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Engineering Properties of Bituminous Binders Modified by Mixing 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.

I. INTRODUCTION
1.1 General: It is a great challenge in the development of infrastructure of Indian road transportation as it contains the 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 used for construction of highways in terms of Flexible pavement. One of the biggest advantage of using bitumen as a civil engineering material is its 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.

Bitumen is hydrocarbon material of either natural or pyrogenous origin found in gaseous, liquid, semisolid or solid form and is completely soluble in carbon disulphide and in carbon tetra chloride. Bitumen is a complex organic material and occurs either naturally or may be obtained artificially during the distillation of petroleum. Bituminous materials are commonly used in highway construction because of their binding and water proofing properties. The different grades of bitumen used for pavement construction work of road and airfields are called paving grade bitumen and those used for water proofing of structures and industrial floors etc. are called industrial grade bitumen.

Paving grade bitumen which is obtained from the distillation process of petroleum crude is extensively used in the construction of flexible pavement layers, particularly the surface and binder courses. At normal range of atmospheric temperature, bitumen is in semisolid state and remains highly viscous and sticky. When the paving grade bitumen is heated, it soften at rapid rate and attains fluid consistency and the viscosity decreases with further increase in

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temperature. For the construction of bitumen pavements, the paving grade bitumen is heated to temperature in the range of 130 to 175°C or even higher, depending upon the type and grade of bitumen selected and type of construction work. Mixing of bitumen with the aggregates is done in a hot mix plant to obtain hot bituminous mix.

Another entirely different approach of achieving fluid consistency of bitumen for use in road works without the need to heat the binder is the bitumen emulsion. Bitumen emulsion or emulsified bitumen is prepared by dispersing between in the form of fine globules suspended in water with the help of a suitable emulsifier. The properties of bituminous emulsions vary depending upon the properties of the bituminous binders. Its proportions with respect to water and the properties of the emulsifier. Appropriate type and a grade of bitumen emulsion may be selected for being directly sprayed as prime coat to tack coat and for being mixed with aggregates to prepare cold bituminous mix.

1.2 Objectives of Research: 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.

II. DISCUSSION

Based upon the various laboratory tests on cement when fly ash is mixed with it in different proportions the following conclusions can be made:
Based upon the various laboratory tests on bitumen when sulphur is mixed with it in different proportions the following conclusions can be made:

- The addition of sulphur affects the properties of the bitumen and bitumen mixes. These changes can be controlled to change the mechanical stability of bitumen pavements.
- Sulphur appears to improve the aging resistance of the mastics, thereby increasing the longevity of pavement infrastructure by reducing aging related cracks.
- Microstructural investigations of bitumen binders with sulphur demonstrated the crack arresting effect induced by the fly ash particles at low temperatures.
- The adddition of Sulphur does not affect the compactability of asphalt mixture therefore the conventional mix design procedures and pavement construction technologies are applicable for asphalt with Sulphur futheremore the use of round particles of Sulphur in bitumen can help reduce mixing and placing temperature and extend workability of mixures for effective placement in the field.
- Sulphur appears to effectively extent the asphalt binder used in the mix thereby reducing amount of bitumen binder needed for required performance.

The experiments conducted by adding various proportions of Sulphur with bitumen recommends that the appropriate range of Sulphur in bitumen can be varied from 10%.

2.1Physical properties of modified and un modified bitumen binder test results:

The physical properties test results are presented in a tabular form Table 5.2 for unaged and aged VG 30 and 2%S modified VG 30 bitumen binder.

From the result obtained it can be concluded that 2% S modified VG 30 bitumen enhanced the physical properties more than the VG 30 bitumen. The increases in absolute viscosity of modified binder than neat binder indicate towards the more stiffness value to withstand against rutting failure. The increase in softening point of modified binder than conventional binder indicates towards increase in temperature susceptibility. Also due to less penetration value of modified binder than neat bitumen indicate the high stiffness value to resist rutting.

There is an increase in elastic recovery percentage value which results in more elasticity to resist fatigue failure. Similarly there exists a very good adhesion between modified binder and aggregate to decrease striping value more than neat bitumen binder.

III. 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 at140ºC 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:

- Considering the criteria of complex modulus and Phase angle, addition of 2% sulphur by weight of VG 30 bitumen blended at 140^0C 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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