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# Evaluation of physical properties of SBS modified bitumen and effect of aging

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**ABSTRACT**

The failures of the bituminous pavements are not only due to increase in traffic but also due to extreme climatic conditions prevailing in the country. The addition of polymers to bitumen can improve the quality of binders and enhance the properties of binders used in the road construction. Bitumen ageing is one of the principal factors causing the deterioration of asphalt pavements due to the prolonged exposure to air and environmental conditions. Short-term ageing occurs when binder is mixed with aggregates in a mixing facility. Long-term ageing occurs after pavement construction and is generally due to environmental exposure and loading. The properties of bitumen mainly depend on the age of bitumen. Therefore there is a need to study the properties of modified bitumen before and after ageing. In this paper the effect of Aging on the physical properties of SBS (Styrene Butadiene Styrene) modified bitumen is discussed.



## Introduction

In recent years, modified bituminous mixes have gained popularity because of their ability to reduce rutting at warm temperatures, thermal cracking/fracture at cold temperatures. It also enhances the service properties over wide range of temperatures. The performance of bituminous road surfacing depends upon flow properties of bitumen and these are controlled by composition of bitumen. Hence, properties of bitumen may be modified by certain additives such as polymer, crumb rubber, sulphur etc. Addition of polymers and rubbers in bitumen increases the life span of the road pavement considerably. Binder modification results in improvement of one or more properties of binder and (hence the mix) viz. fatigue resistance, stiffness modulus, rutting resistance, stripping potential, temperature susceptibility, oxidation potential etc. Both high elastic modulus as well as high fatigue life can be achieved with modified binder. Addition of natural or synthetic polymers to bitumen is known to impart enhanced service properties. The purpose of bitumen modification using polymers is to achieve desired engineering properties such as increased shear modulus and reduced plastic flow at high temperatures and/or increased resistance to thermal fracture at low temperatures. The beneficial effects include decreased thermal susceptibility and permanent deformation under load and increased resistance to low temperature cracking. Binder modification is aiming to produce new binders with better rheological and mechanical properties. The improvement is based on the modification of their internal structure in order to achieve following properties:

- Reduction in thermal susceptibility.
- Fatigue resistance.
- Resistance to cracking and dynamic deformation.
- Increase in life span and resistance to ageing.
- Increase in softening point.
- Improvement in Frass point.
- Reduction in penetration value and hence improvement in penetration index.

## SOME SELECTED PREVIOUS RESEARCH WORK

Many researchers have shown their interest in studying the properties of the modified binders and evaluating their advantage over the conventional bitumen. The major studies carried out by different researchers using Styrene Butadiene Styrene are discussed below:

Lu and Iscasson (1997) reported SBS polymer modification increases the binder elasticity at high temperatures and improves the flexibility at low temperatures. These improved properties should lead to an increased resistance to asphalt rutting and cracking at high and low temperatures, respectively. A significant improvement in the rheological characteristics is observed when the SBS content is increased from 3% to 6% by weight. The modified binders containing branched SBS exhibit a higher elasticity and less temperature susceptibility than the modified binders with linear SBS at high temperatures but these two polymer types do not differ in their effects at low temperatures.[10]

Lu and Isacsson (1999) investigated that the rheological properties of bitumen are improved by SBS modification. The improved properties may be identified by various parameters obtained using DMA (Dynamic mechanical Analysis) and BBR (Bending Beam Rheometer). The degree of modification is influenced by bitumen source and grade and SBS content and structure. The modified binders produced from the base bitumen with different penetration grade or the same penetration grade but different source may differ substantially in their rheological behaviour. Regarding the effect of SBS structure, the modified binders containing branched SBS exhibited higher elasticity than modified binders with linear SBS at high temperatures. The improved rheological parameters should lead to increased resistance to asphalt rutting and cracking in practice. GPC (Gel Permeation Chromatography) and FTIR (Fourier Transformation Infrared) analyses indicate that the aging characteristics of SBS-modified binders are dependent on a combined effect of bitumen oxidation and polymer degradation.[12]

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Airey (2003) studied the effect of SBS polymer modification on the conventional polymer content. Although the decrease in penetration is relatively uniform with increasing polymer content but there is significant larger increase in softening point at high polymer content of 5% and 7%. In addition to the increase in stiffness, the increased penetration indices of PMB indicate a significant reduction in temperature susceptibility with polymer modification particularly at higher polymer content.[1]

Kim et al. (2003) conducted the investigation to evaluate the effects of SBS polymer modification on the cracking resistance and healing characteristics of coarse graded SUPERPAVE (Superior Performing Asphalt Pavement) mixtures and reported that the primary benefit of SBS modifiers to mixture cracking resistance appeared to be primarily derived from a reduced rate of micro damage accumulation. SBS offers lower m value (the rate of change of the stiffness) without any significant reduction, and possibly an increase, in the fracture energy limits of the mixture. [10]

Airey (2004) reported that the rheological properties of road bitumen are improved by means of SBS polymer modification. The mechanism associated with SBS polymer modification consists of a swelling of the polymer through the absorption of the light fractions of the base bitumen and the establishing of a rubber-elastic network within the modified binder. The nature of the network and its influence on polymer modification is a function of the nature of the base bitumen, the nature and content of the polymer and the bitumen-polymer compatibility.[2]

Xiao-Qing et al. (2009) reported that the 10 wt. % mixture of mechano-chemically devulcanized tire rubber (m-GTR) and SBS modified bitumen improved the conventional properties such as softening point and 5°C ductility and also enhanced bitumen blends properties at high in-service temperatures. It gives rise to an obvious increase in elastic modulus (G') and viscous modulus (G'') at high temperature and has low tan $\delta$, reducing permanent deformation in the road application.[14]

Romeo et al. (2010) conducted a laboratory investigation to evaluate the effect of SBS modifiers on HMA-cracking performance. Both cross-linked and linear SBS polymer-modified mixtures as well as the control unmodified mixture were tested using the SUPERPAVE IDT (Indirect Tensile) and the SCB (Semi Circular Bending) test. Polymer modification at intermediate temperatures does not have significant effect on the resilient modulus, but during tensile creep testing, the rate of creep was lower implying less micro-damage accumulation. Polymer modification has also proven to improve tensile failure limits of mixtures and makes the stress states more homogeneous.[13]

Al Hadidy and Qui (2010) studied and compared the properties of modified asphalt binders and SMAC (Stone Mastic Asphalt Concrete) containing such asphalt binders with those of asphalt cement. The addition of SBS raises the Marshall stability, and Marshall Quotient (MQ) of control SMAC by 8% and 11% respectively, whereas decreases the flow value. Moisture susceptibility of SBS is lower when compared to neat SMAC. SBS modified SMAC is found to have lesser strain values compared to neat SMAC. The wheel tracking results indicated that rutting resistance of SBS modified SMAC is 78.8% higher when compared to control SMAC, which is a desirable characteristic of SBS modified SMAC. [3]

## EXPERIMENTAL PROGRAMME

### *Materials*

The materials which are used in the thesis work are as follows

### *Bitumen*

The VG 30 (Viscosity Grade) bitumen supplied by the Mathura Refinery is used in this study.

### *Modifiers*

Styrene Butadiene Styrene is used to modify the conventional VG 30 bitumen.

### *Preparation of Modified Binders*

To prepare the modified binders, about 1.5 Kg of bitumen is taken in a 3 litre metal container and heated to fluid condition. The mixing of modifiers is carried out using a mechanical stirrer. Bitumen was heated to a temperature of 170ºC and the appropriate quantity of SBS copolymer was added. The temperature was maintained between 175ºC to 180ºC. The contents were gradually stirred for about 2 hours. [11]

### *Tests Conducted*

The following conventional tests were conducted on the modified and unmodified binders.

### *Penetration Test*

The penetration of a bituminous material is the distance in tenths of millimetre that a standard needle will penetrate vertically into a sample of the material under standard condition of temperature, load and time. Penetration test is the most commonly adopted test on bitumen to grade the material in terms of its hardness. The test is conducted as per IS: 1203-1978. [7]

### *Softening point Test*

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test. The softening point of bitumen is determined as per IS: 1205-1978. [8]

### *Ductility Test*

The ductility of bitumen is expressed as the distance in centimetres to which the bitumen filled in a standard briquette elongates before the breaking of the thread of bitumen formed due to elongation under specified conditions. The ductility test is conducted as per IS: 1208-1978. [9]

### *Elastic Recovery*

The elastic recovery of the binder is evaluated by measuring the recovery of the binder thread formed by the elongation of binder specimen when it is cut down by a scissor at standard conditions. The elastic recovery test is carried out as per IRC: SP 53-2002 specifications. [6]

### *Viscosity Test*

The ratio between the applied shear stress and the rate of shear is called the coefficient of viscosity. This coefficient is a measure of the resistance to flow of the liquid. It is commonly called the viscosity. The viscosity of a fluid is highly dependent on the temperature. It gets reduced with the increase in temperature. To determine the influence of temperature on the viscosity of bituminous binders we have to determine the viscosity at different temperatures. Brookfield viscometer is used for the purpose and the test is conducted as per ASTM D 4402- 2006. [4]

### *Thin-Film Oven Test(TFOT)*

The thin-film oven (TFO) test simulates short-term ageing by heating a film of asphalt binder in an oven for 5 hours at 163o C (325o F). The standard TFO test is AASHTO T 179 and ASTM D 1754: Effects of Heat and Air on Asphalt Materials. The effects of heat and air are determined from changes incurred in the physical properties measured before and after the oven treatment including change in sample mass. The method indicates approximate change in properties of asphalt during conventional hot- mixing at about 150ºC. It yields a residue which approximates the asphalt condition as incorporated in the pavement.[5]

## TEST RESULTS AND DISCUSSION

The physical properties of the bitumen modified with the Styrene Butadiene Styrene and the effect of aging on these properties are discussed in the subsequent paragraphs.

### *Penetration Value*

The penetration values of the unmodified and modified binders, before and after aging are tabulated in the Table 1 and shown in Fig. 1

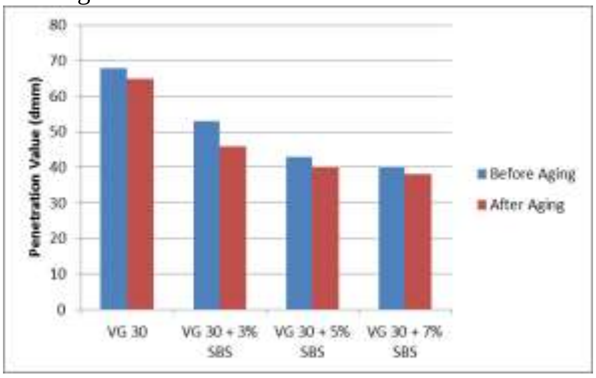


**Fig.1 Penetration Value Before and After TFOT**

### *Softening Point*

The softening point values of the unmodified and modified binders, before and after aging are tabulated in the Table 2 and shown in Fig. 2

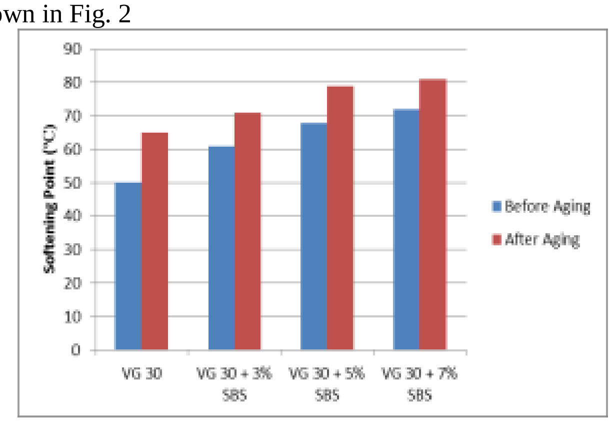


**Fig.2 Softening Point Value Before and After TFOT**

### *Viscosity*

The Viscosity values of the unmodified and modified binders, before and after aging are tabulated in the Table 3 and shown in Fig. 3

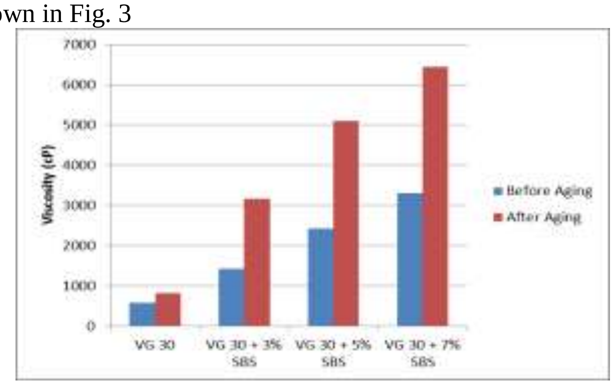


**Fig.3 Viscosity Before and After TFOT**

### *Ductility*

The Ductility values of the unmodified and modified binders, are tabulated in the Table 4 and shown in Fig. 4

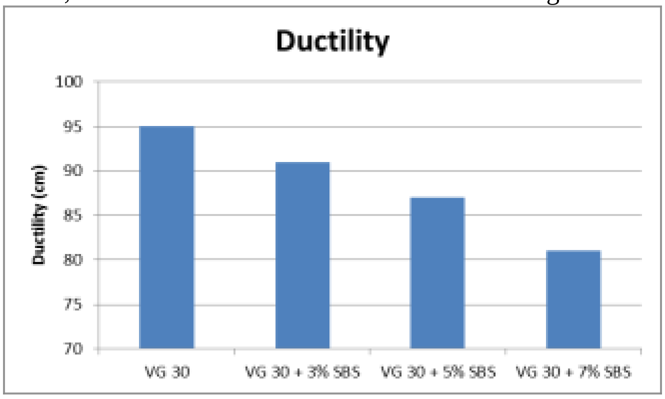


**Fig. 4 Variation in Ductility**

### *Elastic Recovery*

The Elastic Recovery values of the unmodified and modified binders, are tabulated in the Table 5 and shown in Fig.5

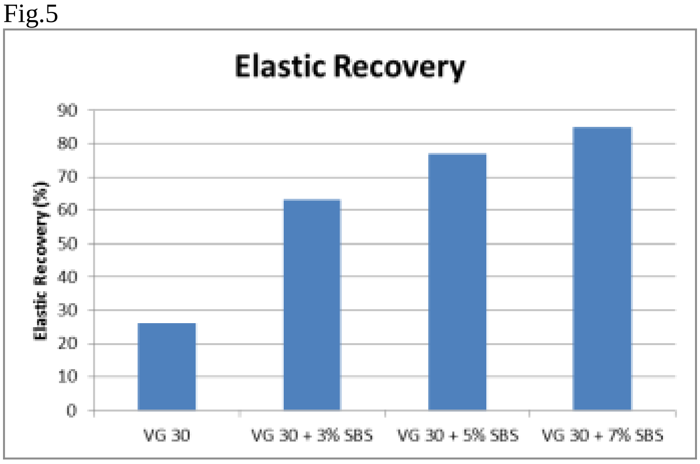


**Fig. 5 Variation in Elastic Recovery**

### *Weight Loss*

Loss in weight is another important parameter which is used to judge the effect of aging on the bituminous binders.The loss of volatile fractions contributes to the difference in weights between original and aged sample. The maximum loss in weight should be 1% as per IRC: SP: 53:2002. [5] The weight loss after conducting TFOT on the SBS modified bitumen in tabulated in Table 6

## CONCLUSIONS

The following conclusions are drawn based on the results obtained in the present study:

1. The physical properties of bitumen such as penetration and softening point are improved with addition of polymers.
2. SBS modified binder gives lower Penetration value as compared to neat bitumen
3. SBS modified binder gives higher Softening point value as compared to neat bitumen.
4. SBS modified binder gives higher Viscosity as compared to neat bitumen.
5. Effect of Aging on SBS modified binder is with in permissible limits as far as Indian conditions are concerned in particular and world condition in general.

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**Table1. Penetration Value Before and After TFOT**

| Binders | Penetration at 25ºC (dmm) | |
|---|---|---|
| | Before Aging | After Aging |
| VG 30 | 68 | 65 |
| VG 30 + 3% SBS | 53 | 46 |
| VG 30 + 5% SBS | 43 | 40 |
| VG 30 + 7% SBS | 40 | 38 |

**Table 2. Softening Point Value Before and After TFOT**

| Binders | Softening Point (ºC) | |
|---|---|---|
| | Before Aging | After Aging |
| VG 30 | 50 | 65 |
| VG 30 + 3% SBS | 61 | 71 |
| VG 30 + 5% SBS | 68 | 79 |
| VG 30 + 7% SBS | 72 | 81 |

**Table 3. Viscosity Before and After TFOT**

| Binders | Viscosity (cP) | |
|---|---|---|
| | Before Aging | After Aging |
| VG 30 | 575 | 825 |
| VG 30 + 3% SBS | 1425 | 3175 |
| VG 30 + 5% SBS | 2425 | 5100 |
| VG 30 + 7% SBS | 3300 | 6450 |

**Table 4. Variation in Ductility**

| Binders | Ductility |
|---|---|
| VG 30 | 95 |
| VG 30 + 3% SBS | 91 |
| VG 30 + 5% SBS | 87 |
| VG 30 + 7% SBS | 81 |

**Table 5. Variation in Elastic Recovery**

| Binders | Elastic Recovery |
|---|---|
| VG 30 | 26 |
| VG 30 + 3% SBS | 63 |
| VG 30 + 5% SBS | 77 |
| VG 30 + 7% SBS | 85 |

**Table 6. Variation in Weight Loss**

| Binder | Weight before TFOT | Weight after TFOT | Weight loss (%) |
|---|---|---|---|
| VG 30 | 50.238 | 50.231 | 0.013 |
| VG 30 + 3%SBS | 50.183 | 50.171 | 0.023 |
| VG 30 + 5%SBS | 50.041 | 50.017 | 0.048 |
| VG 30 + 7%SBS | 50.312 | 50.266 | 0.091 |