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Various Properties Of Bituminous (Asphalt) Binder By Sulphur

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ABSTRACT:
The demand on bituminous flexible pavement, as a result of growth in heavy traffic loads and their tyre contact pressure with adverse climatic conditions, fatigue and rutting performance has resulted in an interest towards the modified bituminous binders. There are various popular modified binders already available worldwide. These modifiers significantly alter the rheological and morphological properties of the binder, as characterized by rheological testing methods along with the morphological rather than the conventional methods, to enhance the performance of the binder. This study is intended towards the modification of the conventional viscosity grade VG 30 bitumen and applications of commercial sulphur available in local market to modify the VG 30 bitumen and to evaluate the rheological characteristics of unaged and aged samples of these two binders using a Dynamic Shear Rheometer (DSR). Attempt has been made to decide the appropriate conditions for binder development such as mixing/blending time and temperature to ensure proper modification, through the rheological parameters of phase angle and complex modulus. This development ultimately helps to influence the fatigue and rutting resistances of bituminous mixes. The modification of bitumen with sulphur at six different mixing temperature such as 100ºC, 110ºC, 120ºC, 130ºC, 140ºC, 150ºC and 160ºC, each made at five different mixing times such as 5 min, 10 min, 15 min, 20 min, 30 min. has also been carried out. The optimum modification level has been evaluated considering unaging and aging criteria for five sulphur contents such as 1%, 2%, 3%, 4% and 5% by weight of the bitumen. It is observed that the addition of 2% sulphur by weight with bitumen blended at 140ºC temperature for about 30 min., results in the best modification of VG 30 bitumen in terms of the rheological properties, and satisfying the requirements of conventional properties.

1.INTRODUCTION

1.1 Background of the study

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 SadakYojana (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. It is also highly resistive to the actions of most acids, alkalis, and salts**.**

The principle of use of bitumen is as a binder in the road construction where it is mixed with aggregate to produce bituminous mixture. This mixture is then laid as the structural pavement layers as base and surface course of a road. The main function of these 'bitumen-bound' layers is to transfer upcoming traffic loads evenly over the unbound pavement layers of the road and natural sub-grade to prevent failure due to overstressing**.** Bitumen being a viscoelastic material is effectively used as a binder. VG-30 andVG-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 fulfill certain mechanical and rheological requirements to ensure the integrity of the road**.**

Generally two characteristics of bitumen affect the service life of flexible pavement. First it has to stiff enough to resist rutting deformation at the highest pavement service temperature nearby 60ºC, depending on the climate. Second, it should be elastic enough at lower temperatures down to 20ºC depending on the local climate to resist fatigue cracking. But due to the increase in heavy traffic loading and adverse climatic conditions the conventional VG-30 bitumen is not fulfilling the performance criteria in the improvement of service life of the flexible pavement. To enhance the flexible pavement performance regarding fatigue and rutting resistance of the bitumen so as the pavement, bitumen need to be modified with some additives whose tendency is to empower the bitumen performance. Several modifiers are available in the market. But in this study sulphur in powder form has been utilized as a modifier by considering its huge production in industries.

The performance related study of bitumen is also known as bitumen rheology and its analysis is conducted by Dynamic Mechanical Analysis. The rheological properties of bitumen are typically determined in terms of dynamic mechanical analysis (DMA) utilizing a dynamic shear rheometer (DSR) tests. The test is lead within the linear viscoelastic (LVE) region**.** The rheological properties of bitumen has been growing and importance in specifications in the USA since the early 1990's following the **Strategic Highway Research Program (SHRP).** The DSR instrument, however, does have its limitations where the measured rheological data are exposed to the measurement error particularly at low temperatures and/or high frequencies.

Apart from these the modification process has a great importance on the homogeneity of the modification of bitumen with sulphur modifier. The morphological analysis provides an idea about the disperse medium of unmodified and modified bitumen, as a result of which the homogeneity of the blending of bitumen with modifier can be observed properly.

1.2 Problem Statement

In India, the type of bitumen grade used is based on the penetration test, which is conducted to know the softness of bitumen at a temperature of 25°C. The pavement failure is due to heavy traffic loads and seasonal variations, which are directly, affect the durability and performance of pavements. The most common problem associated with the performance of bituminous pavements is low temperature distress type or fatigue cracking and Permanent failure or rutting failure.

The pavement surface temperature on hot summer season is within 60°C, which makes bitumen soft and results in permanent deformation as rutting in pavement. It usually occurs along longitudinal direction of the flexible pavement under the traffic wheel path accompanied by small upheavals to the sides. At low temperature in winter season, bituminous pavements become too brittle and there exist fatigue cracking. Fatigue cracking is processed as cumulative damage resulting from repeated traffic loading. Therefore, to minimize the distresses of the flexible pavement some measures can be performed such as:

- Improving the mix design of bituminous mixtures.
- By improving the construction methods and maintenance techniques.
- Introduce modification of bitumen so as to improving the bituminous mixture.

The one effective approach for pavement distresses minimization is to explore and use a new modified binder with the help of an additive. There are several additives available to develop modification of bitumen by using different additives. Sulphur has also been used as a common method to enhance the bitumen characteristics and is found to have wide range of application and potential for use as a good modifier. It is also very important to study the thermal behavior and morphology, which will provide information regarding the changes those usually occur due to modification, which affect the chemical compositions of conventional bitumen binder.

2.LITERATURE REVIEW

2.1 Introduction

The aim of this study is to gather some knowledge of previous research work those has been already executed, which are related to rheology, morphology and thermal characteristics of unmodified and modified bitumen binder. This chapter covers five sections through which related literatures of this research work has been included.

Section 1 deals with the literature review concerning constitution of bitumen with its elementary analysis and chemical composition.

Section 2 the literature survey gives a brief description of the Empirical tests as softening point, penetration and viscosity.

Section 3 described the bituminous binder rheology, its viscoelastic characteristics, effect of ageing, chemical composition, thermal analysis and morphology of bituminous binder.

Section 4 this section deals some common distresses inflexible pavement.

Section 5 deals with the modification of bitumen. The review included various types of modifiers and different modification mechanism.

2.2 Bitumen constitution (chemical composition)

2.2.1 Elemental Composition of Bitumen

The bitumen is a dark brown to black in color, sticky and viscous material which is

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composed of high molecular weight hydrocarbons. It is obtained from the bottom of the vacuum distillation columns in the crude oil refineries.

Elementary analysis of bitumen manufactured from the various crude oils has varying physical properties. It i s predominately consists of carbon and hydrogen. Most bitumen binder contains heteroatom such as carbon, hydrogen, sulphur, oxygen and nitrogen. The elementary analysis of the bitumen binder is summarized below in Table 2.1

Table 2.1 Elemental Analysis of Bitumen

Component of Bitumen	**Percentage**
Carbon	82% -88%
Hydrogen	8% -11%
Sulphur	0% -6%
Oxygen	0% -1.5%
Nitrogen	0% -1%

2.2.2 Chemical Groups of Bitumen

Bitumen consists of two major chemical groups known as asphaltenes and maltenes. Further the Maltenes has three groups under it. The major chemical composition for bitumen is shown below [figure 2.1]

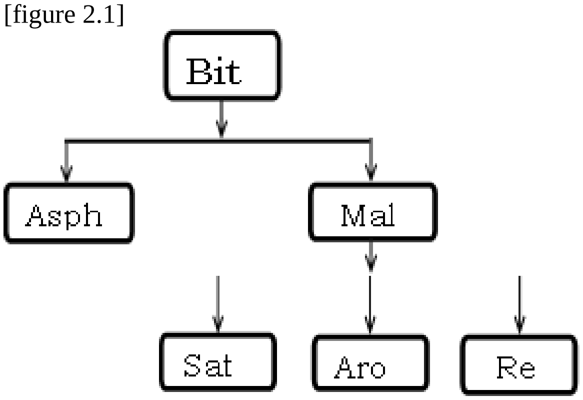

Figure 2.1ChemicalGroups of Bitumen

3.METHODOLOGY

3.1 Introduction

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.

3.2 Determination of rheological properties of bitumen

Rheological properties are utilized as execution parameter has favorable circumstances and disadvantage. The point is that it permits estimation of physical properties with wide temperature range at high and low recurrence, which is prone to be accomplished in the field because of movement. Dynamic shear rheometer need qualified individual with high encounter to work the element tests and additionally to get great rheological results. In this section a concise representation of the element shear rheometer (DSR) device and in addition the geometry and example creation and example measurement will be exhibited. In this section additionally a point of interest description of all rheological test methods received for the characterization of materials are given.

The examination led for the Strategic Highway Research Program (SHRP), testing system acquainted with describe the rheological, durability and failure properties of asphalt binders totally focused around the rheological properties. The examination results were examined in four principle points:(i) The viscoelastic nature of bitumen and its connection to performance of pavement; (ii) the crucial issues identified with these tests and; the sorts of traditional estimations are utilized now (iii) the idea of selecting the new test routines and the new properties; and (iv) how to analyze the new measured properties to thetraditional properties **[Bahia et al(1993)].**

3.3 Viscoelastic Properties of bitumen

Viscoelastic properties from Dynamic mechanical analysis through DSR indicate the

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reaction of a material as it is subjected to a cyclic stress. These properties may be communicated as far as dynamic storage modulus, dynamic loss modulus, and a mechanical damping term. The performance of bituminous binders is affected by viscosity and two critical rheological parameters as phase angle and complex modulus. The constraints and their effect over bitumen performance have been talked about quickly underneath**[Airey]**.

3.3.1 Viscosity of bitumen

Viscosity is defined as the resistance to flow. Bitumen is a visco elastic material that is at room temperature it act as a semi solid in high temperatures over 60°C it acts as a Newtonian fluid or low viscosity liquid. Hence viscosity is the main two properties checked to categories bitumen. Viscosity of bitumen is characterized in two different ways one being absolute or dynamic and other is Kinematic Viscosity. Absolute viscosity or dynamic viscosity (60°C) is defined as the resistance of a material when it is subjected to an external and controlled shear stress, which represents its internal resistance to the applied force and is calculated as given in equation 3.1

Absolute Viscosity (Pa·s)=K*t (3.1)

Where

K = calibration factor, (Pa · s/s) t = flow time(s)

Similarly Kinematic viscosity (135°C) can be defined as the resistance of a material, when it is subjected to no external force. Generally speaking, kinematic viscosity (cSt) is associated to absolute viscosity (cP) as a function of the material's specific gravity (SG) according to the equations 3.2.

Kinematic Viscosity (cst) = Dynamic Viscosity/ Density (3.2)

3.3.1.1 Measurement of Viscosity

Viscosity of bitumen can be measured in several methods such as through DSR, Brookfield rotational viscometer and Capillary Viscometer. The working principles of measurement are different for all the above mentioned viscometer and are briefly summarized below.

3.3.1.2 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.

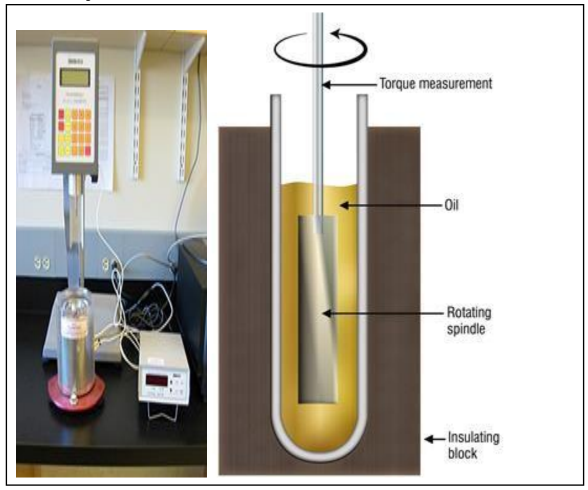

Figure 3.1: Rotational Viscometer and working principle **[**www.pavementinteractive.org**]**

This viscometer is meant for evaluation of viscosity at high temperature at least the temperature at which the sample begins to flow. Disadvantage of this instrument is that absolute or dynamic viscosity cannot be evaluated due to pivoting of spindle is not possible inside the fluid filled tube at low temperature.

4.EXPERIMENTAL PROGRAM

Introduction

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 Viscometer 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

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expansion the service life of the pavement, enhance its performance, meet the overwhelming traffic demands and at last saving the expense of maintenance.

Observing the production and cost, Sulfur being in powder structure utilized as modifier for modification of bitumen as shown in figure below.

5.RESULTS AND ANALYSIS

5.1 Introduction

This section portrays the rheological properties in terms of fatigue and rutting behavior results for unmodified bitumen and sulphur modified bitumen as well as short dissection of test information. The skeleton of testing covers was chosen keeping in mind the end goal to research that impact of sulfur in the bitumen properties subjected to distinctive loading parameters. The rheological properties of the different binders were portrayed utilizing dynamic shear rheometer over wide ranges of temperatures and frequencies. In this study both VG 30 bitumen and its modification with sulphur was tried and a summary of all results introduced underneath in tables and graphical structure.

6.CONCLUSIONS AND RECOMMENDATIONS

6.1 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 at140^{o}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 sand 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:

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