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Evaluation of Physical Properties of Sulphur Modified Bitumen and its Resistance to Ageing

Praveen Kumar and Md. Tanveer Khan
Department of Civil Engineering, IIT Roorkee, India.

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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 sulphur to the bitumen can improve the quality of bitumen and enhance its properties as far as its use in the road construction is considered. In this paper the effect of addition of sulphur on the physical properties of the bitumen is studied and the optimum dose of sulphur to be added to the bitumen is also determined. The effect of Aging on the physical properties of Sulphur modified bitumen is also discussed in this paper.

I. INTRODUCTION

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 binders such as polymer, crumb rubber, sulphur etc. 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. The purpose of bitumen modification 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, Reduced thermal susceptibility to both high and low temperature, to improve binders behaviour to fatigue by increasing its mechanical properties particularly to tractive force, to improve binders elastic qualities to cope with cracking and dynamic deformation, to increase life span and resistance to ageing, increase of plasticity interval and softening point and improvement in Frass point, decrease in penetration and hence improvement in penetration index.

II. SOME SELECTED PREVIOUS RESEARCH WORK

Many researchers have shown there 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 Sulphur are discussed below:

Fritschy and Chambu (1981) modified the bitumen after a treatment with 2% sulphur, at 160°C. The chemical bonding of sulphur to bitumen leads to a new binder in which asphaltenes present a more gel-like type of structure resulting from a higher ability to form aggregates. The decrease in dynamic mechanical properties, with respect to the pure binder, is due to parent plastification of the material.[3]

Gawel (2000) reported that the sulphur-substituted asphalt mixes exhibit significantly higher fatigue life than comparable conventional mixes. The behaviour of sulphur-containing pavements is more elastic compared with conventional pavements (at the same loading time). The addition of sulphur makes it possible for softer asphalts to be used in order to reduce low-temperature cracking without the high-temperature deformation which occurs when virgin asphalt is used. It has been found that the use of sulphur-extended asphalt with 30% to 40 % of sulphur in paving mixes leads to the reduction in deformation approximately by a half. Paving materials based on sulphur-asphalt and binder exhibit a better resistance to water as compared with conventional mixes. The use of sulphur in asphalt-aggregate mixes permits the design of impervious materials being suitable for hydraulic applications. A saving of 20% asphalt can be reached by incorporating sulphur into an asphalt paving mix.[4]

Ghaly (2008) reported that the storage stability of TR (Tyre rubber)/SBS modified asphalt after vulcanization process has been achieved at 160°C while the critical degradation temperature reached to 200°C. Marshall Stability and resistance to plastic deformation of TR/SBS were increased after the addition of sulphur. The best improvements were obtained at 4% TR/SBS/ 1%S.[5]

III. EXPERIMENTAL PROGRAMME

A. Materials

The materials which are used in the present study are as follows

1) Bitumen

The 60/70 grade bitumen supplied by the Mathura Refinery is used in this study.

Tele:
E-mail addresses: tanveer_rm@yahoo.co.in

2) Modifiers

Sulphur is used to modify the conventional 60/70 bitumen.

B. 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 110ºC and the appropriate quantity of Sulphur was added. The temperature was maintained between 100ºC to 120ºC. The contents were gradually stirred for about 30 minutes.

C. Tests Conducted

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

1) 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]

2) 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]

3) 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]

4) 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]

5) 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. [2]

6) Rolling Thin-Film Oven Test(RTFOT)

Ageing or hardening of bituminous binder occurs during the mixing and during service. Short term ageing of the binders is performed by two methods, Thin Film Oven test (TFOT, ASTM D 1754) and Rolling Thin Film Oven Test (RTFOT, ASTM D 2872), respectively. The TFOT and RTFOT are used to simulate the hardening which bitumen undergoes during mixing. In RTFOT, the glass jars were loaded with 35 gm of the sample. The jars with the samples are kept in an oven for about 15 minutes at 160°C. According to the standardized procedures, the samples are aged at 163°C and 1.5 hrs for RTFOT. [1]

IV. TEST RESULTS AND DISCUSSION

The physical properties of the bitumen modified with the Sulphur are discussed in the subsequent paragraphs.

A. Penetration Value

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

TABLE 1 PENETRATION VALUES

Binder Type	Modifier Content (%)	Penetration at 25 °C (dmm)
VG 30	0	68
VG30 + Sulphur	1	44
	2	33
	3	26
	4	21
	5	18
	6	07

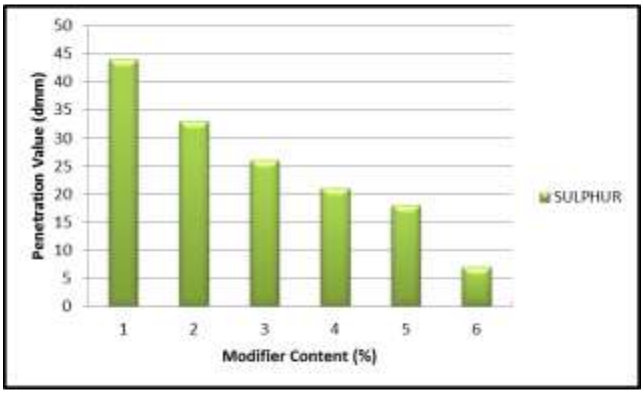

Fig.1 Variation in Penetration Value

B. Softening Point

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

TABLE 2 SOFTENING POINT VALUES

Binder Type	Modifier Content (%)	Softening Point (ºC)
VG 30	0	50
VG30 + Sulphur	1	61
	2	68
	3	73
	4	80
	5	84
	6	88

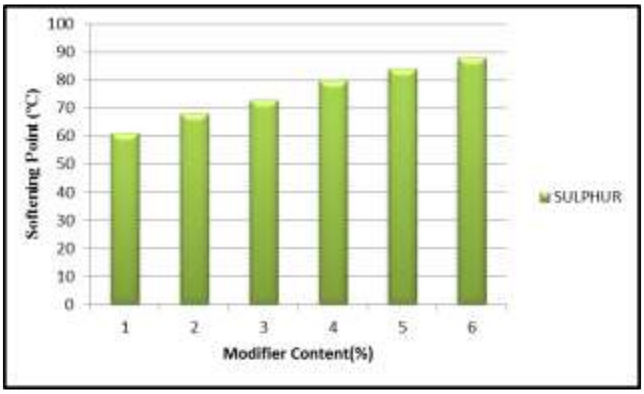

Fig. 2 Variation in Softening Point Value

C. Viscosity

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

TABLE 3 VISCOSITY VALUES

Binder Type	Modifier Content (%)	Viscosity at 135 ºC (cP)
VG 30	0	575
VG30 + Sulphur	1	1025
	2	1400
	3	1775
	4	2300
	5	3025
	6	3950

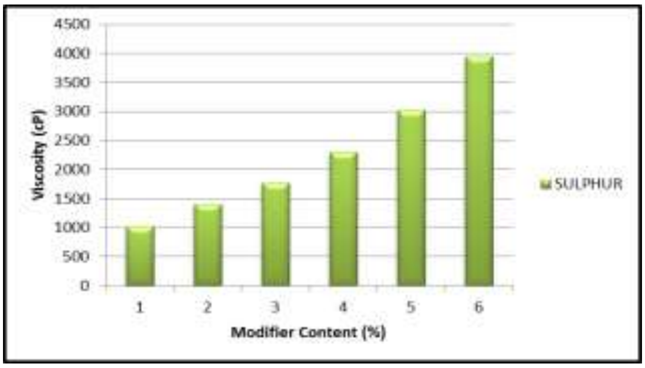

Fig.3 Variation in Viscosity

D. Ductility

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

TABLE 4 DUCTILITY VALUES

Binder Type	Modifier Content (%)	Ductility (mm)
VG 30	0	100
VG30 + Sulphur	1	100
	2	86
	3	63
	4	26
	5	21
	6	11

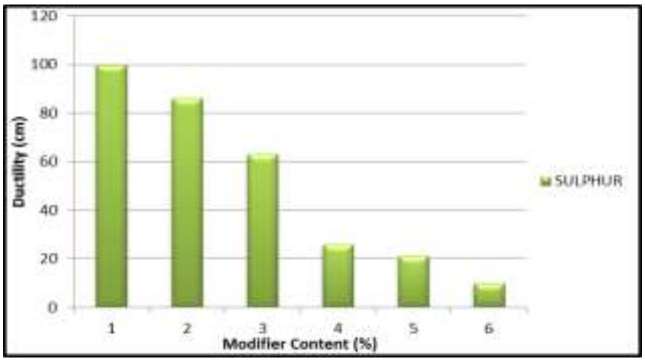

Fig. 4 Variation in Ductility

E. Elastic Recovery

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

TABLE 5 ELASTIC RECOVERY VALUES

Binder Type	Modifier Content (%)	Elastic Recovery at 15ºC (%)
VG 30	0	26
VG30 + Sulphur	1	29
	2	31
	3	36
	4	42
	5	46
	6	ND*

* The sample was broken before elongating up to 10 cm

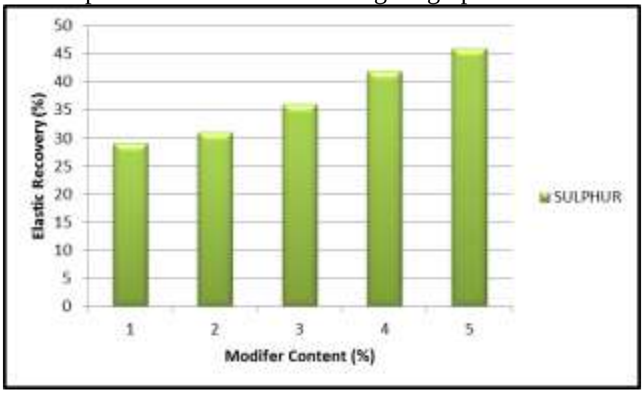

Fig. 5 Variation in Elastic Recovery

F. Penetration Index

The values of penetration Index are tabulated in the table below.

TABLE 6 PENETRATION INDEX VALUES

Binder Type	Modifier Content (%)	Penetration Index
VG 30	0	-0.4488
VG30 + Sulphur	1	0.9115
	2	1.4948
	3	1.7645
	4	2.3098
	5	2.5188
	6	1.3927

V. DETERMINATION OF OPTIMUM DOSE

The requirement of penetration, softening point and ductility is satisfied at 3% of Sulphur as per IRC: SP: 53-2002 and IS 15462-2004. From penetration index point of view also, up to 3% Sulphur can be used in paving bitumen as the PI value lies between +2 to –2 as indicated in the Table 6

VI. EFFECT OF AGEING

The effect of ageing is depicted by the changes in the physical properties of the different modified binders after RTFOT. The changes in physical properties are shown in Table 7

TABLE 7 THE CHANGES IN PHYSICAL PROPERTIES AFTER RTFOT

Designation	Binder Type	Test Results
Loss in Weight (%)	VG 30 + 3% Sulphur	0.15
Increase in Softening Point (ºC)	VG 30 + 3% Sulphur	3.72
Reduction in Penetration of Residue at 25ºC (%)	VG 30 + 3% Sulphur	23
Elastic Recovery at 25ºC (%)	VG 30 + 3% Sulphur	30

VII. 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 sulphur
2. Sulphur modified binder gives lower Penetration value as compared to neat bitumen
3. Sulphur modified binder gives Higher Softening point value as compared to neat bitumen
4. Sulphur modified binder gives Higher Viscosity as compared to neat bitumen.
5. Effect of Aging on Sulphur modified binder is with in permissible limits.

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