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Engineering Characterization of Sulphur Modified Bituminous Binders

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Abstract - The increased demand on bituminous flexible pavements, due to heavy traffic loads, tire pressures, and extreme climatic conditions, has intensified efforts to enhance fatigue and rutting resistance using modified bituminous binders. Modifiers globally are improving the rheological and morphological properties of bitumen, with rheological testing providing critical insights beyond conventional methods.This study explores modifying viscosity grade (VG 30) bitumen with commercial sulfur sourced locally, focusing on both unaged and aged samples analyzed through a Dynamic Shear Rheometer (DSR). The objective is to establish optimal binder conditions by assessing parameters such as phase angle and complex shear modulus, which influence fatigue and rutting resistance.Sulfur was added to bitumen at six temperatures—100°C to 150°C—and mixed at five intervals (5 to 30 minutes), with concentrations of 1% to 5% by weight. Results indicated that the optimal modification was achieved with 2% sulfur at 140°C for 30 minutes, yielding enhanced rheological properties and meeting standard requirements.

Key Words: Bitumen, Rheology, Viscosity, Elasticity, Phase Angle, Complex Shear Modulus.

1.INTRODUCTION

In India, data management and analysis are increasingly essential for planning and executing infrastructure projects. In road construction, particularly for flexible pavements, data-driven methods are preferred for their efficiency and cost-effectiveness. Flexible pavements, made from bituminous materials and aggregates, are often chosen for their smooth performance and lower costs compared to rigid pavements. India's data infrastructure significantly supports large-scale projects like the National Highways Development Program (NHDP), Pradhan Mantri Gram Sadak Yojana (PMGSY), and State Highways Improvement Programs (SHIPs). These initiatives, funded by the Government of India, utilize data analytics to enhance pavement performance and ensure successful project outcomes.

Data is crucial in optimizing materials used in civil engineering, especially for highways with flexible pavements. A key material in this field is bitumen, valued for its versatility and effectiveness as a binder. Its strong adhesive properties, waterproofing capabilities, and resistance to acids, alkalis, and salts make bitumen ideal for road construction. Through data analysis, the performance of bitumen—especially when combined with aggregate to form bituminous mixtures—can be assessed, providing insights into the behavior of these mixtures in structural pavement layers. These layers, comprising the base and surface courses of roads, are essential for distributing traffic loads evenly and preventing pavement failure due to overstressing.

2. OBJECTIVES OF THE WORK

1. The aim of this study is to explore the use of modified data sets to improve the performance analysis of flexible pavement materials.
2. A dynamic shear rheometer (DSR) is employed to determine the rheological characteristics of data-driven models for bitumen binders across a wide range of temperature and loading conditions.
3. The study compares the rheological properties at high, medium, and low temperatures for unmodified and modified bitumen using Dynamic Mechanical Analysis.
4. The impact of sulfur on data modifications is analyzed in terms of rheological properties, storage stability, and morphological changes
5. The effects of data ageing on the rheology and morphology of unmodified and modified bitumen are examined using the Rolling Thin Film Oven (RTFO), Pressure Aging Vessel (PAV), and Field Emission Scanning Electron Microscopy (FESEM).

2. 1SCOPE OF THE WORK

This study focuses on the characterization of sulfur-modified bituminous data models. The primary objective is to evaluate the rheological properties of VG-30 bitumen data models, both in unmodified form and modified with sulfur, through dynamic mechanical analysis. The study incorporates morphological and thermal data analyses. The evaluation process includes creep recovery tests along with morphological and thermal analyses, using a dynamic shear rheometer (DSR) and field emission scanning electron microscope (FESEM). Additionally, the impact of data ageing on both unmodified and modified models is assessed through short-term and long-term ageing simulations, using the Rolling Thin Film Oven (RTFO) and Pressure Aging Vessel (PAV), respectively. The study systematically examines the effects of ageing on rheological, morphological, and thermal data parameters.

4. THEORY AND METHODOLOGY

3.1 Materials

VG-30 Bitumen: This viscosity-grade bitumen was selected for modification due to its widespread use in road construction. The physical properties of VG-30 bitumen, such as its penetration index and softening point, make it ideal for modification with sulphur.Sulphur: Commercial-grade elemental sulphur was used as a modifier. Sulphur content was varied between 1% and 5% by weight of the bitumen.

3.2 Experimental Setup

The modification process involved heating VG-30 bitumen to a fluid state in a metal container. Sulphur was then gradually added to the bitumen while stirring continuously at different temperatures (100°C to 150°C) for different mixing times (5 to 30 minutes). The purpose was to ensure complete dispersion of sulphur into the bitumen matrix without causing excessive thermal degradation.

3.3 Testing Procedures

The rheological properties of the modified binders were tested using a Dynamic Shear Rheometer (DSR) in accordance with ASTM standards. The following tests were performed:

Viscosity Tests: These included absolute and kinematic viscosity measurements at 60°C and 135°C, respectively. Brookfield viscometer readings provided insights into the bitumen's flow behavior.

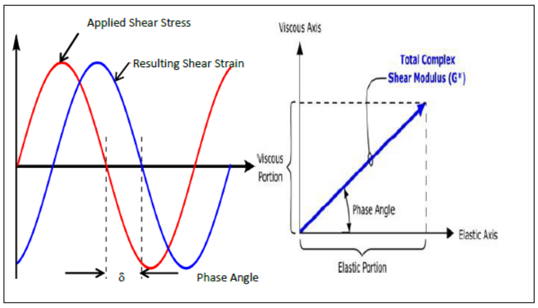


Fig. 1 Phase Angle and Complex Modulus

Dynamic Shear Rheometer (DSR) Tests: The DSR tests provided a comprehensive understanding of the viscoelastic properties of the modified bitumen. Phase angle (δ) and complex shear modulus (G*) were measured under oscillatory loading.Morphology Analysis: The morphological characteristics of the modified binders were evaluated using Field Emission Scanning Electron Microscopy (FESEM). The uniformity of sulphur dispersion and the resulting microstructural changes in the bitumen matrix were observed.

Fig. 2 Striping Test of Aggregates

5. RESULTS AND DISCUSSIONS

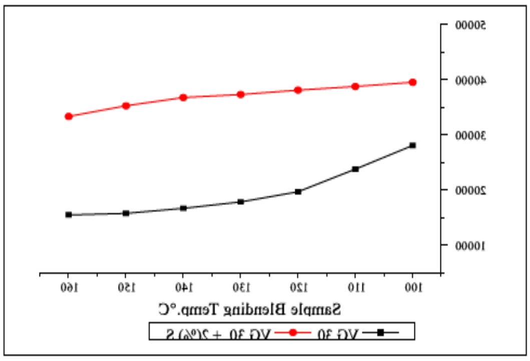
5.1 Rheological Properties

The sulphur-modified bitumen exhibited significant improvements in rheological properties. As shown in Table 1, the addition of sulphur reduced the penetration values and increased the softening point of the bitumen, indicating enhanced stiffness.

Table 1 Penetration Values

Sulphur Content	Penetration (mm)	Softening Point (°C)	Viscosity at 60°C (cP)
0%	58	47	2450
2%	48	52	3120
5%	42	58	3760

Figure 3 shows the variation in complex shear modulus (G*) with increasing sulphur content. It was observed that the 2% sulphur-modified binder exhibited the best balance between stiffness and flexibility, making it suitable for use in both high and low-temperature conditions.



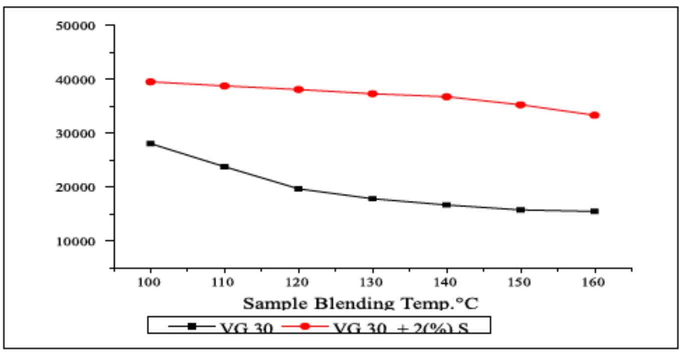


Figure 3 Variations of complex modulus with different blending temperature

5.2 Morphological Analysis

FESEM analysis of the sulphur-modified binders revealed significant microstructural changes. The sulphur was uniformly dispersed within the bitumen matrix, as seen in Figure 1, leading to improved performance. The presence of well-distributed sulphur particles ensured better adhesion between aggregates in the pavement mix.

5.3 Viscosity Measurements

Viscosity tests showed that the sulphur-modified binders had higher viscosity values compared to unmodified bitumen. This increase in viscosity is beneficial for preventing deformation under high temperatures, which is a common issue in tropical regions with heavy traffic. The results are summarized in Table 2 below**.**

Sulphur Content	Viscosity at 135°C (cSt)
0%	365
2%	410
5%	455

Table 2 Viscosity Measures

6. CONCLUSION

This study demonstrates that sulphur-modified bitumen offers significant improvements in both the rheological and morphological properties of VG-30 bitumen. The addition of 2% sulphur resulted in optimal performance, enhancing the binder's stiffness, reducing rutting susceptibility, and improving overall durability under heavy traffic conditions.

The key findings of this study include:

Sulphur modification improves the high-temperature performance of bitumen, reducing the risk of rutting and permanent deformation.

The 2% sulphur-modified binder exhibited the best balance between stiffness and flexibility, making it suitable for both hot and cold climates.

Morphological analysis confirmed the uniform dispersion of sulphur in the bitumen matrix, which contributes to the improved mechanical properties of the binder.

Future research should explore the long-term aging characteristics of sulphur-modified bitumen in real-world conditions. Additionally, field trials should be conducted to validate the laboratory results and assess the performance of sulphur-modified pavements under heavy traffic and extreme weather conditions.

REFERENCES:

[1] AASHTO Provisional Standards: AASHTO T315-08, "Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)", Washington.2011

[2] ASTM D5/D5M-13, "the standard test method for penetration of bituminous materials".

[3]ASTM D113 – 07, "the standard test method for ductility of bituminous materials".

[4] ASTM D36 / D36M – 12, "the standard test method for softening point of bitumen (ring- and-ball apparatus)".

[5]ASTMD7003,"thestandardtestmethodforspecificgravityand densityofsemi-solid bituminous materials (pycnometer method)".

[6] ASTM Standards D 8, "terminology relating to Materials for Roads and Pavements".

[7] ASTM Standards D 2872, "Test Method for Effect of Heat and Air on Rolling Film of Asphalt (Rolling Thin-Film Oven Test)".

[8] ASTM Standards D2171"Standard Test Method for absolute Viscosity of Asphalts by Vacuum Capillary Viscometer."

[9] ASTM Standards D2170"Standard Test Method for kinematic Viscosity of Asphalts by Vacuum Capillary Viscometer."

[10] ASTM Standards D 6084,"Standard Test Method for Elastic Recovery of Bituminous Materials by Ductilometer."

[11] Airey, Gordon D. "Rheological properties of styrene butadiene styrene polymer

modified road bitumens." Fuel 82.14 (2003): 1709-1719.

[12] Airey, G.D., “rheological characteristics of polymer modified and aged binders”, unpublished PhD thesis, University of Nottingham.1997

[13] Al-Ansary,“innovative solutions for sulphur in Qatar”, presented at the sulphur institutes, sulphur world symposium, Doha, Qatar. 2010

14. Al-Mehthel, Mohammed, et al. "Sulfur extended asphalt as a major outlet for sulfur that outperformed other asphalt mixes in the Gulf." Sulfur World Symposium, Qatar. 2010.