IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ASSESSMENT OF BITUMINOUS BINDER PERFORMANCE PROPERTIES

[1]Mr. Ankit Kumar Agrahari, [2]Mr. Mehtab Aalam Darjee,
[3]Mr. Ashish Pathak, [4]Mr. Kamal Ansari, [5] Dr. Akshit Lamba

[1, 2, 3, 4] Students, [5]Assistant Professor,
[1, 2, 3, 4, 5] Department of Civil Engineering
[1, 2, 3, 4, 5] Kalinga University Raipur

Abstract: The main application of bitumen is in the construction of airport, highway, and road pavements. Because bitumen is viscoelastic, temperature and the pace at which loads are applied have a significant impact on bitumen performance in pavements. The standards for bituminous binders in India are based on many empirical tests that little affect the bituminous binders' performance characteristics.

This study aims to investigate the performance characteristics of bituminous binders, which are widely used in India, with respect to their rheological properties at both high and intermediate field temperatures. Variations in temperature, loading rate, and amount have all been examined in relation to the various factors that impact bituminous binders' behavior. It has been researched how the characteristics of bitumen, both unaltered and amended with crumb rubber, have changed in two regularly used grades (80-100 and 60-70). Additionally, research has been done on how age affects bituminous binders' rheological characteristics. It has been noted that the binders employed in this study meet the fatigue and rutting requirements outlined in the revised definition of Superior Performing Asphalt Pavement (super pave). The goal of the study is to comprehend how these characteristics affect bituminous materials' resistance, stability, and durability under various road conditions.

***Index Terms* – Bitumen, Rheological Properties, Performance characteristics, Binders.**

I. INTRODUCTION

The Indian government is investing heavily in road infrastructure development programs like National Highways Development Programs (NHDP), State Highways Improvement Programs (SHIPs), Bharat Nirman, and Pradhan Mantri Gram Sadak Yojana (PMGSY) to improve pavement performance. Flexible pavements with top-layer bituminous layers are popular in India due to their affordability and ease of installation and maintenance. Current Indian specifications provide acceptance criteria for these binders based on empirical physical tests, but there is no connection between bitumen's actual field performance and this test. To address all types of pavement failure, the Strategic Highway Research Program (SHRP) introduced performance-based binder specifications based on shear susceptibility parameters. This project investigates the performance-related properties of two modified binders, CRMB 55 and bitumen 80/100, commonly used for paving in India. The primary goal is to establish a correlation between the binder type and these binders' performance characteristics, which could help develop new specifications for paving binders in India.

The literature on bituminous pavements' rheological characteristics is evaluated in four sections: bitumen's chemical makeup and viscoelastic characteristics, classification of frequent flexible pavement distresses, aging processes in pavements, and laboratory procedures used to assess bituminous binders' rheological characteristics. The most common types of bituminous pavement failure, rutting and fatigue cracking, are mostly caused by the binders' rheological characteristics. Dynamic shear rheometers are used in experimental research to examine the main rheological parameters.

This chapter presents the binder's rheological characteristics, fatigue behavior findings, and a synopsis of analytical test results. The rheological characteristics of the various binders were assessed using a dynamic shear rheometer across a broad spectrum of frequencies and temperatures.

1. Bitumen Modifiers

Bitumen modification is a process used to improve a material's initial qualities when it doesn't meet traffic, pavement structure, or climate needs. Polymer modified bitumen has been used for years to produce superior performance. Modifiers are used to prevent fatigue cracking in pavements by producing softer binders at low temperatures and stiffer ones at high service temperatures to resist rutting. Modifiers directly affect pavement performance by stiffening the bitumen.

2. Aging of Bitumen

Aging in bituminous materials refers to the changes that occur in the material over time due to exposure environmental factors, such as sunlight, temperature changes, and moisture. Aging can affect the properties of bituminous materials, such as stiffness, viscosity, and durability.

There are two types of aging in bituminous materials: -

- Short Term Aging
- Long Term Aging

3. RHEOLOGICAL PROPERTIES OF BITUMINOUS MATERIALS

Rheological properties of bituminous materials refer to their behavior under stress or deformation, particularly in response to changes in temperature, time, and applied load. Bituminous materials, commonly used in road construction and waterproofing, exhibit viscoelastic behavior, meaning they possess both viscous (flow-like) and elastic (spring-like) characteristics.

Key rheological properties include:

- **Viscosity**: The resistance of bituminous materials to flow. It can vary with temperature and shear rate. Higher viscosity indicates greater resistance to flow.

- **Elasticity**: The ability of bituminous materials to return to their original shape after deformation. This property is essential for withstanding traffic loads and thermal stresses.

- **Viscoelasticity**: Bituminous materials exhibit both viscous and elastic behavior simultaneously. This property enables them to deform under stress while also partially recovering their original shape.

- **Temperature** Susceptibility: Bituminous materials undergo significant changes in rheological properties with temperature variations. This property influences their performance under different climatic conditions.

- **Shear Stress and Strain**: Rheological testing involves measuring the response of bituminous materials to applied shear stress and strain. This helps characterize their flow and deformation behavior.

II. LITERATURE REVIEW

This paper aims to evaluate the literature on bituminous pavements' rheological characteristics, which are divided into four sections. The first part discusses bitumen's chemical makeup and viscoelastic characteristics, while the second section focuses on classifying frequent flexible pavement distresses. The third section covers aging processes in the pavements, and the final section outlines laboratory procedures used to assess the bituminous binders' rheological characteristics.

Flexible pavements are sturdy surface materials placed on surfaces meant for foot or vehicle traffic, such as roads or sidewalks. They are divided into two categories: flexible pavements and stiff pavements. The most severe distresses that affect flexible pavements are rutting, which happens at high temperatures, and cracking, which happens at intermediate and low temperatures. These distresses are responsible for the pavements' shorter service lives and higher maintenance expenses.

The performance of flexible pavements depends on the main component, bitumen, which controls the viscoelastic properties during production in the plant and service on the road. Their mechanical behavior is dependent on both the temperature and rate of loading. At low temperatures and short loading times, bitumen behaves as elastic solids, while at high temperatures and long loading times, they behave as simple viscous liquids. At intermediate temperatures and loading times, the behavior is more complex.

Bitumen is composed of two major chemical groups: asphaltenes and maltenes. Asphaltenes are highly polar, complex aromatic materials with higher molecular weight than maltenes, while maltenes are divided into three components: 5-10% bitumen includes both waxy and non-waxy saturates. The polar nature of the aromatics gives fluidity and viscosity to the bitumen, while resins give adhesion properties and ductility for the bituminous materials.

Viscoelastic material is defined as material which stores and dissipates mechanical energy in response to a mechanical stress. Bitumen's mechanical behavior depends on both the temperature and rate of loading. Modifiers are used when a material fails to meet the needs of traffic, pavement structure, climate, or both, improving the substance's initial qualities. Polymer modified bitumen has been utilized for a long time to produce superior performance.

The aging process of bitumen causes embrittlement and hardening of the material during application and use. It is widely acknowledged that the aging process of bituminous binders is one of the primary reasons for pavement cracking and disintegration. There are two stages in which the binder hardens: short-term aging, due to the loss of binder volatile components during mixing, and prolonged oxidative hardening due to oxidative hardening over service life.

Rheology science is the study of material deformation and is a branch of continuum mechanics. The rheological characteristics are correlated with the rutting behavior of pavements at high temperatures, and pavement fatigue cracking is influenced by rheology. Numerous pavement distresses are thought to be connected to binders' rheological characteristics.

III. METHODOLOGY

- **Sampling:** Obtain samples of the bituminous binder from the source, such as refineries or suppliers, ensuring that the samples are representative of the material being used in the construction.

- **Testing Standards:** Identify relevant testing standards based on the specific requirements and regulations of your region or project. Common standards include those from ASTM International, AASHTO, or local regulatory agencies.

- **Physical Properties Testing:**
  - **Penetration Test:** Measure the consistency of the binder by determining the depth in tenths of a millimeter to which a standard needle penetrates the binder sample under specific conditions of loading, time, and temperature.

- **Softening Point Test:** Determine the temperature at which the binder softens by measuring the temperature at which a steel ball sinks a specified distance into the sample.
- **Ductility Test:** Assess the binder's ability to stretch without breaking by measuring the distance a standard briquette can be stretched before breaking at a specified temperature and rate.

❖ **Chemical Properties Testing:**

- Thin-Film Oven Test (TFOT): Evaluate the aging properties of the binder by exposing it to elevated temperatures in an oven for a specified duration.
- Rolling Thin-Film Oven Test (RTFOT): Simulate the short-term aging that occurs during the mixing and compaction of asphalt mixtures by exposing the binder to heat and air in a rolling thin-film oven.

❖ **Performance Testing:**

- Dynamic Shear Rheometer (DSR): Measure the stiffness and viscoelastic properties of the binder across a range of temperatures and frequencies to assess its suitability for varying climatic conditions.
- Multiple Stress Creep Recovery (MSCR): Determine the binder's resistance to rutting and thermal cracking by subjecting it to repeated loading and recovery cycles at different temperatures.

❖ **Aggregate-Binder Compatibility Testing:**

- Aggregate Immersion Test: Assess the adhesion between the binder and aggregates by immersing aggregate particles in the binder and evaluating the extent of coating and stripping.

❖ **Data Analysis and Interpretation**: Analyze the test results to assess the performance properties of the binder and identify any deficiencies or areas for improvement. Compare the results against specifications and standards to determine compliance.

❖ **Reporting:** Document the testing methodology, procedures, results, and any recommendations in a comprehensive report for reference by project stakeholders and regulatory authorities.

IV. RESULT

This paper presents the binder's rheological characteristics, fatigue behavior findings, and a synopsis of the analytical test results. Using a dynamic shear rheometer, the rheological characteristics of the various binders were assessed throughout a broad spectrum of frequencies and temperatures. In the sections that follow, a table and graphical summary of the test findings are provided.

Table 1: A summary of the test results is presented in Table

Table 2. BINDER CHARACTERISATION UNDER STANDARD CONDITIONS

	TEST CONDITIONS		RESULTS OBTAINED					REMARKS	
Binder Type	Temperature °C	Angular Frequency rad/s	Phase Angle °	Strain	Complex Modulus Pa	G*/Sin(δ) Pa	G* x sin(δ)	Specifications	Remarks
°C	60	10.03	88.21	0.0487	4183.59	4185.64		>1kPa	Passed
rad/s	60	10.03	76.13	0.014	8564	8822		>1kPa	Passed
°	60	10.03	87.89	0.0479	4594	4597.25		>2.2kPa	Passed
Strain	60	10.03	74.91	0.0095	9120	9447.4		>2.2kPa	Passed
Pa	40	10.03	65.17	0.012	528400		479500	< 5000kPa	Passed
80-100	40	10.03	68.79	0.012	250400		233400	< 5000kPa	Passed
crmb	40	10.03	60.65	0.012	749700		653400	< 5000kPa	Passed

Table 2: MSCR Recovery Calculations (80-100)

Stress Cycle	γ0	γc	γ1	γr	γ10	Recovery
0	0.000124	0.01264	0.012516	0.01267	0.012546	-0.2397
1	0.000119	0.01209	0.011971	0.01212	0.012001	-0.2506
2	0.000125	0.01157	0.011445	0.0116	0.011475	-0.26213
3	0.000117	0.01121	0.011093	0.0112	0.011083	0.090145
4	0.000112	0.01054	0.010428	0.01047	0.010358	0.671276
5	0.000109	0.01013	0.010021	0.01001	0.009901	1.197497
6	0.00011	0.01013	0.01002	0.009576	0.009466	5.529108
7	0.000105	0.009155	0.009051	0.009576	0.009472	-4.65168
8	9.93E-05	0.008707	0.008608	0.008573	0.008474	1.556748
9	9.84E-05	0.008308	0.00821	0.008156	0.008058	1.851498
10	9.72E-05	0.007909	0.007812	0.007746	0.007649	2.08659
						0.688978

Table 3: MSCR Recovery Calculations (CRMB)

Stress Cycle	γ0	γc	γ1	γr	γ10	Recovery
0	1.94E-05	0.000394	3.74E-04	0.000157	1.37E-04	63.28
1	1.81E-05	0.000369	3.50E-04	0.000144	1.26E-04	64.10
2	1.76E-05	0.00035	3.32E-04	0.000133	1.15E-04	65.42
3	1.64E-05	0.000334	3.17E-04	0.000124	1.07E-04	66.25
4	1.53E-05	0.000317	3.01E-04	0.000112	9.63E-05	68.03
5	1.49E-05	0.000296	2.81E-04	0.000102	8.71E-05	68.97
6	1.41E-05	0.000278	2.64E-04	0.000102	8.79E-05	66.71
7	1.35E-05	0.000266	2.52E-04	8.74E-05	7.39E-05	70.69
8	1.31E-05	0.000254	2.41E-04	8.18E-05	6.87E-05	71.46
9	1.24E-05	0.000243	2.31E-04	7.79E-05	6.55E-05	71.62
10	1.21E-05	0.000231	2.19E-04	6.94E-05	5.73E-05	73.88
						68.22

Table 4: Fatigue Test Result

Type of Bitumen	Log Fatigue life	Fatigue life	
80-100	0.1228ln(DE)-0.4239	Nf = 0.6545 (1/DE)^-0.1228	
		K1=0.6545	K2=-0.1228
60-70	0.1091ln(DE)-0.3787	Nf = 0.6847 (1/DE)^-0.1091	
		K1=0.6847	K2=-0.1091
CRMB	0.0574ln(DE)-0.1994	Nf = 0.8192 (1/DE)^-0.0574	
		K1=0.8192	K2=-0.0574

Figure 1: Dynamic Shear Rheometer

Figure 2: Thin Film Oven for short term aging

Figure 3: Pressure Vessel Aging for long term aging

Figure 4: Vacuum Oven for degassing

V. CONCLUSION

This research aimed to characterize bituminous binders by examining their viscoelastic behavior and rheological properties. The addition of modifiers to pure bitumen improved its viscoelastic behavior and rheological properties. The process of ageing also improved the rheological properties. Laboratory tests revealed that adding rubber to the base bitumen reduced phase angle, affecting elastic recovery properties and resisting rutting. Ageing tests generally showed a decrease in phase angle, indicating a greater increase in storage modulus (elastic component, G`). The high value of G` prevents further rutting during service. MSCR tests showed that 80-100 binder's elastic recovery is less than that of CRMB, which recovers to its original shape faster when load is withdrawn. This indicates that CRMB is superior to 80/100 binder and significantly improves fatigue behavior compared to neat binders. The results suggest that modified binder use can improve pavement materials' performance.

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, D.C.; 1994.

[2] Bahia H. and Anderson D.A.: The new proposed rheological properties of asphalt binders: why are they required and how do they compare to conventional properties. ASTM Conference: Physical Properties of Asphalt Cement Binders, Texas, pp.1-27; 1993.

[3] Bahia, H., and Davies. R.: Effect of crumb-rubber modifiers on performance-related properties of asphalt binders. Proceedings of the Association of Asphalt Paving Technologists, Volume 63, pp.414-449; 1994.

[4] Bahia, H. A.: Critical Evaluation of asphalt modification using strategic highway research program concepts. Transportation Research Record Volume 1488, Washington D.C., pp. 82- 88.; 1995.

[5] Briscoe O. E.: Asphalt Rheology – Relationship to Mixture. ASTM Standard Test Designation; 1987.

[6] Clyne Timothy R, Marasteanu Mihai O.; Inventory of Properties of Minnesota Certified Asphalt Binders; Minnesota Department of Transportation Research Services Section; University of Minnesota; Department of Civil Engineering; April 2004.

[7] Goodrich J.L.: Asphalt and polymer modified asphalt properties related to the performance of asphalt concrete mixes, Journal of the Association of Asphalt Pavement Technologists, Volume 57, pp.116-160; 198.8

[8] Isacsson. U. and Lu, X.: Testing and appraisal of polymer modified road bitumen. Material structure Volume 28, pp. 139–159; 1995.

[9] Jones David R. and Kennedy Thomas W.: THE ASPHALT MODEL: Results of the SHRP Asphalt Research Program, SHRP A-001 Contract, Center for Transportation Research, University of Texas, Austin, USA; 1994.

[10] Mahrez Abdelaziz, Mohamed Rehan KARIM; Dept. Of Civil Engineering University Malaya 50603 Kuala Lumpur Malaysia; Rheological Evaluation Of Ageing Properties Of Rubber Crumb Modified Bitumen; Journal of the Eastern Asia Society for Transportation Studies, Vol.5, October, 2003

[11] Pronk, A.C., In Proceedings of the Eighth International Conference on Asphalt Pavements, Seattle, 1997, 987-994.

[12] Oliver John: Crumb Rubber Asphalt Fatigue Study-Phase 1: Binder Testing ARRB Transport Research Ltd.; 1982.

[13] Roberts, F.L., Kandhal, P.S., Brown, E. Ray, Lee, D., Kennedy, T.W.: Hot Mix Asphalt Materials, Mixture Design and Construction, NAPA Research and Education Foundation, Lanham; 1996.

[14] Terrel, R. L.: Fatigue Behavior: Field Observations and Analytical Predictions. American Society for Testing and Materials, ASTM Report 508; 1971.

[15] Van der Poel., C.: A general System Describing the Viscoelastic Properties of Bitumen and its Relation to Routine Test Journal of Applied Chemistry Volume 4, pp.221-232; 1954.