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PERFORMANCE BASED CHARACTERIZATION OF BITUMINOUS BINDER

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ABSTRACT:-Bitumen is fantastically used to create black-tops for avenues, turnpikes, and plane terminals. Due to the viscoelasticity thought of bitumen, it expect an otherworldly activity in the execution of the pavements where temperature and rate of load application have a magnificent effect. In India, the subtle elements for bituminous folios rely upon different exploratory tests which have no importance on their execution properties. In this examination, an undertaking has been made to mull over the rheological properties of bituminous folios normally used in India, at high and widely appealing field temperatures to the extent their execution characteristics. Considering a couple of components that impact the lead of bituminous clasp, the effects of assortments in temperature, rate of stacking and proportion of stacking have moreover been inspected. The modifications in the properties of typically used assessments (80-100 and 60-70) bitumen both unmodified and changed with piece flexible has been inspected. Moreover the effect of developing on the rheological properties of bituminous spreads has been thought about. It has been seen that the folios used in this examination satisfy the rutting and fatigue criteria as stipulated under the new thought of Superior Performing black-top (super clear).

I INTRODUCTION

With the quickly growing Indian street transportation framework, the street arrange is experiencing a testing advancement under National Highways Development Programs (NHDP), State Highways Improvement Programs (SHIPs), Bharat Nirman, PradhanMantri Gram SadakYojana (PMGSY) and so forth where an enormous aggregate of cash is being put by the Indian Government keeping in mind the end goal to achieve magnificent asphalt execution. The adaptable asphalts, which have bituminous layers in top, are more favored in India as these are more affordable as to both beginning and support costs. Bituminous folios generally utilized in surface courses are unmodified fasteners, for example, 60/70 or 80/100 bitumen (contingent upon the climatic conditions) and adjusted covers, for example, CRMB. The present Indian details have cleared suggestions about acknowledgment criteria for these covers considering diverse physical tests which are generally observational in nature. For instance, in India, infiltration tests which is an essentially an observational test used to demonstrate the hardness or delicateness of a folio by deciding the entrance of a standard needle under 100 grams of stacking for 5 seconds at 25°C . This test has no connection of bitumen with respect to its genuine field execution. While there is extraordinary interest and resulting speculation on bituminous street foundations, it is fundamental to consider utilization of execution based determinations of materials utilized in these developments with the goal that a definitive targets of such enormous ventures might be defended. As of late, Strategic Highway Research Program (SHRP) presented execution based folio particular in all out quality point of view in light of the shear vulnerability parameters, tending to each kind of asphalts disappointment. For India, the disappointment modes might be recognized as basic asphalt bothers coming about because of rutting and exhaustion breaking just as low temperature impacts are just constrained to just little part. Thinking about this, an endeavor is made in this task to ponder the execution related qualities of one unmodified bitumen i.e. bitumen 80/100 and a changed folio i.e. CRMB 55 which are ordinarily utilized for clearing in our nation. The principle target of this investigation is to relate the execution attributes of these fasteners to the folio compose. It is normal this can investigate the extent of improvement of new details for clearing covers in India.

II EXPERIMENTAL PROCEDURE

Rutting and fatigue cracking are the most common modes of failure for bituminous pavements which are mainly related to the rheological properties of the binders. To study the major rheological properties, experimental investigations are carried out using dynamic shear rheometer.

2.1 EVALUATION OF BITUMEN PROPERTIES

Goodrich J.L. (1998) reported that bituminous material exhibit viscoelastic response and the performance of the flexible pavements depend on rate of loading and temperatures. There are two types of tests that can be used to measure properties of the bitumen; conventional physical testing methods and fundamental rheological tests. The empirical physical tests fail to characterize the performance of bitumen binders and are related to a narrow range of temperature. The performance of bituminous binders can be measured by means of rheological parameters because the tests can be done under wide range of temperature and frequency.

Bahia, et al. (1993) presented in the research conducted for the Strategic Highway Research Program (SHRP), a new testing method to characterize the rheological properties of binders. The benefit of this technique is that it provides measurement of rheological properties at different frequencies with wide temperature range and is directly related to the field performance.

2.2 DYNAMIC SHEAR RHEOMETER

Dynamic shear rheometer is used to measure visco-elastic properties at high and intermediate temperature. This device employs a dynamic oscillatory load, where sinusoidal shear stress is applied in the form of sinusoidal time function. The bitumen's sample is sandwiched between two parallel plates where the lower plate is fixed and upper plate is movable. The dynamic load can be presented as sinusoidal time function.The test simulates the shearing action of traffic at a certain speed and two important rheological parameters are determines which are used to predict pavement performance.

- the complex shear modulus (G*) and
- the phase angle (δ).

Roberts, et al., (1996) mentioned that the data acquisition unit records the test temperature, applied load, loading frequency and deflection angle during the test cycles, then directly sends the test data to the personal computer which calculates the rheological parameters such as the shear stress, shear strain, complex modulus and phase angle and presents it in the form of table and figure.

2.3 Rheological Properties

Briscoe (1987) demonstrated the advantage of using (DSR) to describe the viscous and elastic behavior of bituminous binders at high and intermediate service temperatures. From the rheological test, two main parameters are obtained i.e. complex shear modulus (G*) and phase (δ). Complex modulus (G*) is defined as the total resistance of the binder to deformation when repeatedly sheared. The complex shear modulus (G*) consists of two components;

- **Storage modulus, (G′):** - It is the elastic (recoverable) component, and is related to the amount of energy stored in the sample during each testing cycle.
- **Loss modulus, (G″):** - It is the viscous (non-recoverable) component, and related to the energy lost during each testing cycle through permanent flow or deformation.

2.4 TEST SPECIFICATION

The rheological tests were done according to the AASHTO Designation: T 315-08 (Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)). This test method contains the determination of the dynamic shear modulus and phase angle of bitumen binder when tested in dynamic (oscillatory) shear using parallel plate test geometry. It is applicable to binders having dynamic shear modulus values in the range from 100 Pa to 10 MPa obtained between 6 and 88°C at an angular frequency of 10 rad/s.

2.5 BINDERS USED Bitumen binders used in this study were (80-100 and 60-70) penetration grade bitumen, which is the most widely used in India. The second binder is crumb rubber modified bitumen which is also commonly used in India.

2.6 SPECIMEN GEOMETRY

The specimen geometry was chosen according to the test type, condition and specification. The specimen geometry at high temperature should have big diameter (25mm) with small thickness (1mm) to save the specimen from melting. At intermediate temperature the specimen should have small diameter (8mm) with high thickness (2mm) to prevent it from brittle crack.

2.7 BITUMEN BINDER RHEOLOGY TESTS

The rheological properties and fatigue resistances were performed using three different binders. The tests were performed under range of frequency and temperatures.

1. Characterization of binders under standard conditions
2. Amplitude Sweep Test
3. Frequency Sweep Test
4. Temperature Sweep Test
5. Multiple Shear Creep Recovery Test
6. Fatigue behavior test

1.Characterization of binders under standard conditions:- The test is conducted under certain standard conditions as given by SHRP which is used to characterize the bituminous binders. The test conditions are 60°C temperature, 120 Pa stress, and 10 rad/sec frequency with the 25mm diameter plate having specimen thickness 1mm for unaged and TFO aged binders. For PAV aged binders, the test temperature was changed to 40° C with 8mm diameter plate having specimen thickness 2mm.

2.Amplitude Sweep Test:- A stress sweep was first conducted to determine the flow behavior for different binders. Measurements were performed at 60°C for unaged and TFO aged binders and 40 ° C for PAV aged binders with a shear stress range from 10Pa to 10 kPa and at 10 Hz. The complex shear modulus G* versus stress/strain plot was used to determine the linear viscoelastic region.

3.Frequency sweep Test:- Frequency sweep tests were performed on bituminous binders. The samples were all poured and trimmed at the PG temperature (60°C for unaged and TFO aged binders and 40° C for PAV aged binders). All of the frequency sweep tests were performed from 1 to 50 rad/s under a stress of 500 Pa.

4.Temperature Sweeps Test:- Dynamic Shear Rheometer test was conducted by using a temperature sweep starting from 20ºC to 80ºC, while the frequency was fixed at 10 Hz under a stress of 500 Pa. Parallel plates with diameter of 8 mm and 2 mm gap were used.

5. Multiple Shear Creep Recovery Test:- Using the Dynamic Shear Rheometer (DSR), an one-second creep load is applied to the short term aged binder sample (TFO aged). After the 1-second load is removed, then sample is allowed to recover for 9 seconds. The test is started with the application of a low stress (0.1 kPa) for 10 creep/recovery cycles then the stress in increased to 3.2 kPa and repeated for an additional 10 cycles.

6. Fatiguebehavior test:-Bituminous pavements exhibit fatigue cracking under repeated traffic load in the intermediate temperature range. One of the most important tests used to determine fatigue behavior for bitumen binder is oscillatory time sweeps test.

Bahia, H., and Anderson, D. A. (1993) explained that fatigue damage in viscoelastic materials can be evaluated using stored and dissipated energies. The energy balance is influenced by rheological properties of the binder, which are in turn functions of temperature and the rate of loading. In this study dissipated energy concept is used to determine the fatigue life for PAV aged binder. The dissipated energy as outlined by Pronk is given below:

$$Wi = \Pi * \tau 2 * \sin(\delta)/G^*$$

Where:

Wi: Dissipated energy per cycle τ : Applied stress (Pa)

G *: Complex modulus (Pa) δ: Phase angle (Degree)

The fatigue test was performed on long term (PAV) aged binder with 8-mm plates and 2.0 mm thickness. A time sweep was performed, in which an oscillating stress of 10 Pa and 10 kPa was applied with constant frequency 10 Hz.

Fatigue can be minimized by controlling the dissipated energy. The relationship between the fatigue life of a binder (Nf) and the energy input (Wi) is given by a conventional power law model:

$$Nf=K1 *(1/Wi) K2$$

After the fatigue parameters are calculated, K1 and K2 are used to describe the fatigue behavior of the bitumen binder.

III RESULTS & DISCUSSION

3.1 Characterization of binders under standard conditions

- The test is conducted under certain standard conditions as given by SHRP which is used to characterize the bituminous binders.
- The following specifications are provided by SHRP for different binders:
- To minimize rutting, the stiffness value G*/sin (δ) of the binder after TFO must be greater than 2.2kPa at the maximum 7-day average pavement design temperature.

- To control possible tenderness, if ageing does not occur during construction, the stiffness value G*/sin (δ) of the original binder does not exceed 1.0 kPa at the same pavement temperature.
- To minimize cracking, the stiffness value G* x sin (δ) of the binder after PAV must be less than 5000 kPa at the intermediate pavement design temperature. This is to minimize the work dissipated.

3.2 Stress Sweep Test Result

Stress sweep testing was carried out using the dynamic shear rheometer, which is used to determine the linear visco-elastic limits as a percentage decrease of the initial complex shear modulus value at selected temperature, frequency and the stress.The results of different binders were compared, which could help to determine the linearity limits. Based on the linear limits, the input parameter for other sweep tests is chosen for different bitumen binders.For the majority of binders; it has been found that the linear range lies between 100 Pa to 8000 Pa. To make the tests much easier, the same stress level was chosen for all bituminous binders. Therefore, 500 Pascal was chosen as the constant stress used as input parameter for frequency sweep test for all binders.

3.3 Frequency Sweep Test Result

The highest loading frequency (50 Hz) was selected because it specified high traffic speeds, and the lowest testing frequency (0.1 Hz) was selected because it intended loading in slow moving traffic conditions.

3.4 Temperature Sweep Test Result

Temperature has great effect on bitumen binder properties such as stiffness. As expected, shear modulus for all binders is a function of temperature: the higher the testing temperature, the lower the complex shear modulus.

3.5 Multiple Shear Creep Recovery Test

In the MSCR test, higher levels of stress & strain are applied to the binder, better representing what occurs in the actual pavements. The Jnr parameter (creep compliance) represents the rut resistance and the amount of recovered strain from the test identifies the presence of polymer.This shows that the permanent strain that is accumulated of the neat binder is more than that of modified binder. Hence, this provides an indication of the delayed elastic response of the binder which is an indication that the binder has a significant elastic component at that test temperature.From the above results, it is found that the elastic recovery in 80-100 binder is 0% and in CRMB is 68.22%. So, the 80-100 binder does not recover its original shape when tension is released but CRMB recovers to its original when load is withdrawn at a faster rate. This degree of elastic recovery was used as an indicator of permanent deformation in pavement materials.

3.6 Fatigue behavior

Test results include measurements of complex modulus (G*) and phase angle (δ) as a function of the time in the DSR. Excel work sheets were used to calculate dissipated energy to get number of cycles to failure. The relation between DE and number of load cycles to failure were used to determine fatigue life parameter K1 and K2. From the result analysis given in figure (5.11), it can be seen that a linear fit is obtained between dissipated energy and number of cycles. The classic power law relationship is used to establish the relationship relating number of failures to dissipated energy as given in table (5).In conclusion from laboratory fatigue test, the fatigue behavior of crumb rubber modified bitumen was found to be significantly improved compared to base bitumen. Crumb rubber modified bitumen has the higher fatigue life; followed by 60-70 as observed from laboratory fatigue test results. On the other hand, 80-100 grade bitumen shows no significant effect in fatigue life.

IV CONCLUSION

The main objectives of this research were to characterize the bituminous binders. The additions of modifier to the pure bitumen improve the viscoelastic behavior of the bitumen and change its rheological properties. Also the process of ageing improves the rheological properties as compared to aged ones. After conducting laboratory tests on binders and after analyzing the data and comparing the results, the following conclusions have been drawn:

- From the results, it appears clearly that when the rubber was added to the base bitumen phase angle decreases which directly affects the elastic recovery properties and helps the bitumen to be fully recovered when the load is removed and helps for resisting rutting.
- A decrease in phase angle is generally observed after ageing tests, when compared with the original ones. Since phase angle is a measure of the ratio between loss modulus and storage modulus, the increased phase angle (loss tangent) implies that ageing leads to a greater increase in storage modulus (elastic component, G`). The high value of G` is an advantage since it will not cause further rutting during service.
- From MSCR tests, it is observed that the elastic recovery in 80-100 binder is much less than that of CRMB. So, the 80-100 binder does not recover its original shape when tension is released but CRMB recovers to its original when load is withdrawn at a faster rate. This degree of elastic recovery was used as an indicator of permanent deformation in pavement materials.
- The above performance related tests indicate that CRMB is superior to 80/100. The result showed significant improvement in fatigue behavior of modified binder used when compared with the neat binders.

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