, non-porous surfaces. Now a day's stone dust is used as replacement to fine aggregate and showing better results.

The requirement of filler in bituminous concrete shall normally be met by the material passing through 75µm sieve in fine aggregate, if any. In case the fine aggregate is deficient in material passing through 75µm sieve, extra filler shall be added. The filler shall be a inert material, the whole of which passes 600µm sieve, at least 90% passing 150µm sieve & not less than 70% passing 75µm sieve. The filler used in this paper is stone dust.

2.2.4 BITUMEN

Bitumen acts as a binder which binds coarse aggregate, fine aggregate & filler material and imparts strength. Bitumen of 80/100 grade is used in this study. 5% of total mix is added.

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consist of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight.

hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

3. STYRENE BUTADIENE RUBBER LATEX:

In this study SBR latex is used as modifier, which is an elastomer generally used as waterproofing material in constructions, it reduces cracking, increases wear resistance and improves bond strength. SBR describes families of synthetic rubbers from styrene and butadiene. SBR is a non-oily resistant, low cost material that can be used in many rubber products. This is used in liquid form in this study. It is added in 0, 3, 5, 7, and 9 % by weight of bitumen.

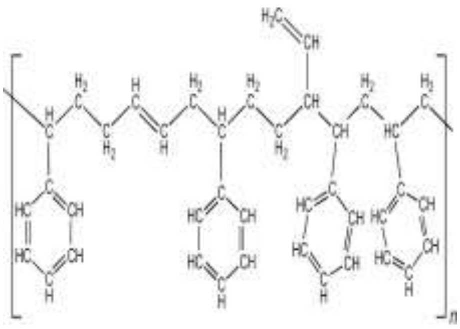


Fig.1 Molecular structure of SBR in 2D view

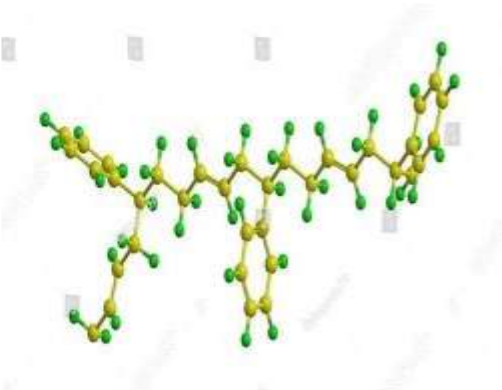


Fig.2 Polymerization of SBR

3.1 Tests conducted on Materials

AGGREGATE CRUSHING TEST

Aggregate crushing value test on coarse aggregate gives relative measure of resistance of an aggregate crushing under gradually applied compressive load.

3.2 IMPACT TEST

The property of material to resist impact loads is known as toughness. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock and assesses the aggregates suitability in road construction.

Table 1value of impact value

S. No	Test	Experimental Value (%)	IS 2386 recommended values (%)
1	Aggregate crushing value	18.43	30
2	Aggregate Impact value	24.17	30
3	Los Angeles Abrasion value	24	40
4	Shape test (flakiness index and elongation index)	24.23	40
5	Specific gravity	2.93	2.5 – 3.0

1. GRADATION OF COARSE AGGREGATE

Particle size determination on large samples of aggregate are necessary to ensure that aggregate performs as intended for their specified use.

TABLE 2 – PARTICLE SIZE DISTRIBUTON DETAILS

S. No	IS Sieve Sizes (mm)	Weight retained (kg)	% weight retained	Cumulative % weight retained	Cumulative % passing
1	25	0.12	2.4	2.4	97.6
2	20	1.34	16.8	19.2	80.8
3	16	2.26	45.2	74.4	25.6
4	12.5	1.06	21.2	95.6	4.4
5	10	0.16	3.2	98.8	1.2
6	pan	0.06	1.2	100	0

2. ABRASION TEST

Abrasion test is a measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration

3.3 GRADATION TEST ON FINE AGGREGATE:

Particle size determination on large samples of aggregate are necessary to ensure that aggregate performs as intended for their specified use.

TABLE 4 – PARTICLE SIZE DISTRIBUTON DETAILS

S. No	IS Sieve size (mm)	Weight retained (kg)	% weight retained	Cumulative % retained	Cumulative % passing
1	4.75	0.012	1.2	1.2	98.8
2	2.36	0.033	3.3	4.5	95.5
3	1.18	0.133	13.3	17.8	82.2
4	0.6	0.272	27.2	45	55
5	0.3	0.405	40.5	85.5	14.5
6	0.15	0.13	13	98.5	1.5
7	0.075	0.01	1	99.5	0.5
8	Pan	0.005	0.5	100	0

3.4 PENETRATION TEST:

S. No	Details	Observed Values
1	Total weight of dry sample, W1 (g)	3000
2	Weight of fines passing 2.36 mm IS sieve, W2 (g)	553
3	Aggregate Crushing Value (%)	18.43

Penetration test is the simplest among all the tests to check the consistency of bitumen with respect to time. It determines the consistency of these materials for the purpose of grading them, by measuring the depth in units of one tenth of a millimeter to which a standard needle will penetrate vertically under specified conditions of standard load, duration and temperature.

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimetre to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardised the equipment and test procedure. The

penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25 C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred.

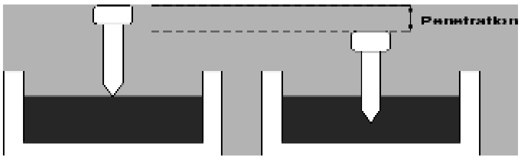
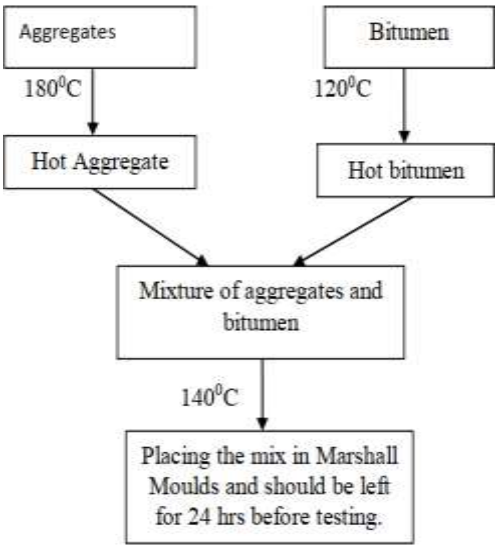


Fig.3 Penetration Test Setup

1. DUCTILITY TEST:

The bitumen used as the binder in the flexible pavements should form ductile thin layers around the aggregates which improves the physical interlocking of the aggregates. In this test the bitumen is stretched at a uniform velocity of pull and at a standard temperature to check for ductility.

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the



briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould

assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27 C temperature. The excess bitumen is cut and the surface is levelled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS.

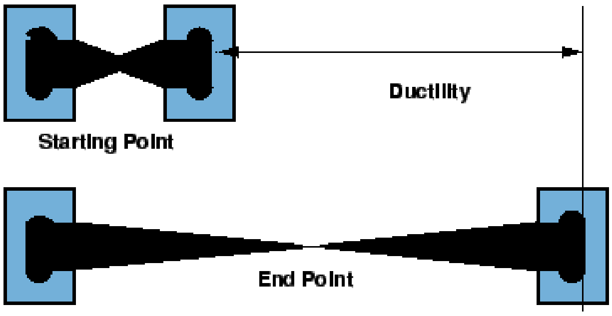


Fig.4 Ductility test

Table value of softing pont

S. No	Test	Experimental values	IS 73 - 2006 Specified values
1	Penetration Value (0.1 mm)	95.66 (80/100 grade)	80/100
2	Softening Point (0C)	48	420-500C
3	Ductility Value (cm)	67.5	50 - 75
4	Viscosity (seconds)	3	3 - 5 seconds

4. MARSHALL STABILITY TEST

The Marshall Stability test provides the performance prediction measure for the bitumen mix. This finally determines optimum binder content.

4.1PREPARATION OF CONVENTIONAL BITUMINOUS MIX:

Approximately 1200 gm of material is taken which constitute:

- coarse aggregate of 60%
- fine aggregate of 20%
- filler material of 15% an

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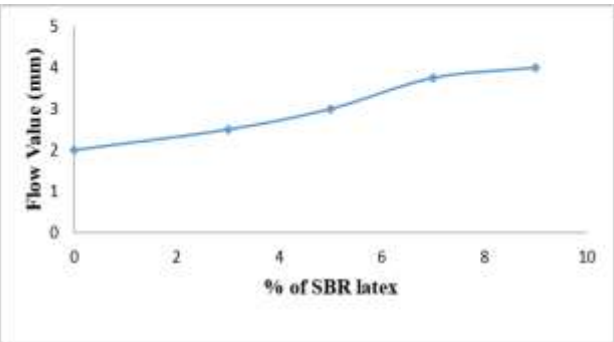
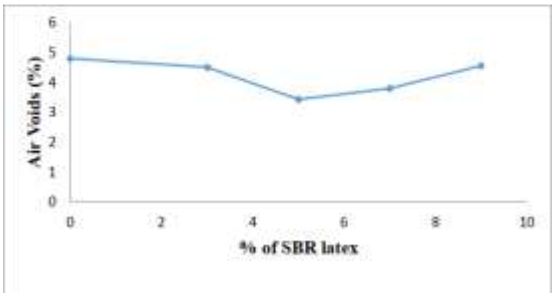
Fig.5 Flow chart of process of preparation of conventional bitumen mix

4.2 EFFECT OF SBR ON MARSHALL STABILITY VALUE





5. CONCLUSIONS

- From the Marshall Stability test results, on comparison between conventional and SBR latex modified bitumen, it can concluded that there is a considerable increase in the stability value in the modified bitumen.
- Marshall Stability value at 5% SBR is 15.7 kN which is maximum and least at 0% SBR as 8.9 kN.
- Flow value increases on addition of SBR content, this indicate flexibility of the mix. Air voids in a mix must be minimum and in this study minimum air void of 3.43% is observed at 5% of SBR content and maximum is observed at 0% SBR as 4.8.
- VMA value of 15.2% is observed as least at 5% of SBR and 16.87% at 0% SBR.
- VFB value of 77.5% is observed as maximum at 5% of SBR and minimum is observed at 0% of SBR as 70.3%.
- From these results it is concluded that optimum SBR content to replace bitumen by weight is 5%.
- Therefore usage of SBR latex as modifier fetched better results and is even economical.

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