A Review on Styrene-Butadiene-Styrene Polymer Modified Bitumen

Dr. Maninder Singh[1], Akshat Sharma[2*]

[1,2]Department of Civil Engineering
Punjabi University Patiala
Punjab, India

Abstract: *In this technological era, due to high traffic speed, fluctuations in pavement temperature, overloading of vehicles, several problems may occur early in the flexible pavement of bituminous surfaces, like cracking, rutting, bleeding, shoving and potholing. By adding polymers, we can boost the properties of bitumen. In this article, our goal is to understand the thermoplastic elastomer, i.e. SBS (styrene butadiene-styrene). The structure of the SBS can be discussed in this article. SBS has been produced to prevent low temperature cracking, to avoid early weathering, to reduce the temperature vulnerability of bitumen. SBS PMB strengthens conventional properties (penetration, softening point, etc.) and mechanical properties (Marshall, indirect tensile strength) etc. In this article, we analyse numerous experiments carried out by the authors on SBS PMB, such as the elastic recovery test, the Marshall Stability Test and the indirect tensile strength test..*

Keywords: **SBS Polymer modified bitumen, Marshall Stability, thermal oxidative aging**

1.**Introduction**

In India flexible pavements with bituminous layers are commonly used. Bitumen in flexible pavement layer composed primarily of hydrocarbons and Made after extracting the light fractions of crude oil while refining [1]. Much of produced bitumen is used to make roads. But in today's time due to overloading and increasing traffic, the major fluctuations in daily and seasonal temperatures the pavements made with conventional bitumen resulted in early formation of distress signs including cracking, rutting, and undulation, ravelling and shoving. Due mainly to these poor mechanical properties, bitumen is hard and fragile in cold conditions and soft and fluid in warm climates. One approach to enhance the properties of base bitumen is by combining it with polymers so that pavement can resist high traffic loads and varying temperature levels. Plastomers and thermoplastic elastomers are used as modifier. Plastomers include Polyethylene (PE), Polypropylene (PP), Ethylene–vinyl acetate (EVA), Ethylene–butyl acrylate (EBA). In Thermoplastic elastomers Styrene-butadiene–styrene (SBS), Styrene–isoprene–styrene (SIS), Styrene–ethylene/butylene styrene (SEBS). SBS copolymers consists of polystyrene (PB) and polybutadiene (PB) blocks with dispersed and continuous phase respectively. When a thermoplastic elastomer of styrene block-type copolymer is added to hot bitumen, it starts to absorb several saturated branches and few rings of light components of bitumen, so the styrene rubber domain gets dispersed and swollen. Two continuous interlocking phases are formed: the bitumen-rich phase and the SBS-rich phase [2]. Unless the SBS-rich phase begins to emerge, a rubber support network is formed in the modified bitumen resultsin increased viscosity, enhanced elastic reaction and complex modulus and increased cracking resistance at low temperatures of the polymer modified bitumen. Compared to other modifiers, the structure design generated in a modified bitumen prepared with SBS modifier is specific. As per IRC-SP-98-2013 for the production of PMB the dry process and wet process techniques are adopted. In dry process, we directly mix polymer with hot bitumen, while in wet process we firstly coat the aggregate by polymer and then bitumen is added.

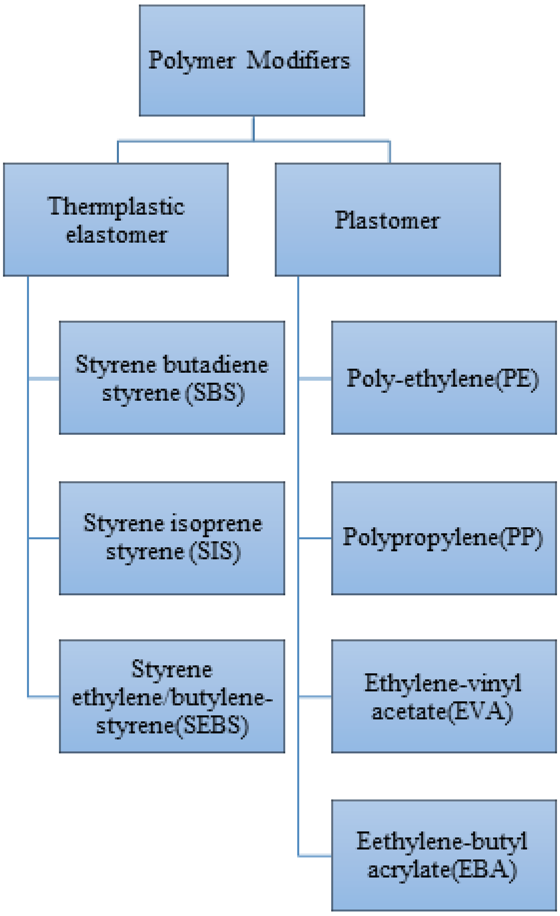

Fig.1 Types of polymer used for the modification of bitumen.

While preparing SBS PMB As bitumen temperature rises to 170-180 ° C, SBS polymer was inserted gradually in bitumen. To mix SBS and bitumen shear mechanical mixer is used which either be high shear or low shear mixer. The mixing proceeded for at least 2 hours, at 4000 rpm to create the homogeneous mixture of SBS modified bitumen.

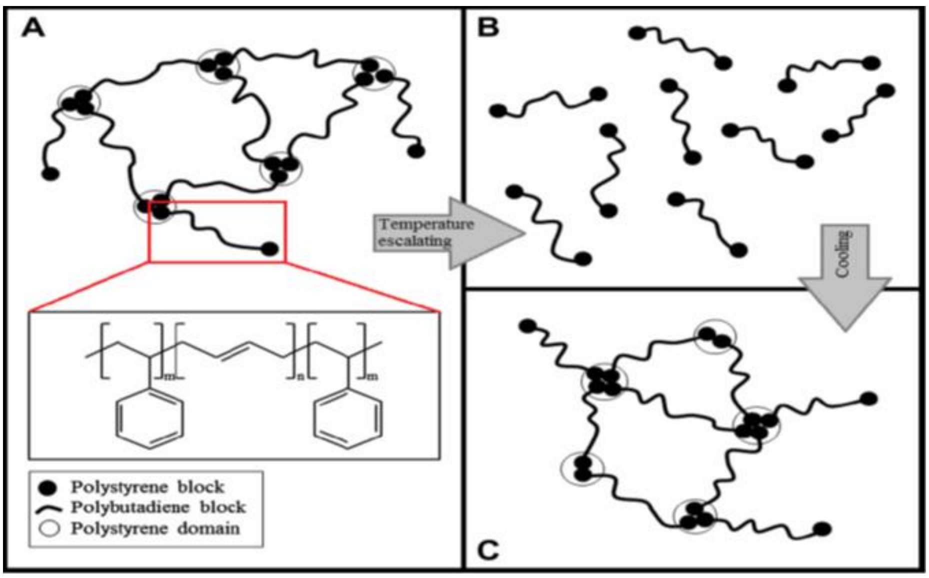

Figure 2. Structure of SBS modified bitumen [2]

1.1 Properties of SBS polymer modified bitumen

1. Softening point is the temperature indicator at which the bitumen softens [3]. In order to be used in the area of paving surfaces, the bitumen will have fluidity such that it can be poured uniformly over the aggregate. It is checked with ring and ball apparatus.
2. Ductility is the measurements of bitumen elasticity [4].It indicates the capacity of modified bitumen to extend. Modified bitumen can create a thin film across the aggregate and therefore this film enables the binder to connect the aggregates [5]. It can be checked using briquette mould and water bath with fixers for the mould.
3. The penetration level of bituminous surface is a representation of hardness or softness. Due to heavy load, high temperature or low temperature different bitumen grade has to be used in pavement layer. This bitumen grade is decided by penetration point [6].
4. To determine the compatibility of bitumen with SBS polymer Storage stability test is done. Due to the probability of phase separation between SBS polymer and bitumen. This problem is due to the low amount of light components in bitumen which are to be absorbed by SBS co polymer.
5. Marshall Stability test is used to calculate optimal binder composition in bituminous mix so that the pavement layers safely bear heavy traffic loads and temperature variations [7]. In this test there are two values, flow value and stability value. The average load sustained by the trial specimen at a loading value of 50.8 mm per minute is Marshall Value and deformation at this load is flow value. At 5% SBS content for modification of bitumen good results are obtained.
6. Fuel leakage can occur in places where the vehicles parks, petrol stations, airports etc [8]. then there is possibility of solubility of modified bitumen with the oil derived components, which is huge cause of the pavement disruption. Linear SBS affects differently from that of the radial SBS.
7. Knowing thermal properties are important to understand SBS modified bitumen's behaviour at differing temperatures. Thermos gravimetric analyser (TGA) is the apparatus to check the thermal properties [9]. The viscosity of SBS modified bitumen is calculated by the Brookfield viscometer. It is the representation of internal resistance to deformation at a given rate. Simply it decides the workability of modified bitumen [10] [11].
8. To analyse the morphological character of SBS modified bitumen Optical Fluorescent Microscopy (OFM) is used. The images decide the existence of polymer in bitumen surface [12].

2. Literature Review

Polymer rich and asphaltene rich are the phases of SBS polymer modified bitumen. These are thermodynamically unstable, so phase separation problem occurs and the problem is discussed by using dynamic mechanical analysis (DMA) and Fourier transform infrared (FTIR) spectroscopy in [13] [14]. Kraton D-1101 and Kraton D – 1184 with linear and branched structure respectively are used to perform experiments. Phase separation of SBS modified bitumen is influenced by the nature of base bitumen and polymer content.

Increase in asphaltenes may increase phase separation. Softening point is inadequate in case of modified binders to check properties.

The rheological properties of SBS polymer modified bitumen is explained by [15] and concluded that when we add SBS to hot bitumen, swelling of polymer by absorption of light fractions of base bitumen, a rubber elastic network is established . There is a significant increase in conventional properties like softening point, viscosity and stiffness but the author was unable to determine any major variations in rheological behaviour of SBS PMB after performing the conventional binder tests.

Author [16] discuss the effect of Styrene butadiene styrene (SBS) and EVA on the properties, morphology and mechanical properties of base bitumen. For this study he uses 50/70 penetration grade bitumen and the SBS co-polymer used are Kraton D-1101 in powder, pellet form which has a linear molecular structure. Tests conducted on modified bitumen and base bitumen are softening point,penetration, thin film oven test (TFOT), after TFOT penetration and softening point. By The softening point temperatures at the top and bottom of cylindrical mould storage stability value has been determined. Using penetration index the temperature susceptibility of SBS modified bitumen can be calculated. Results showed that penetration point decreases only up to a 5% SBS content, at 6% it remains same. Softening point of SBS modified bitumen increases as the SBS concentration increases, so that rutting resistance increases. Penetration index showed that SBS modification reduces temperature susceptibility. Marshall Stability value increases with increase in SBS content up to 5%.flow value increases with increase in SBS percentage in bitumen. Fluorescent microscopic images shows a continuous polymer rich phase forms at 5% SBS.

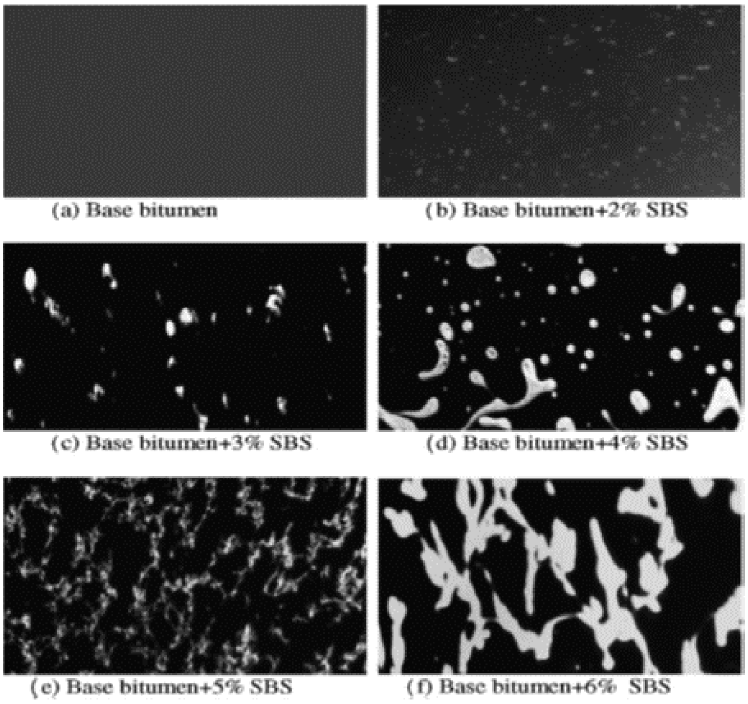

Figure 2. Fluorescent images of SBS polymer modified bitumen [16]

Author of [17] discussed the combined effect of styrene butadiene styrene polymer (SBS) and high density polyethylene homopolymer (HDPEHP) on the asphalt binder properties. Viscosity grade 30 (VG 30) bitumen with various percentages of SBS polymer Kraton D0243 K is used which is linear and in pellet form. It seems that at all temperatures and ageing conditions addition of SBS resulted the increase in viscosity. At 5% and 6% SBS

TABLE I Physical properties of base bitumen and SBS modified bitumen [18]

Property	Standard	Base bitumen	Binder type		
			VG 30 +3%SBS	VG 30 +5%SBS	VG 30 +7%SBS
Penetration (0.1 mm)	ASTM D5	67(50-70)	52 (50–89)	47 (30-49)	47 (30–49)
Softening point (°C)	ASTM D36	49(min 47)	57 (min 48)	70 (min 59)	70 (min 59)
Penetration index (PI)	-	-0.698	0.51	2.67	3.03
Specific Gravity	ASTM D70	1.01	1.00	0.99	0.98
Viscosity at 150 _C (Pa s)		0.172	0.68	1.25	2.2

content it is maximum under unaged and short term aged conditions. Softening point is observed maximum at 4% polymer content Higher complex modulus was observed with all blends at lower loading frequencies when compared to bitumen Comparison of creep compliance and relaxation modulus master curves indicated combination of SBS and HDPEHP offered higher resistance to creep load and applied strain under long term conditions. 4.5% SBS and 1.5% HDPEHP can be considered as optimal percentage of additives.

The effect of SBS modifier on the strength characteristics of hot mix asphalt mixes has been studied by [18] . VG 30 paving grade bitumen with SBS Kraton D1101 at percentages 3%, 5% and 7% by weight is used. Linear molecular structure of SBS in pellet form is added in bitumen at 180°C. For SBS modified bitumen the mixing and compacting temperatures are less if we use phase angle method compared to Brookfield viscometer.There is increase in rutting resistance with the increase in SBS percentage in bitumen at all temperatures. Decrease in penetration value for up to 5% SBS concentration. Softening point and stiffness increases with increase in modifier percentage because of increase in asphaltenes content. Marshall stability values increases with the increase in SBS content and is more if aggregate used is marble compared to granite and quartzite retained Marshall stability(RMS) and tensile strength ratio values for modified mixes are increases with increase in SBS content (only up to 5%). SBS modified bitumen is more beneficial with siliceous aggregate compared to calcareous ones. All this paper concludes 5% SBS content is recommended for better strength and susceptibility.

According to the [19], the rise in the amount of freeze-thaw cycles, the viscous loss became extreme and the loss rate slowly improved. The value of the phase angle parameter of the SBS-modified bitumen was far higher than that of bitumen, and there was also presence of high temperature and rutting resistance. And the temperature sensitivity of the SBS- modified bitumen was lower than that of bitumen.

The author shows that the SBS additive can decrease the temperature sensitivity of the bitumen and enhance its antirutting capability. The quality and proportion of the different chemical components in the bitumen have changed, making the bitumen hard, brittle and durable.

Since the chemical composition of linear SBS and radial SBS is nearly similar, radial and linear SBS provide varying results on the resistance to fuel oil. The radial SBS copolymer is somewhat very effective. The 4% SBS content in bitumen considered optimum for fuel resistance because uniform dispersion is confirmed in this polymer content.

The author [20] provides a view of the penetration test, the penetration value of the adjusted bitumen increased with an improvement in the additive ratio and the softening point temperature values decreased during the softening point test. These values suggest a decrease in the adjusted bitumen quality and an improvement in temperature sensitivity. The cohesion properties of modified bitumen have not changed and the cohesion properties of SBS modified bitumen have not been affected despite the increased additive rate as a result of the ductility test. As a consequence of the RV test, the viscosity of bitumen decreases with an increase in oil contribution. It has been noted that the workability of SBS modified bitumen, which is difficult to process, has been increased. When the test results are analysed. Collectively, Waste Cooking Oil (WCO) Additive increases the workability of bitumen, making it easier to manufacture asphalt mixtures that save energy in mixing and compaction tests.

That one analyses the physical and mechanical properties of SBS modified BITUMEN and traditional binder samples. Blends will be compacted using both Marshall and Superpave Gyratory Compactor (SGC), and a link is created here between two in terms of resilient modulus and fatigue life. It is clarified that the fatigue life of polymer-modified blends increases over regular mixes. The performance indicators such as tensile strength, Marshall Stability values of SBS modified mixes were higher than regular mixes by 21 % and 25 % respectively. The improvement of 2 to 2.5 times was observed in resilient modulus of polymer-modified samples relative to regular bituminous mixes. In polymer-modified samples, better tensile strength percentage is observed which signifies improved cohesive performance of such mixes compared to traditional mixes [21].

Normal bituminous concrete is combined with SBS and polyethylene and the properties are compared in [22]. It is concluded that improvement in properties like penetration point, softening point, ductility value, Marshall Stability values are more for SBS compared to polyethylene. Only Marshall Flow value for SBS is lesser than polyethylene. Bitumen 80/100 and SBS polymer in power form in 2%, 4%, 6% for Marshall Stability test is used.

The author [23] states that Stone Mix Asphalt Mixtures (SMA) made from polymer-modified bitumen PMB 70 containing SBS as well as coconut fibres to hold back asphalt draining . THE Adequate binder amount recorded for SMA with SBS modified bitumen is 0.3% higher than SMA of VG 30 grade bitumen. Presence of SBS Polymer in bitumen decreased drain down compared with simple bitumen. When compared SMA with VG 30 and SMA with PMB 70 using coconut fibre, polymer modification displays 42 per cent more rut resistance, Better fatigue life by 36 per cent, less susceptibility to moister. The static indirect tensile strength measurements for SMA with SBS are higher than SMA with neat bitumen at temperatures 10, 20, 30 and 40 deg. Cent.

3. Conclusion

Using SBS to define traditional and fundamental parameters, the properties of polymer modified bitumen's are enhanced. Penetration point, softening point, ductility, elastic recovery, frass braking point, and high-temperature viscosity studies revealed increased stiffness and enhanced temperature sensitivity. One may be suggested that a swelling of the polymer by absorbing the light segments of base bitumen is a process linked to SBS polymer modification and a rubber-elastic network is formed inside the modified binder. This paper first describes the background and alteration of bitumen with polymer. We explored the processing of SBS polymer modified bitumen. The preceding segment addresses the mechanical and conventional properties of modified bitumen, conventional or typical properties includes softening point, penetration, penetration index ductility. Marshall Stability test, Spectroscopy study, storage stability test, stripping value and optical fluorescent microscopy are the mechanical properties of SBS polymer modified bitumen. While evaluating the different studies, we find that the temperature for mixing bitumen is not greater than 200 degrees centigrade and that of polymer is not less than 150 degrees centigrade and that a minimum of 3 hours of mixing time is necessary, whether it is dry or wet process.

Base bitumen influences the SBS polymer modified bitumen structure, its evolution while ageing and polymer swelling. Better compatibility between bitumen and SBS makes the binder more homogeneous upon ageing. Rutting resistance, fuel resistance and resistance to cracking are higher for the SBS modified bitumen compared to any other bitumen modifier. We will continue to expand this work in the future.

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