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STUDY ON SULPHUR-MODIFIED BINDER TECHNIQUE AND EXPLORE THE DISSIPATED ENERGY TECHNIQUE TO DETERMINE THE FATIGUE LIFE OF BITUMINOUS BINDER

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Abstract: Bitumen's technical qualities and performance standards have been improved by a variety of modifiers in an effort to better handle the enormous wheel loads of today's traffic. Bitumen binder performance is improved by the use of sulphur as an ingredient. Sulphur was added to VG 30 bitumen and mechanically stirred for 30 minutes at 140oC to create a homogenous modified binder. Sulphur concentrations in bitumen were altered from 0 percent to 5 percent by weight to determine how the quality and quantity of the mixture was affected by these changes in temperature, time, and sulphur concentrations. Both aged and unaged situations have been researched for the qualities of the binder. The following are the final thoughts. Complex modulus and Phase angle considerations indicate that adding 2 percent sulphur by weight to bitumen mixed at 140 C for roughly 30 minutes at 140 C resulted in the ideal mixing/blending state. Adding 2% sulphur to ordinary VG 30bitumen increases viscoelastic behaviour in contrast to unmodified binder, which is better at resisting fatigue and rutting than an unaged binder. Sulfur-modified binder has improved viscoelastic and rheological properties even when used with older binders. Sulphur-modified binders have been discovered to meet the physical property criteria. In the bitumen matrix, morphological examinations reveal that the sulphur is uniformly distributed. The softening point test did not reveal any no homogeneity when using a modified binder for storage stability testing. The thesis suggestions for more investigation in the future. In order to determine the fatigue life of changed binders, it is advised that time sweep tests via DSR be performed on several models. It is suggested to use the dissipated energy technique to determine the fatigue life of bituminous binder. No matter how many stresses are applied, a binder's performance should be studied. Strong indirect strength, strong modulus, and fatigue health may be associated with Rheological testing of modified binders.

Keywords: Sulphur-Modified Binder, Bituminous Binder, Sulphur

I. INTRODUCTION

The principal form of transportation in India is the road and highway. Because of its smooth ride quality and lower construction costs, flexible pavement roads are always prioritised over rigid pavement roads. Flexible paving roads are built using bituminous materials and aggregates. The government of India is spending a significant amount of money to improve the performance of the pavement in order to construct various highway improvement programmes, such as the National Highway Development Programs (NHDP), Pradhan Mantri Gram Sadak Yojana (PMGSY), and State Highway Improvement Programs (SHIPs), among others.

Highways with flexible pavement are built using bitumen, a civil engineering material. Bitumen's high degree of adaptability makes it an excellent choice for use in engineering projects. Bitumen is a highly sticky, waterproof, and long-lasting binder that is ideal for use in road construction. Almost all acids, alkalis, and salts have no effect on it [Minnesota Asphalt Pavement Association, 2003]. When roads are built, bitumen and gravel are mixed together to create something called bituminous mixture. This combination is used in the construction of the structural pavement layers of a road, such as the foundation and surface course of the roadway. [2009]. Because of its viscoelastic properties, bitumen is an excellent binder. Bitumen grades VG-30 and VG-10 are typically utilised depending on the weather.

These mechanisms include fatigue cracking and rutting failure. [Lesueur, 2009] In order to maintain the road's structural integrity, it is necessary for the binder to fulfil certain mechanical and rheological criteria. The lifespan of flexible pavement is mostly determined by two properties of bitumen. To begin, it must be rigid enough to withstand rutting deformation at temperatures as high as 60oC, depending on the environment. It must be. Second, it should be able to withstand fatigue cracking at temperatures as low as 20oC, depending on the local environment. However, the typical VG-30 bitumen does not meet the performance parameters for improving the service life of the flexible pavement owing to an increase in high traffic and bad weather conditions. Bitumen has to be amended with various additives that tend to empower the bitumen's performance in order to improve the flexible pavement's performance in terms of fatigue and rutting resistance. There are a variety of modifiers on the market. However, because of its widespread use in industry, sulphur powder was used in this investigation as a modifier.

Bitumen rheology is a performance-related study of bitumen that is carried out using Dynamic Mechanical Analysis. Dynamic mechanical analysis (DMA) and dynamic shear rheometer (DSR) tests are used to investigate the rheological characteristics of bitumen. [Airey 2002a] The test is conducted in the linear viscoelastic (LVE) area. Since the Strategic Highway Research Program in the early 1990s, the rheological qualities of bitumen have gained prominence in American standards (SHRP).

II. METHODOLOGY

When it comes to bitumin's viscoelastic nature, typical consistency tests like penetration and softening point tests aren't enough. As a result, the evaluation of bitumen qualities should be focused on its fatigue and rutting safety performance. Because of these advancements, new rheological characteristics of bitumen have been developed using modern test devices such as the Dynamic Shear Rheometer (DSR) and Brookfield Viscometer. As far as flow qualities go, the DSR may be regarded as being the most complicated and appealing instrument available. Understanding the chemical changes that have occurred during sulphur transformation of bitumen is also critical.

Purpose of rheological properties of bitumen

The advantages and disadvantages of relying on rheological qualities as an execution parameter are well documented. As a result, physical qualities with large temperature ranges and high and low recurrence may be accurately estimated, which is difficult to do in the field due to movement. To perform the element tests and get excellent rheological findings using a dynamic shear rheometer, you'll need a highly skilled professional with extensive experience. Examples of how to create a DSR device and how to measure it will be shown here in a brief summary of how the DSR device works. The rheological experiments used to visualize objects are also described in this section as "point of interest."

In addition, it was determined that the critical issues identified in these trials and the types of traditional standards currently in use would also be the focus of the study. The issue of selecting new test methods and unique attributes was also considered in the study [Bahia et al (1993)], as was the question of how to compare later measured structures with those previously tested.

Viscoelastic Chattels of bitumen

Mechanical damping and flexible storage module may be used to define these features. Two important rheological features, a phase angle and a complex modulus, determine the performance of bituminous bonds. Under [Airey], its limitations and impacts on tar performance were immediately discussed.

Viscosity of bitumen

Flow resistance is what we call "viscosity." Visco elastic substance, bitumen acts as a semi-solid at room temperature and as a Newtonian liquid or liquid with low viscosity at temperatures above 60 ° C. As a result, viscosity is the main principle used to classify bitumen. Kinematic Viscosity and Absolute Viscosity are two ways to measure the viscosity of bitumen.

Quantity of Viscosity

DSR, Brookfield rotational viscometer, and Capillary Viscometer are just a few of the instruments that may be used to gauge bitumen's viscosity. Here are short descriptions of the various viscometers' operational concepts and measuring methods.

Brookfield Viscometer

[Figure 1] illustrates the most often used technique for determining fluid viscosity. Research, quality control, and grease analysis in the equipment lubrication industry have typically relied on absolute viscosity assessment. Its operating principle is to deliver shear stress and torque to a bitumen-filled metal tube so that an overall constructed shaft may rotate with appropriate disturbance for correct rotation, and this allows the bitumen resistance to be measured and its viscosity to be examined.

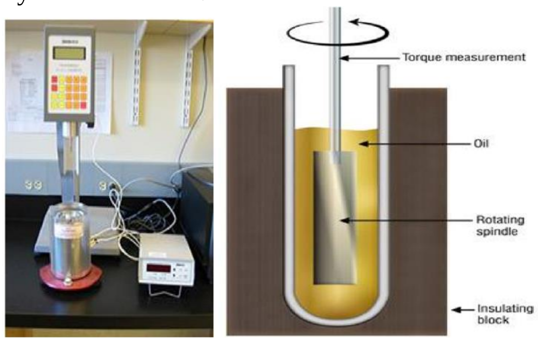

Figure 1: Rotating Viscometer and operating system

At high temperatures, this viscometer is able to detect viscosity, at least up to the point when the sample begins to move. This instrument is unable to detect either absolute or dynamic viscosity due to the fact that the spindle cannot rotate freely inside the fluid-filled tube when the temperature is low.

Capillary Viscometer

The ASTM D 2170 and D 2171 viscometers are used to measure both absolute and kinematic viscosity. contained well-defined resistance provided by the liquid to the vacuum pressure is used to change the absolute viscosity. At the set temperature and pressure within the glass tube, kinematic viscosity is also matched with respect to the resistance of the liquid to flow under gravity. Silicon oil is used to keep the temperature stable in both circumstances. Figure 2 depicts the viscometer and its components.

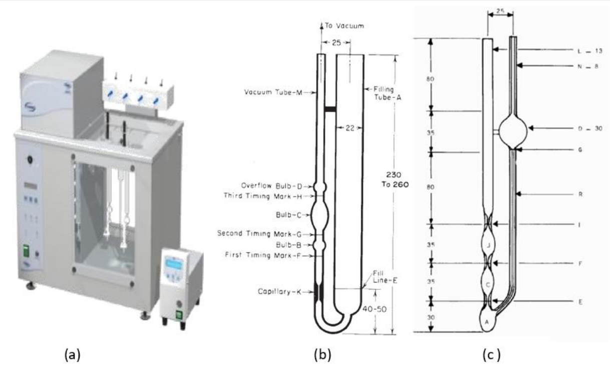

Figure 2: (a) Cannon Capillary Vacuum Viscometer (b) Absolute viscosity glass tube (c) Kinematic viscosity glass tube

III. EXPERIMENTAL PROGRAM

order to make the information presented here more understandable, it has been organised into four main parts. The study will concentrate on the materials that were used, the standard characteristics of those materials, and the processing of samples for testing.

Second, the performance parameters of Viscometry and DSR are defined in terms of stress levels associated with non-recoverable difficulty levels, as well as sample test conditions. Finally, we looked at how different temperatures affected the testing of our tangible assets. Samples were analysed chemically, morphological, and thermal structures in the fourth phase of this study.

Material

This research has shown a correlation between neat bitumen types and modifier types and the amount of modification they undergo. On the subject of sulphur conversion, there have been a number of studies and explanations of the need to use sulphur modifiers in the field of bitumen.

There are many different reasons why bitumen fixers are used in the bitumen industry. Some of these reasons include increasing the service life of the paved area, improving its performance, and addressing traffic needs.

IV. RESULTS AND ANALYSIS

To study the effect of sulphur on bitumen elements under different loading conditions, the skeletal structure of the test cover is selected. A flexible shear rheometer was used to display the rheological features of various binder throughout a wide range of temperatures and waves. The sulphur-refined bitumen VG 30 and VG 30 were both tested in this study, and the findings are summarized in the tables and graphs below.

Rheological features of the test results of the aging and adult binder

SHRP test results for suitable temperature mixing / mixing of sulphur conversion tar under General Conditions of SHRP Test

Complex shear modulus and blending temperature are examined using diagrams [figure 3 (a) & (b)] based on phase angle and complex shear modulus.

Bitumen prepared by the sulphur has a lower phase angle than the unmodified bitumen VG 30, which indicates that it is more elastic than normal bitumen, as shown in Figure 3 (a). As the temperature of mixing and mixing rises above 150oC, the viscosity of the sulphur powder increases, and this results in the converting bitumen to reflect the lower phase angle than any other temperature tested.

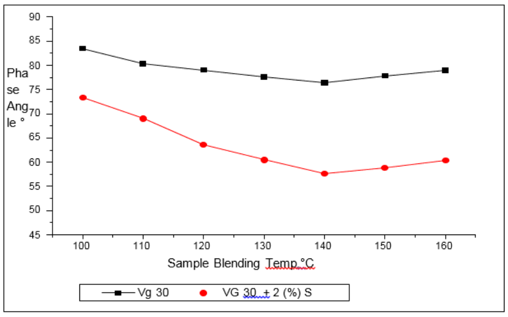

Figure 3: (a) Variation of phase angle with different blending temperature

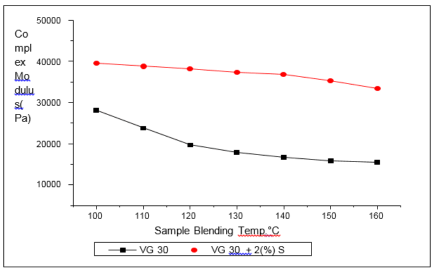

Figure 4: (b): Variation of complex modulus with different blending temperatures

Sulfur modified bitumen has a higher complex modulus than standard VG 30, as seen in Figure 4 (b). The complex modulus of sulfur-modified bitumen decreases as the temperature rises over 140°C. As a result, the elasticity and strength of sulphur-modified bitumen were measured at 140°C for the purpose of validly combining or blending sulphur and bitumen.

SHRP test results for the appropriate time / mixing of sulfur conversion tar under General Conditions for SHRP testing

Phase angle and complex modulus are analysed in order to determine how long it will take to combine sulphur and bitumen. Figure 5 (a) and (b) show their correlations with various blending temperatures.

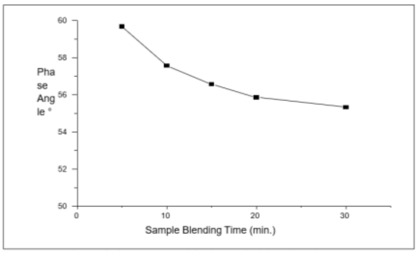

Figure 5: (a) Behaviour of phase angle with change in blending time

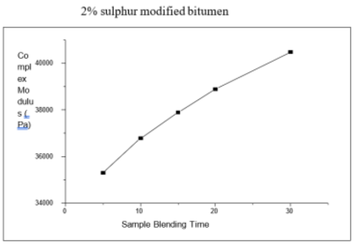

Figure 5: (b)Variation of complex modulus with change in blending time for 2% sulphur modified bitumen

With these phase angles and the variability of the complex modulus of bitumen prepared with sulphur, it can be said that approximately half an hours of continuous mixing is sufficient to achieve the same mixing which lowers the phase angle and increases complexity, resulting in more elastic and strong sulphur bitumen.

Storage stability Test results

Table 1 shows the test results for VG 30 and VG 30 fixed with 2% Sulphur. The difference in the lubrication zone between Vg 30 and converted bitumen is clearly shown to be 5.1oC, while the gap between the two decreases to 2.5oC when Vg 30 is used. Sulphur enhances the retention of VG 30 tar, as can be seen in the graphs.

Table 1: Results of the bituminous binder storage test results

Type of binder	Difference in softening point value °C
VG 30	5.1
VG 30 + 2% S	2.5

V. CONCLUSIONS AND RECOMMENDATIONS

Bitumen's technical qualities and performance standards have been improved by a variety of modifiers in an effort to better handle the enormous wheel loads of today's traffic. Bitumen binder performance is improved by the use of sulphur as an ingredient. Sulphur was added to VG 30 bitumen and mechanically stirred for 30 minutes at 140oC to create a homogenous modified binder. Sulphur concentrations in bitumen were altered from 0 percent to 5 percent by weight to determine how the quality and quantity of the mixture was affected by these changes in temperature, time, and sulphur concentrations. Both aged and unaged situations have been researched for the qualities of the binder. The following are the final thoughts:

- Complex modulus and Phase angle considerations indicate that adding 2 percent sulphur by weight to bitumen mixed at 140 C for roughly 30 minutes at 140 C resulted in the ideal mixing/blending state.
- Adding 2% sulphur to ordinary VG 30bitumen increases viscoelastic behaviour in contrast to unmodified binder, which is better at resisting fatigue and rutting than an unaged binder.
- Sulfur-modified binder has improved viscoelastic and rheological properties even when used with older binders.
- Sulphur-modified binders have been discovered to meet the physical property criteria.
- In the bitumen matrix, morphological examinations reveal that the sulphur is uniformly distributed.
- The softening point test did not reveal any no homogeneity when using a modified binder for storage stability testing.

Recommendations for future work
The following is a quick list of suggestions for more investigation in the future.

- In order to determine the fatigue life of changed binders, it is advised that time sweep tests via DSR be performed on several models.
- It is suggested to use the dissipated energy technique to determine the fatigue life of bituminous binder.
- No matter how many stresses are applied, a binder's performance should be studied.
- Strong indirect strength, strong modulus, and fatigue health may be associated with Rheological testing of modified binders.

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