

Properties Assessment of Sulfur-Modified Asphalt

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Abstract

The interest on bituminous adaptable asphalt, because of development in weighty rush hour gridlock loads and their tire contact strain with unfriendly climatic circumstances, weakness and rutting execution has brought about an interest towards the changed bituminous fasteners. There are different well known changed folios currently accessible around the world. These modifiers essentially adjust the rheological and morphological properties of the fastener, as described by rheological testing strategies alongside the morphological as opposed to the customary techniques, to upgrade the exhibition of the folio. This review is planned towards the change of the regular thickness grade VG 30 bitumen and utilizations of business sulfur accessible in nearby market to alter the VG 30 bitumen and to assess the rheological qualities of un-aged and matured examples of these two folios utilizing a Unique Shear Rheometer (DSR). Endeavor has been made to conclude the suitable circumstances for fastener improvement like blending/mixing time and temperature to guarantee appropriate adjustment, through the rheological boundaries of stage point and complex modulus. This improvement at last assists with impacting the exhaustion and rutting protections of bituminous blends. The change of bitumen with sulfur at six different blending temperature, for example, 100°C, 110°C, 120°C, 130°C, 140°C, 150°C and 160°C, each made at five different blending times like 5 min, 10 min, 15 min, 20 min, 30 min. has additionally been done. The ideal adjustment level has been assessed considering unaging and maturing measures for five sulfur items, for example, 1%, 2%, 3%, 4% and 5% by weight of the bitumen. It is seen that the expansion of 2% sulfur by weight with bitumen mixed at 140°C temperature for around 30 min., brings about the best adjustment of VG 30 bitumen regarding the rheological properties, and fulfilling the prerequisites of traditional properties.

Introduction

In India roads and highways are preferred as primary modes of transportation. Roads constructed with flexible pavements always given more importance due to its smooth riding quality and less construction costs than in case of rigid pavements. Bituminous materials along with aggregates are utilized for the construction of flexible pavement roads. The Indian road transportation infrastructure is a great challenge in development of National Highways Development Programs (NHDP), Pradhan Mantri Gram Sadak Yojana (PMGSY) and State Highways Improvement Programs (SHIPs) etc. where huge money is being invested by the Government of India in order to empower the pavement performance.

Bitumen is a civil engineering material used for construction of highways in terms of Flexible pavement. One of the advantage of bitumen as an engineering construction material is its great versatility. Bitumen is a strong binding material that has very high adhesive property and highly waterproof and durable, making it useful in road Constructions. Bitumen being a viscoelastic material is effectively used as a binder. VG-30 and VG-10 grades of bitumen are commonly used as depending on the climatic conditions. In addition to increase the performance in terms of stiffness and elasticity, bituminous mixture must be able to resist the most and primary modes of flexible pavement distress types, namely, fatigue cracking and permanent deformation, known as rutting failure. As the mechanical properties of bituminous mixture are strongly dependent upon the properties of the binder, it has to fulfil certain mechanical and rheological requirements to ensure the

integrity of the road.

Objectives of Research

In general, this research is lead to explicate better understanding of the rheological properties of modified and unmodified bitumen binders. Considering the problem statement above, the main objectives of this research are summarized as follows:

1. The aim of this study is to explore the use of modified binder to improve the performance of flexible pavements.
2. The dynamic shear rheometer (DSR) is used to determine the rheological characteristics of bitumen binder over a wide range of temperature and rate of loading conditions.
3. Comparing the rheological properties at high, medium, low temperatures for unmodified bitumen and modified bitumen by Dynamic Mechanical Analysis.
4. The effect of sulphur on modification of bitumen in terms of rheological, storage stability and morphology has been studied.
5. The effect of ageing on unmodified and modified bitumen rheology and morphology using Rolling Thin Film Oven (RTFO) and Pressure Aging Vessel (PAV) and FESEM respectively.

Scope of the study

The scope of this study is to focus on the characterization of sulphur modified bituminous binder. The evaluation of rheological properties of VG-30 bitumen binder without and with modification with sulphur from dynamic mechanical analysis followed by morphological and thermal analysis is the main aim of this study. The rheological properties, creep recovery tests, morphology and thermal analysis are conducted using dynamic shear rheometer (DSR) and field emission scanning electron microscope (FESEM), apparatus. Ageing of bitumen and modified binders has been understand using the Rolling Thin Film Oven (RTFO) for short term ageing and Pressure Aging Vessel (PAV) for long term ageing and effect of ageing on the rheological, morphological and thermal parameters are studied.

Methodology

The viscoelastic behavior of bitumen is exceptionally complex to depict by basic traditional experiments of consistency, for example, penetration tests and softening point tests. Hence, the assessment of bitumen attributes ought to be focused around its performance regarding fatigue and rutting safety. Hence, new test instruments like the Dynamic Shear Rheometer (DSR), Brookfield Viscometer have been created to give rheological properties of bitumen over an extensive variety of loading and encompassing conditions. The DSR might be acknowledged as the most compelling and complex instrument for characterization of the bitumen flow properties. It is additionally really vital to comprehend the chemical progressions of bitumen that has been made throughout change by sulphur. To study the chemical compound arrangement framing, thermal and morphological investigation of unmodified and modified bitumen, a few tests have been led utilizing new innovation instruments, for example, FESEM, TGA, DTA and FTIR Spectroscopy individually.

Brookfield Viscometer

The Brookfield rotary method shown in [Figure 3.1] is the most common method for determination of viscosity of fluid. Absolute viscosity evaluation has traditionally been used for research applications, quality control and grease analysis within the field of machinery lubrication. Its working rule is that an overall composed shaft is to pivot with legitimate unrest for proper revolution inside a bitumen filled metal tube applying shear stress and torque and consequently the resistance given by the bitumen will be calibrated and viscosity of the bitumen will be assessed.

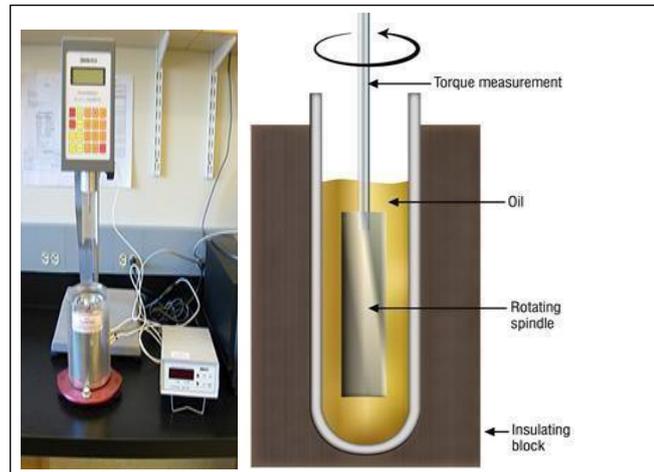


Figure 2.1: Rotational Viscometer and working principle

Capillary Viscometer

This viscometer is utilized to assess both absolute and kinematic viscosity according to ASTM D 2170 and D 2171. Absolute viscosity is adjusted regarding resistance offered by the liquid against the vacuum pressure, when the liquid is inside a legitimately outlined glass tube. Correspondingly the kinematic viscosity is aligned as far as resistance of liquid to stream under gravity at specified temperature inside an exceptionally designed glass tube. The temperature is maintained by silicon oil for both the cases. The viscometer and its component parts are shown in [figure 2s.2] below.

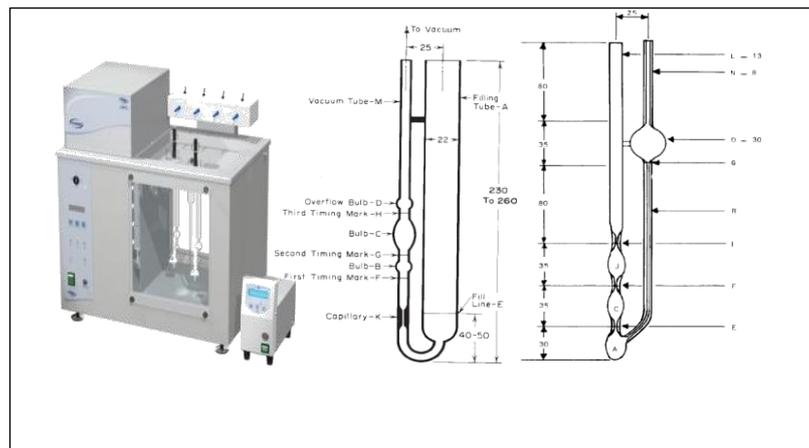


Figure 2.2: (a) Cannon Capillary Vacuum Viscometer (b) Glass tube for Absolute viscosity measurement (c) glass tube for Kinematic viscosity measurement

Phase Angle

For an applied stress shifting sinusoidal with time, a viscoelastic material will additionally react with a sinusoidal strain for low amplitudes of stress. The sinusoidal variety in time angle is defined as the lag between the applied stress and resulting strain of a body when subjected to a sinusoidal shear stress. The phase

angle is a critical parameter to portray the viscoelastic behavior of bitumen, which is a yield result from the dynamic mechanical examination through DSR. Typical phase angle has been illustrated below[figure 2.3].

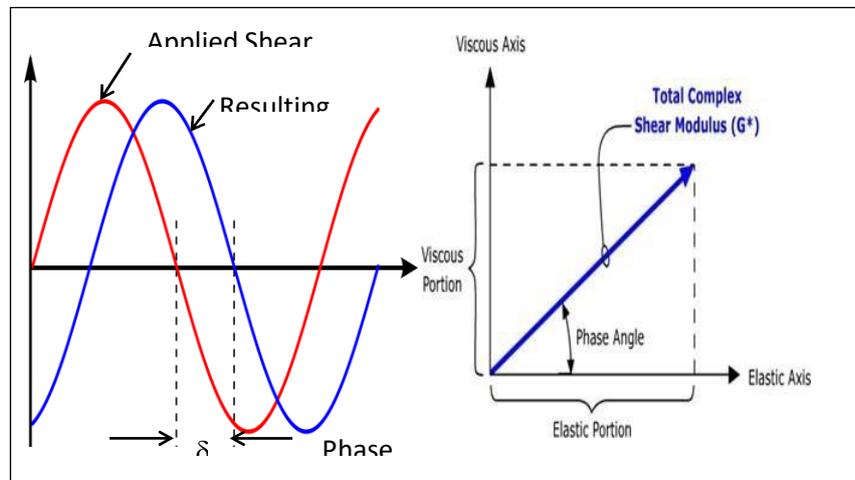


Figure2.3: Illustrating the phase angle and complex modulus

Experimental Program

The work demonstrated in this section has been partitioned into four zones. The primary zone of this study comprises the type of material used, their standard properties and sample preparation for testing. The secondary region of study depicts the operational confinements of the Viscometry and DSR in wording of connected stress levels and recoverable strain levels along with the testing conditions of samples. The third range of study examined the impact of different temperatures on the physical properties tests. The fourth zone of this study summarized with chemical, morphological and thermal analysis with testing conditions of the samples. In this study the rheological, physical, storage stability, chemical, thermal and morphological properties of both unmodified and modified bitumen, their working standards have been briefly discussed.

Material

It is known from the studies that the level of modification relies on upon the neat bitumen type and modifier type. Different studies have been carried out in the field of sulfur modification and there are a few descriptions for the need of utilizing modifier within bitumen industry. There are different explanations behind utilizing bitumen modifier within bitumen industry began with expansion the service life of the pavement, enhance its performance, meet the overwhelming traffic demands and at last saving the expense of maintenance. In this test project viscosity grade bitumen VG-30 has been utilized. The physical properties of VG-30 bitumen were given in table underneath.

Table 3.1 Physical properties of VG -30 bitumen

Properties	Result
Absolute viscosity 60°C (Cp)	2462
Kinematic Viscosity 135°C (cst)	365
Softening point °C	47
Penetration (dmm) 25 °C	57
Ductility (cm) 25°C	>100

Elastic Recovery (%)	26
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Observing the production and cost, Sulfur being in powder structure utilized as modifier for modification of bitumen as shown in figure below. The essential properties of sulphur have been represented in [figure 3.1] beneath

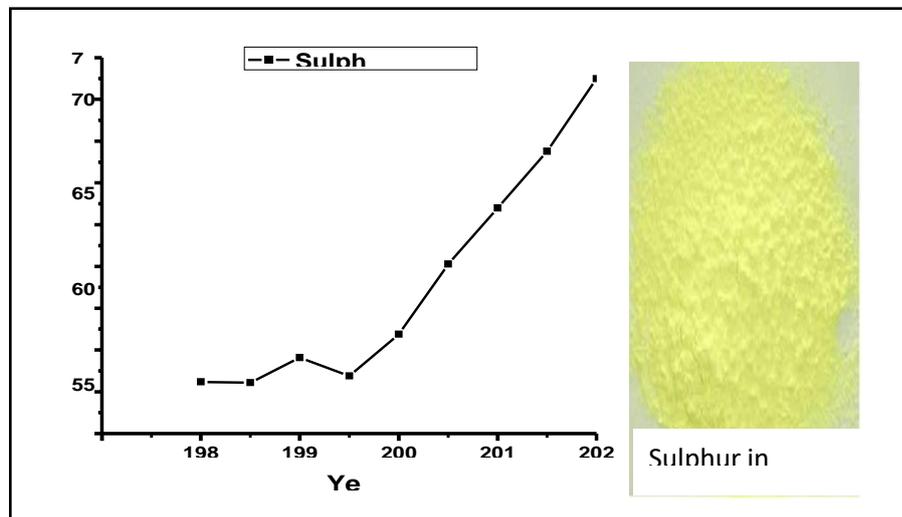


Figure 3.1: Production of sulphur over years and Elemental sulphur powder

Table 3.2 Physical properties of elemental Sulphur

Properties	Result
Appearance	Yellow crystalline solid
Melting point	120°C
Specific Gravity	1.92

At first the Rheological properties of sulfur extended bitumen have been tested to know about the progressions in the viscoelastic properties of modified specimen. To discover a good structure for a good sulphur modified bitumen, four steps are carried out, under which a few sets of tests are to be directed with viscometry and DSR instrument to evaluate the rheological properties of sulphur extended bitumen to evaluate the optimum sulphur content and ideal condition for proper modification and are explained below. After obtaining the proper sulphur content and blending condition in terms of blending time and temperature analysis of physical, chemical, thermal and morphological properties has been carried out. To prepare the modification of VG 30 bitumen with sulphur, about 1.0 Kg of bitumen is taken in a 3 liter metal container and heated up to fluid condition. The blending of sulphur with bitumen is carried out using a mechanical stirrer at a stirring speed of 3000 R.P.M. for temperature beyond 120 °C, but for temperature within 100°C to 120°C, speed of the stirrer for blending was kept 1500 R.P.M.

Results And Analysis

SHRP test results for appropriate mixing/blending temperature for modification of bitumen by sulphur under Standard Conditions of SHRP test

Test results are analyzed on the basis of phase angle and complex shear modulus and their behavior with variations in blending temperature and are presented in diagrams [figure 4.1 (a) & (b)]. From the Figure 4.1 (a)

two statement are observed one is the phase angle of sulfur modified bitumen having less esteem than the unmodified VG 30 bitumen, which indicate towards more elastic nature than conventional bitumen. Second is at 1400c of mixing/blending temperature the sulphur modified bitumen indicates least value of phase angle than other temperature because of the expansion in viscosity of sulphur powder for temperature beyond 150°C.

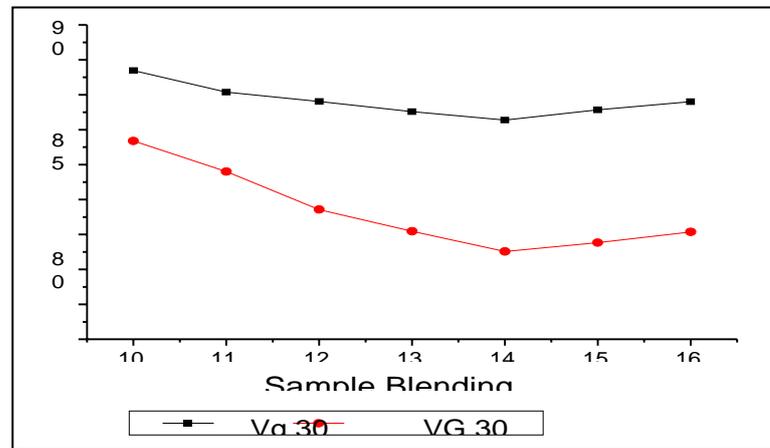


Figure 4.1 (a): Variations of phase angle with different blending temperature

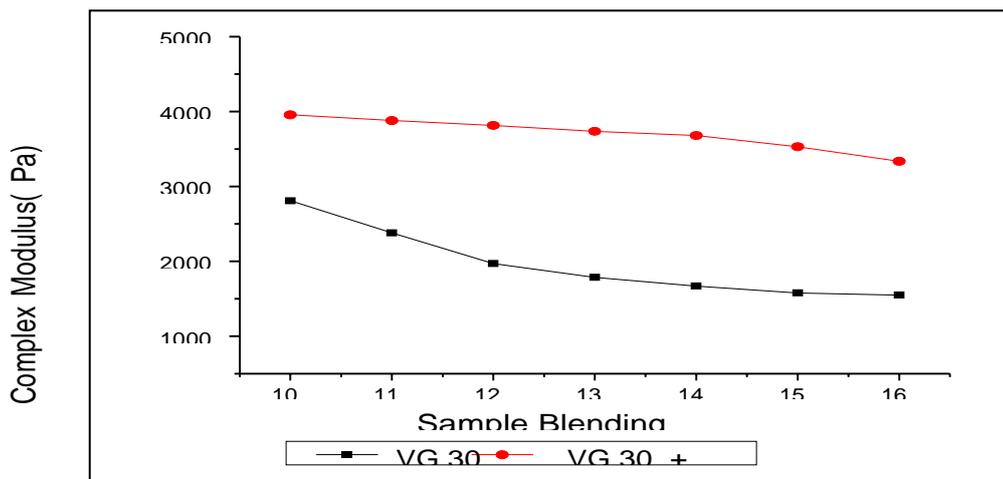


Figure 4.1 (b): Variations of complex modulus with different blending temperatures

SHRP test results for appropriate mixing/blending time for modification of bitumen by sulphur under Standard Conditions of SHRP test

These test results are mulled over regarding phase angle and complex modulus for proper time needed for mixing/blending of sulfur and bitumen. Their relationships with different blending temperature are presented in graphs [Figure 4.2 (a) & (b)] below.

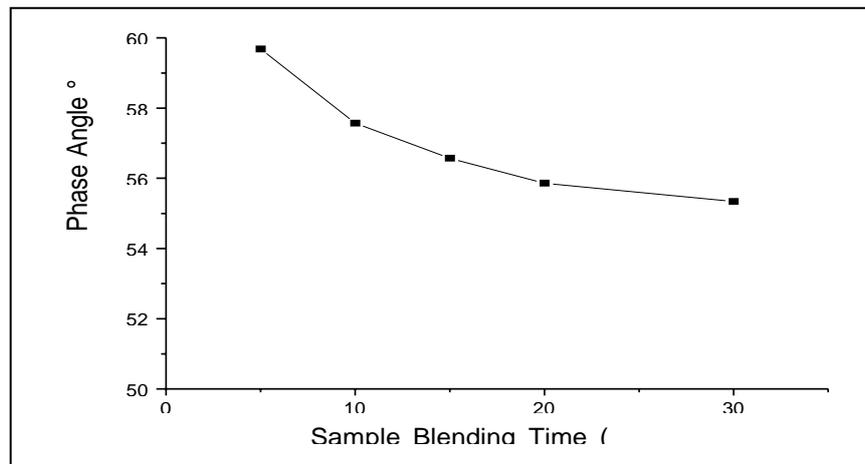


Figure 4.2 (a): Behavior of phase angle with change in blending time for 2% sulphur modified bitumen

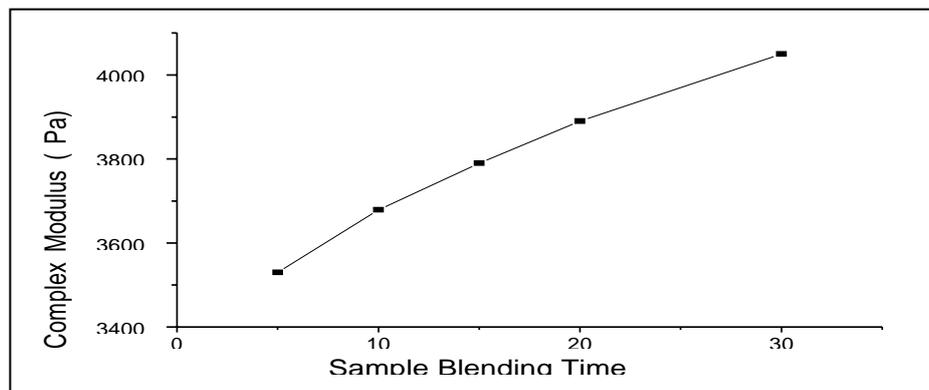


Figure 4.2 (b): Behavior of complex modulus with change in blending time for 2% sulphur modified bitumen

From the above variations of phase angle and complex modulus with variations of blending time for modification of bitumen with sulphur it can be suggested that about 30 minutes of continuous blending provides a homogeneous blending for which decrease in phase angle and increase in complex modulus occurred, as a result of which sulphur modified bitumen becomes more elastic and possess more strength.

Conclusions

Several modifiers have been tried to improve the properties of bitumen in terms of engineering properties and performance criteria to derive the maximum benefits to withstand the wheel loads of the modern day traffic causing heavy stresses. Sulphur is one additive which is found to enhance the performance of the bitumen binder. In this research work, sulphur has been added to VG 30 bitumen maintaining at 140°C temperature through mechanical stirring for about 30 minutes to introduce a homogeneous modified binder. To ascertain the modification in quality and quantity, the temperatures for mixing/ blending, mixing/ blending time and the sulphur concentrations in bitumen were varied from 100°C to 160°C, from 5 min to 30 min and from 0% to 5% by weight respectively. A number of rheological properties have been studied for binders under both aged and unaged conditions. The following concluding remarks have been drawn:

- Considering the criteria of complex modulus and Phase angle, addition of 2% sulphur by weight of VG 30 bitumen blended at 140°C temperature for about 30 minutes time results in the optimum mixing/blending condition.
- In respect of unaged binder situation, the addition of sulphur to the extent of 2% to the

conventional VG 30bitumen improves the viscoelastic behavior in terms of resistance to fatigue and rutting in comparison to the unmodified binder.

- The sulphur modified binder is observed to possess superior viscoelastic and other rheological characteristics in case of the aged binders also.
- The sulphur modified binder is found to satisfy the physical property requirements.
- The morphological tests show homogeneity of sulphur in the bitumen matrix.
- The storage stability test in case of modified binder does not show any non- homogeneity as observed by the conduct of the softening point test.

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