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Comparison of High and Low Temperature Properties of Dual Modified Asphalt Binders with Polyphosphoric Acid and Polymer Modified Bitumen Using Rheological Tests

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Abstract

The main objective of this study was to investigate the properties of asphalt binder mixtures at both high and low temperatures. To achieve this, two types of admixtures were selected and combined, resulting in a technology known as dual modified asphalt binders. Extreme temperatures during summer and winter can lead to significant issues such as cracking and rutting in asphalt binder pavement. In order to address these problems, a comprehensive investigation was conducted using PPA (Polyphosphoric Acid) and PMB40 (Polymer Modified Bitumen 40) To analyze the impact of these admixtures, asphalt concrete mixtures were prepared with varying dosages. For PPA, dosages of 0.5%, 1.0%, 1.5%, and 2% by weight of binder were used, while for Polymer Modified Bitumen40, dosages of 10%, 20%, 30%, 40%, and 50% by weight of binder were employed to reach the optimum content of VG 30 + PPA. The study also involved conducting rheological tests on the asphalt concrete mixtures, including the optimum contents of VG30, PPA mix, and the dual mix asphalt. These tests helped to demonstrate the superior performance of the dual modified asphalt binders in both high and low temperature conditions, effectively addressing the issues of cracking and rutting in asphalt pavement.

Keywords: Polymer modified bitumen, PPA, dual modified, DSR, BBR

INTRODUCTION

Flexible pavements are frequently chosen over rigid pavements because of their lower construction costs, despite their higher life cycle costs. However, as many case studies have shown, stiff pavements have a high initial construction cost but a low life cycle cost [7]. With the increasing traffic channelization, heavy traffic flow, and heavy axle loads in modern highway traffic, asphalt pavement faces serious issues of cracking and rutting, especially due to drastic temperature changes in winter and summer. To address the problem of low temperature cracking and improve thermal stability, research on new types of asphalt modifiers is necessary [6].

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The revised definition of bitumen states that it is a non-crystalline, viscous, viscoelastic liquid with adhesive and water-proofing properties at room temperature [9]. It is categorised as a visco-elastic substance because of how it behaves—it is neither entirely elastic nor purely viscous.

Numerous scholars have explored different approaches to enhance the anti-rutting performance of pavement materials and structures. They have focused on selecting modified asphalt binders and high-quality aggregates to improve material performance by controlling asphalt content, gradation, and incorporating polymer and anti-

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rutting agents [10]. The combination of modified asphalt and high-quality aggregates enhances the binding between aggregates and binder, leading to improved anti-rutting performance in asphalt binder mixtures. Higher ratios of coarse-to-fine aggregates in asphalt mixtures also contribute to better anti-rutting performance. Adding low-density polyethylene to asphalt binder mixtures has proven to efficiently enhance anti-rutting performance [12].

In relation to low temperature cracking resistance, incorporating fibers into bituminous mixtures has been found to decrease the likelihood of premature cracking and improve fatigue resistance. Fibers have been successfully incorporated into asphalt mixtures used in toll stations, bridges, and airports, as observed in several studies [6].

Thermal cracking, especially in cold climates, is a common problem in asphalt pavement. Minimizing this type of cracking is crucial for ensuring the longevity of pavements. Thermal stresses generated during temperature fluctuations can exceed the tensile strength of the bituminous binder mixture, resulting in low temperature cracking. Material factors such as the qualities of bituminous binders play a significant role in low temperature cracking. Therefore, many countries include low-temperature tests and criteria in binder standards [15].

Incorporating fibers into the base bituminous mixture yields several benefits, including increased absorption of asphalt binder, a thicker binder film on aggregate surfaces, higher viscosity of asphalt mortar, and a higher softening point. These improvements enhance the durability of fiber-modified asphalt mixtures at high temperatures and their resistance to water stripping at the asphalt-aggregate interface [14]. Research has demonstrated that incorporating basalt fibers specifically enhances the performance of asphalt mixtures in pavement applications [13].

While the addition of anti-rutting agents significantly improves anti-rutting performance in asphalt binder mixtures at high temperatures, its impact at low temperatures is less pronounced. Conversely, the inclusion of lignin fiber significantly enhances the low-temperature performance of asphalt binder mixtures, albeit with a minor improvement in high-temperature performance. Consequently, no single additive can simultaneously enhance all aspects of bituminous mixture pavement performance. However, combining lignin fiber and rubber powder has been found to enhance the overall performance of asphalt mixtures [11].

To simultaneously address cracking and rutting at both low and high temperatures, this study employs a double-adding technology. The performance effects of the dual admixtures on anti-cracking and anti-rutting properties of asphalt binder mixtures were investigated using various mixture compositions. The objective is to optimize the performance of asphalt mixtures and develop robust solutions capable of withstanding a wide range of temperatures [16]. By incorporating various additives and fibers, researchers aim to improve the durability and stability of asphalt mixtures in different climatic conditions. These enhancements include increasing the absorption of asphalt binder, improving the binder-aggregate bond, and enhancing the viscosity and softening point of asphalt mortar. The objective is to create asphalt mixtures that can maintain their structural integrity and resist rutting, cracking, and moisture damage, regardless of whether they are exposed to high or low temperatures. By achieving this goal, the longevity and performance of asphalt pavements can be significantly improved, reducing maintenance costs and enhancing road safety. Researchers have found that combining lignin fiber and rubber powder leads to improved overall performance of asphalt mixtures. To more efficiently enhance pavement performance in asphalt mixtures, it is important to identify and regulate the most influential element.

Elastomers attempt to increase the base bitumen's elastic recovery since they possess some elastic properties. some of these elastomers' impact on the distresses. Consider SBS, one of the more popular elastomers. SBS exhibits favourable effects on low temperature cracking, fatigue cracking, and permanent deformation [8].

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LITERATURE REVIEW

The study conducted by Pedro Romero and Chun-Hsing Ho focused on utilizing bituminous mixture beams in the Bending Beam Rheometer (BBR) test. The objective was to tackle concerns regarding the sources of unpredictability that arise when using bituminous mixture beams for BBR tests. The researchers investigated the impact of dimensional changes on beam deflection accuracy through the use of finite element method simulations and statistical analyses [1].

The study found that, at low temperatures, the stiffness of asphalt binder mixes was minimally affected by air voids when using nominal maximum aggregate sizes (NMAS) of 4.75mm, 9.5mm, and 12.5mm. Bartlett's test confirmed the statistical validity of the homoscedasticity of variances among the NMAS mixture groups, indicating that the dimensions and assessments of these mixtures were suitable for BBR tests.

Furthermore, a linear viscoelastic investigation (LVE) was conducted to analyze the thermal characteristics of the NMAS mixed beams within the three mixture groups. The LVE results demonstrated that the aggregate size did not significantly influence the low-temperature properties of the asphalt binder mixtures within these groups [2].

The study also provided guidance to highway agencies on performing Quality Assurance/Quality Control (QA/QC) activities by utilizing BBR test data and applying a range of self-assurance intervals. The researchers examined the sources of inconsistency during BBR testing and discussed them through experimental and numerical studies. The use of asphalt binder mixture beams in BBR tests to regulate thermal-induced failures in asphalt binder pavements was shown to be appropriate for QA/QC purposes, supported by experimental and statistical evidence [3].

In the study conducted by Raul Velasquez, Adam Zofka, Mugurel Turosa, and Mihai O. Marasteanu, the researchers explored the use of a bending beam rheometer to conduct creep testing on bituminous mixture beam specimens. The article outlines a test technique for this purpose and addresses the associated challenges [4].

The study begins by presenting a comprehensive sample preparation protocol for the bituminous mixture beams. Experimental data is then provided to assess the consistency of the method. Statistical tools are employed to compare and analyze the results obtained from three different loading procedures [5].

Additionally, the researchers conducted tests on beams of various sizes to make a preliminary assessment of the low-temperature behavior of the typical volume element in asphalt mixtures. This evaluation allows for an understanding of how asphalt mixtures respond to low temperatures and provides insights into their performance under such conditions.

Overall, the study contributes to the development of a testing methodology using the bending beam rheometer for creep testing on bituminous mixture beam specimens. The experimental data, statistical analysis, and assessments of low-temperature behavior help advance the understanding of bituminous mixture performance and pave the way for further research in this area. The BBR test, whose test temperature yields the value, is carried out to assess the low temperature qualities.

MATERIALS AND EXPERIMENTAL INVESTIGATIONS

Materials: In my research, I utilized three main materials: VG30, polyphosphoric acid (PPA), and PMB40 (POLYMER MODIFIED BITUMEN40). The laboratory grade PPA with a 105 percent H_3PO_4 content was provided by Sri Indu Drugs India Private Limited, located in Hyderabad. Hindustan Colas Private Limited, based in Vishakhapatnam, supplied the samples of VG30 and Styrene-Butadiene-Styrene (SBS) polymer modified bitumen (PMB40). Saturates, asphaltenes, aromatics, and resigns are

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the key chemical compositions that alter the structure and binder qualities such as mechanical, rheological, and physical properties. Regarding the fundamental qualities, chemical composition plays a vital role in determining the asphalt binder, such as adhesion, temperature sensitivity, viscosity, chemical composition, and durability. The attributes of asphalt binders are shown in Table 1. In comparison to modified asphalt binders, unmodified asphalt binders have lower viscosities and less adhesive bonding between aggregate particles Table 2 presents the properties of these materials.

The structural strength and stability of asphalt concrete exhibit a discernible rise with decreasing temperatures. Asphalt concrete's stiffness modulus increases at low temperatures, making the substance stiffer and more resistant to deformation. Along with improving the pavement's resistance to rutting, this increase in stiffness makes it more capable of supporting large loads without suffering severe long-term deformation. Although low temperatures enhance these characteristics, they can also raise the risk of thermal cracking because of the heightened brittleness of the asphalt.

Sample preparation: The primary objective of this study is to assess the effectiveness of dual modified asphalt binders. To achieve this, VG30 (a type of bitumen) was modified with varying dosages of PPA to determine the optimal PPA dosage. The laboratory grade PPA used in the experiment contained 105 percent H_3PO_4. The dosages of PPA ranged from 0.5 percent to 2.0 percent, with incremental increases of 0.5 percent.

Once the optimal VG30-PPA mixture was determined, Polymer Modified Bitumen40 (Styrene-Butadiene-Styrene polymer modified bitumen) was added to the mixture. The dosage of Polymer Modified Bitumen40 varied from 10 percent to 50 percent. The resulting mixture was thoroughly mixed. Table 3 presents the results of the optimum asphalt binder and dual modified binder combinations.

To ensure accuracy and reliability, at least three samples were prepared for each combination of bitumen samples. These samples were meticulously prepared according to specified guidelines and subjected to relevant testing protocols under controlled conditions.

Table 1. Properties of Asphalt binders.

Property	**Result**	**Specified limits as per BIS: 73-1992**
Penetration at 25ºC/100 gm /5 sec, mm	65	60 – 70
Softening Point, ºC	43	40 – 55
Specific Gravity, at 27ºC	1.01	>0.99
Ductility, at 25ºC	98	>40

Table 2. Properties of materials.

Material	**Supplier**	**Properties**
VG30	Hindustan Colas Private Limited, Vishakhapatnam	17.33
PPA	Sri Indu Drugs India Private Limited, Hyderabad	15.85
Polymer modified bitumen40	Hindustan Colas Private Limited, Vishakhapatnam	22.14

Table 3. Marshal Properties of Dual Modified.

Polymer modified bitumen 40(%)	**Bulk density (gm/cc)**	**Air voids (%) Vv**	**Voids in mineral aggregates (%) VMA**	**Voids filled with bitumen**	**Corrected stability (KN)**	**Flow (mm)**
10	2.39	5.41	18.32	65.56	16.34	2.67
20	2.46	4.52	16.10	71.67	19.31	3.56
30	2.51	3.46	15.23	82.43	22.14	4
40	2.43	2.34	14.41	88.96	25.43	5.25
50	2.41	1.98	12.94	91.33	23.14	5.47

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Dynamic Shear Rheometer (DSR) Test: According to Section 6 of AASHTO T 315, the testing system for determining the properties of asphalt binder consists of several components. These include a control and data collection system, a loading device, an environmental chamber, and parallel metal plates. The environmental chamber can be either a water bath or an air bath, depending on the specific testing requirements.

When conducting the test, both the original and Rolling Thin Film Oven (RTFO)-conditioned bituminous binder mixtures are tested using 25-mm plates. On the other hand, Pressure Aging Vessel (PAV)-conditioned material is tested using 8-mm plates.

To ensure accurate and reliable testing results, it is recommended to perform calibration of the temperature control system and loading device every six months. This calibration process involves using a reference thermometer and a standard fluid. The details and guidelines for conducting these verifications can be found in Section 9 of AASHTO T 315.

Bending Beam Rheometer (BBR) Test: In 1992, as part of the Strategic Highway Research Program (SHRP), the BBR test method was introduced for asphalt testing. The BBR test focuses on measuring the flexural creep stiffness of asphalt binder. It is specifically designed to assess the performance of asphalt binders under low-temperature conditions. It gauges how effectively the binder can withstand freezing conditions without breaking. This test involves applying a controlled load to an asphalt binder beam at a predefined low temperature, and recording the resultant deflection of the beam.

During the BBR test, asphalt binder samples are shaped into prism-shaped beams, which act as the test samples. The purpose of this test is to evaluate the low-temperature performance of the asphalt binder. The test is typically conducted within a temperature range of -36 to 0 degrees Celsius, as these temperatures are relevant for assessing the material's behavior under cold conditions.

The prism-shaped asphalt binder beams are positioned on a support system, and a constant load is applied at the center of the beam. This load causes the beam to bend, inducing stress within the asphalt binder. The maximum stress experienced by the beam is then measured.

Simultaneously, the corresponding maximum strain, or deformation, observed in the asphalt binder is recorded. The strain refers to the extent to which the material deforms under the applied load.

The flexural creep stiffness of the asphalt binder is determined by dividing the maximum stress by the maximum strain observed during the test. This calculation provides a measure of the binder's ability to resist deformation and maintain its stiffness under bending conditions.

By analyzing the flexural creep stiffness values obtained from the BBR test, researchers can assess the low-temperature performance characteristics of the asphalt binder, including its resistance to cracking and its suitability for cold climate applications.

The BBR test offers important insights into how asphalt binders perform under low-temperature conditions. It helps evaluate the susceptibility of asphalt binders to low-temperature thermal cracking, which can occur when the material's flexural creep stiffness is inadequate to resist the stresses induced by temperature fluctuations.

By assessing the flexural creep stiffness through the BBR test, researchers and engineers can better understand and predict the performance of asphalt binders in cold weather regions. This information is crucial for designing durable and long-lasting pavements that can withstand low-temperature conditions.

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RESULTS AND DISCUSSIONS

The volumetric properties of the bituminous mixture were assessed using Marshall tests. Various parameters such as Stability, flow, Bulk density, air voids, specific gravity, and voids filled with bitumen (VFB) were determined. By plotting the values of these parameters against the percentage of asphalt content, the Optimum Binder Content (OBC) was determined for the control mixture as well as the mixtures containing PPA and Polymer Modified Bitumen 40.

The addition of PPA and Polymer Modified Bitumen 40 had a significant influence on the Marshall characteristics of the asphalt mixes. Based on the Marshall test data, it was observed that as the concentration of PPA and Polymer Modified Bitumen 40 increased, the Marshall Stability, Bulk density, and VFB also increased. This indicates an improvement in the overall stability and compactness of the asphalt mixture.

The observed impact of PPA and Polymer Modified Bitumen 40 on the Marshall characteristics of the asphalt mixes was noteworthy. Analysis of the Marshall Test data consistently showed that higher concentrations of PPA and Polymer Modified Bitumen 40 correlated with increased values in Marshall Stability, Bulk density, and VFB. This trend suggests that the addition of PPA and Polymer Modified Bitumen 40 significantly enhances the overall stability and compactness of the asphalt mixture. These findings highlight the effectiveness of PPA and Polymer Modified Bitumen 40 in improving the performance of asphalt mixes during Marshall testing.

On the other hand, as the content of PPA and Polymer Modified Bitumen 40 increased, the flow and air voids in the mixture decreased. This suggests a reduction in the flowability and the presence of air voids within the mixture.

Despite the observed variations, the data analysis revealed that all the mixtures, including the conventional mix, PPA mix, and Polymer Modified Bitumen 40 mix, met the specifications outlined by the Marshall test. While there were differences between the conventional mix and the PPA and Polymer Modified Bitumen 40 mixes, all of them still satisfied the required standards.

The overall results indicate that the inclusion of PPA and Polymer Modified Bitumen 40 in the asphalt mixes led to improved Marshall Characteristics, highlighting the effectiveness of these additives in enhancing the performance of the asphalt mixture. The incorporation of PPA and Polymer Modified Bitumen 40 resulted in positive outcomes, indicating their potential for optimizing the properties and performance of asphalt mixes for various applications.

The RTFO results for both aged and unaged binder are displayed in Tables 4 and 5. Wherein the aged modified binder has a high softening value and low penetration and ductility values.

Table 4. RTFOT for Aged sample.

Property	**VG30**	**VG 30 + PPA 1.5%**	**VG 30 + PPA 1.5% + polymer modified bitumen 40**
Penetration (mm)	55	32	26
Softening point (ºC)	49	63	69
Ductility (cm)	77	65	37

Table 5. RTFOT for unaged sample.

Property	**VG30**	**VG 30 + PPA 1.5%**	**VG 30 + PPA 1.5% + polymer modified bitumen 40**
Penetration (mm)	65	45	33
Softening point (ºC)	43	59	64
Ductility (cm)	100	73	44

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HIGH TEMPERATURE RHEOLOGICAL TESTS

The fail temperature of the initial RTFO grading values for each binder is shown in Table 6. For dual modified binder, binder modified with PPA, and virgin binder, the values of complex shear modulus and phase angle are shown in Tables 7 and 8.

Table 6. Fail temperature of Original and RTFO grading (AASHTO T315).

Binder	Original grading		RTFO grading	
	Temperature	***G* / Sin δ***	***Temperature***	***G* / Sin δ***
VG 30	76	0.77	76	1.44
VG 30 + PPA	76	0.88	76	1.77
VG 30 + PPA + PMB40	82	0.78	82	11.67

Table 7. Complex Shear Modulus and Phase Angle for Original Grading (AASHTO T315.).

VG 30		VG 30 + PPA		VG 30 + PPA + PMB40	
Complex shear modulus, kPa	***Phase angle***	***Complex shear modulus, kPa***	***Phase angle***	***Complex shear modulus, kPa***	***Phase angle***
6.2750	80.5°	7.8693	80.01°	6.1009	77.81°
2.9002	82.48°	3.8412	81.2°	2.9551	79.2°
1.4986	84.21°	2.3883	83.17°	1.492	80.68°
0.7686	86.00°	0.8857	85.21°	0.7719	82.16°

Table 8. Complex Shear Modulus and Phase Angle for RTFO Grading (AASHTO T315.).

VG 30		VG 30 + PPA		VG 30 + PPA + polymer modified bitumeN40	
Complex shear modulus, kPa	***Phase angle***	***Complex shear modulus, kPa***	***Phase angle***	***Complex shear modulus, kPa***	***Phase angle***
13.5195	77.93°	14.1218	76.32°	13.3573	73.5°
6.4812	80.35°	7.1184	79.13°	6.4272	74.66°
3.8113	81.93°	4.6926	81.34°	3.1860	76.06°
1.4272	83.24°	1.7521	82.96°	1.6311	77.6°

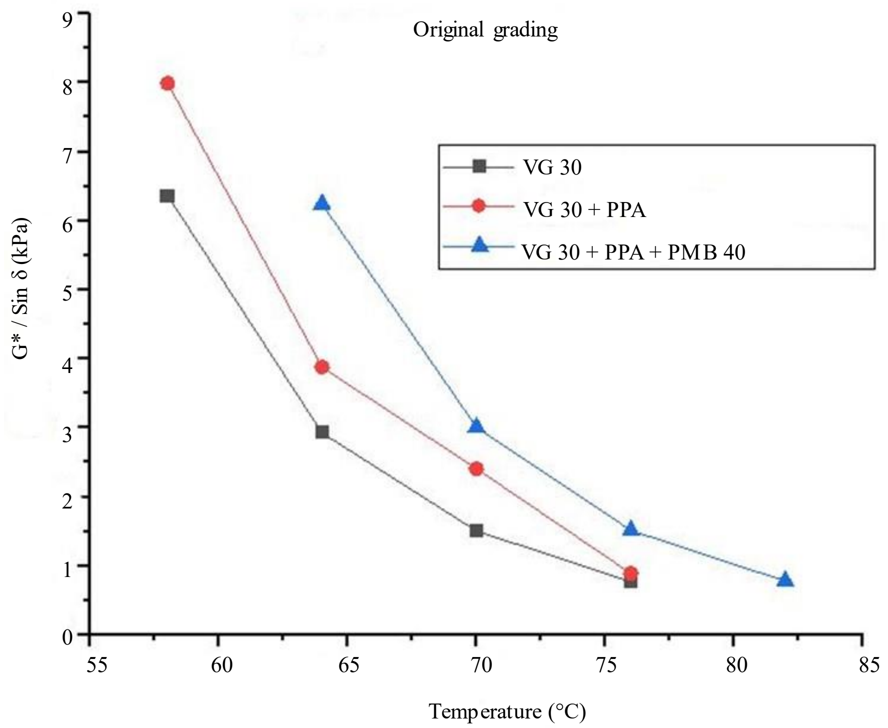

Figure 1. G* / Sin δ values for original grading.

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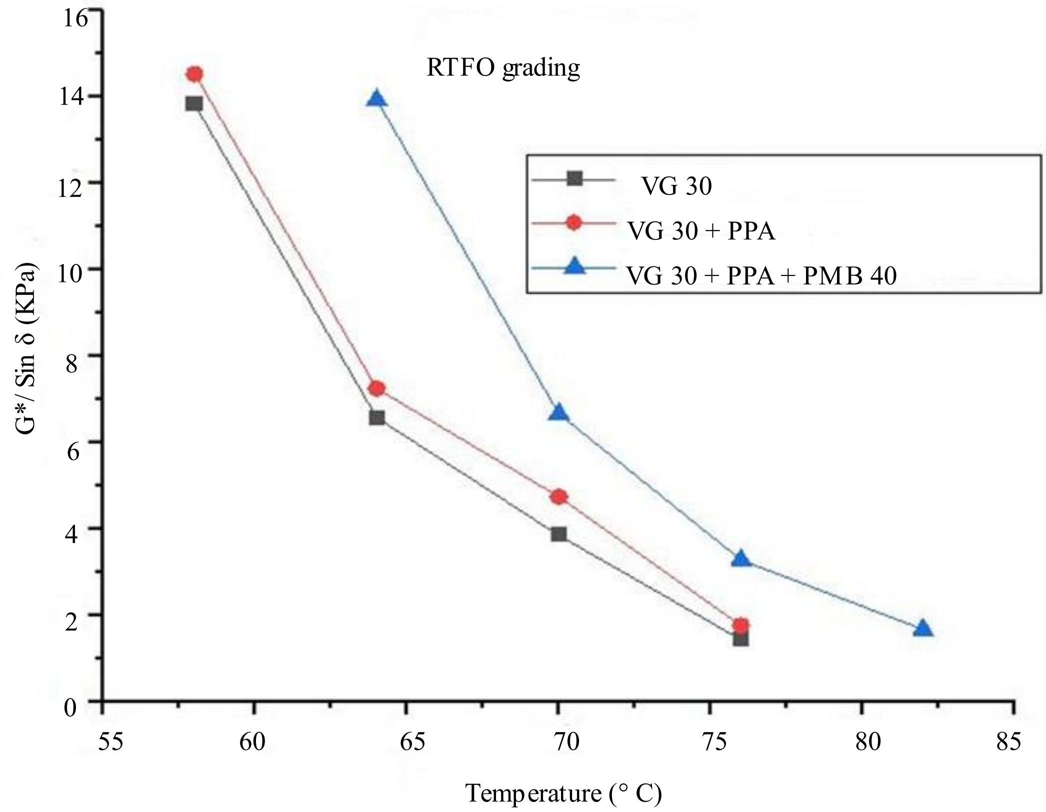

Figure 2. G* / Sin δ values for RTFO grading.

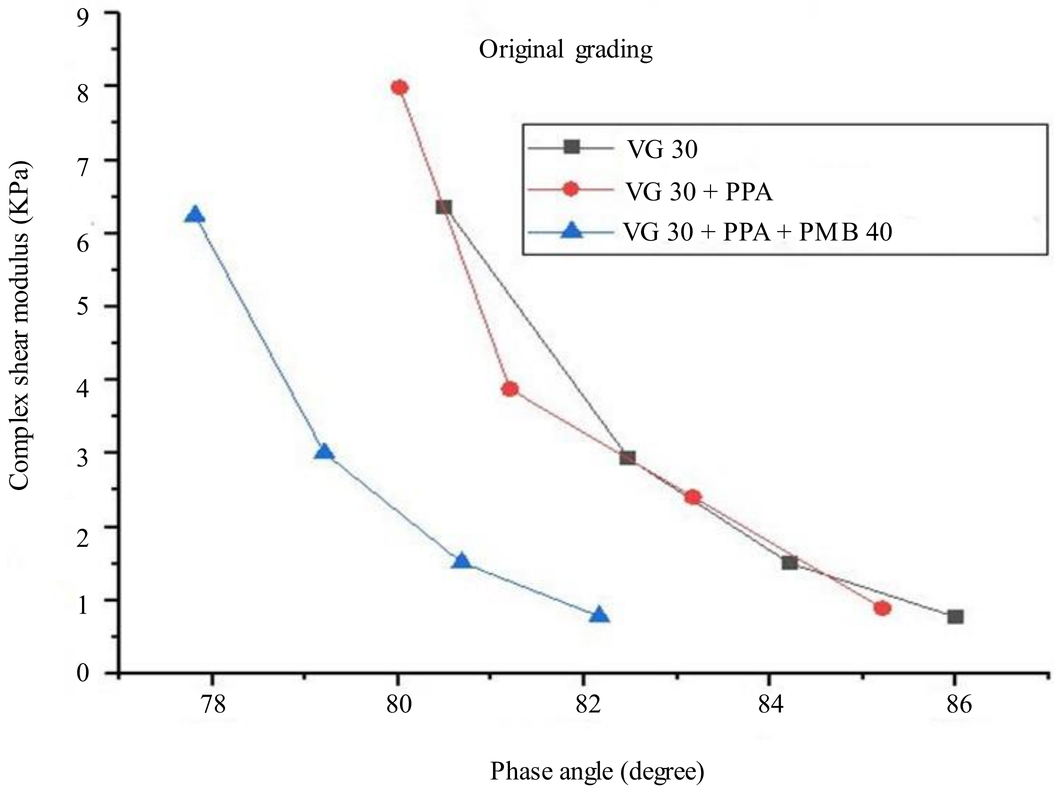

Figure 3. G* / Sin δ v/s Phase angle for original grading.

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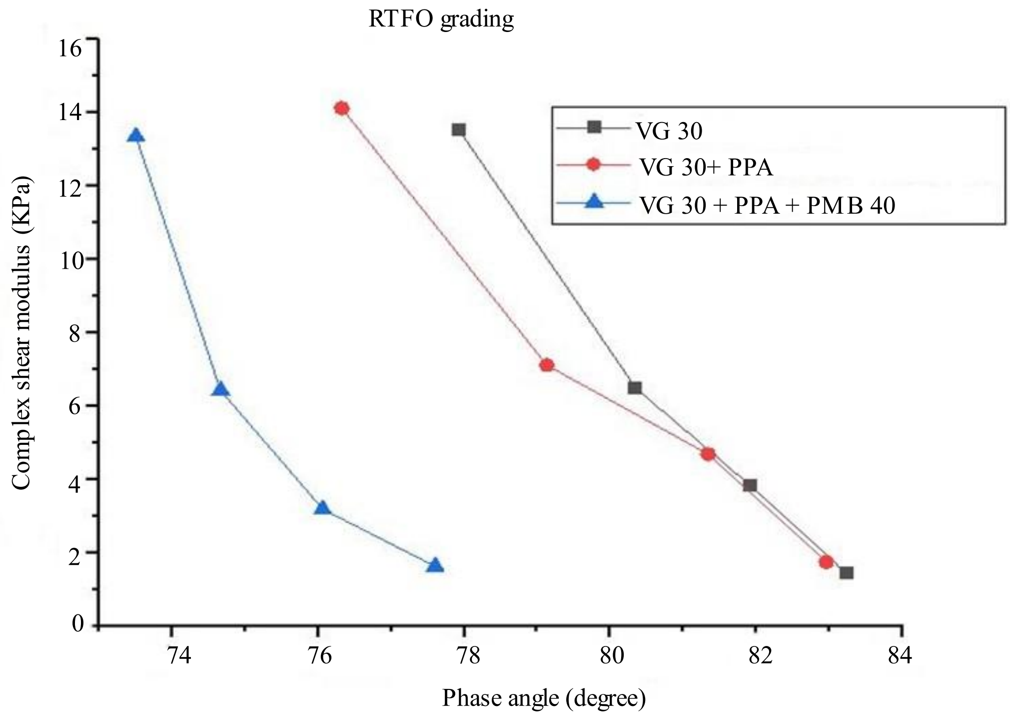

Figure 4. G* / Sin δ v/s Phase angle for RTFO grading.

Tables 7 and 8 provide evidence that the dual modified binder shows superior properties in comparison to conventional asphalt binders, particularly at elevated test temperatures. The dual modified binder exhibits a reduced phase angle and higher complex modulus (G*) at high temperatures, indicating improved resistance to permanent deformation and long-lasting deformation of road pavements. These findings suggest that the dual modified binder offers enhanced performance and durability, making it a promising choice for use in high-temperature environments.

Among the tested binders, VG 30 (conventional binder) shows the least desirable characteristics at high temperatures, highlighting the need for modification to improve its performance.

Figures 1 and 2 display the original and Rolling Thin Film Oven (RTFO) grading failure points for the G*/Sinδ values. These values are less than 1 kPa and 2 kPa, respectively. Figure 3 and 4 shows modified VG 30 + PPA binder exhibits a favorable change in complex modulus (G*) with temperature. It shows lower phase angle (δ) values at lower temperatures and higher complex modulus (G*) values at high temperatures. This behavior indicates improved elasticity and resistance to deformation, even at the highest operating temperatures.

Asphalt binders treated with polymers typically have a lower δ and a higher G*. This indicates that compared to unmodified asphalt cements, they are generally a little bit stiffer and more elastic.

The findings emphasize the positive performance of binders such as VG 30 and VG 30 + PPA, which maintain their elasticity (smaller phase angle) throughout a wide range of temperatures. This highlights their potential for withstanding high-temperature conditions and their suitability for road pavement applications.

LOW TEMPERATURE RHEOLOGICAL TESTS

Bending beam rheometer results for dual modified binder and binder modified with PPA are shown in Tables 9 and 10.

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Table 9. Bending Beam Rheometer (BBR) values for VG 30 + PPA 1.5% + POLYMER MODIFIED BITUMEN40 (AASHTO T 313).

Property	Recovery					
Time (S)	8	15	30	60	120	240
Force, mN	1036	1035	1034	1032	1030	1029
Deflection, mm	0.426	0.512	0.637	0.790	0.992	1.261
Measured Stiffness, MPa	259	216	173	139	111	87.1
Estimated Stiffness, MPa	259	215	174	139	111	87.1
Difference (%)	0	-0.463	0.578	0	0	-0.01
m-Value	0.292	0.303	0.314	0.326	0.338	0.349
Test Temperature = -12°C						
A = 2.66 B = -0.257 C = -0.0194 R2 = 0.999974						

Table 10. Bending Beam Rheometer (BBR) values for VG 30 + PPA 1.5% (AASHTO T 313).

Property	Recovery					
Time (S)	8	15	30	60	120	240
Force, mN	1008	1006	1005	1004	1003	1001
Deflection, mm	0.181	0.225	0.311	0.359	0.478	0.604
Measured Stiffness, MPa	954	447	345	298	224	117
Estimated Stiffness, MPa	954	447	345	298	224	117
Difference (%)	0	-0.15	-0.355	0.267	-0.211	-0.248
m-Value	0.102	0.126	0.158	0.163	0.178	0.182
Test Temperature = -6°C						
A = 1.82 B = -0.181 C = - 0.0062 R2 = 0.999						

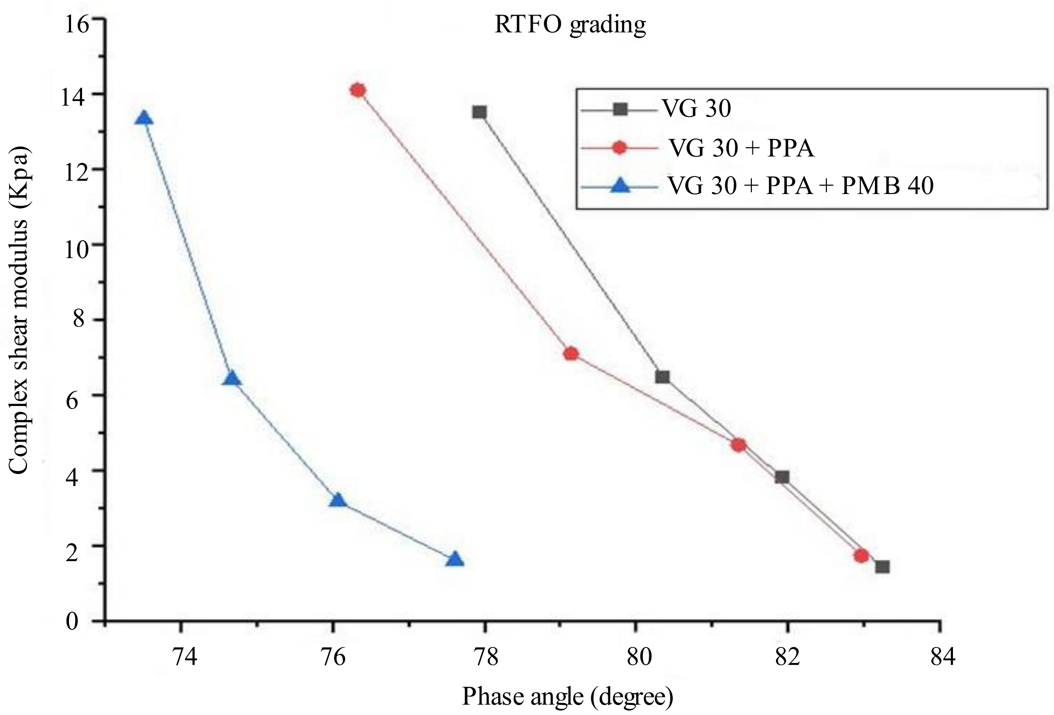

Figure 5. Stiffness v/s time.

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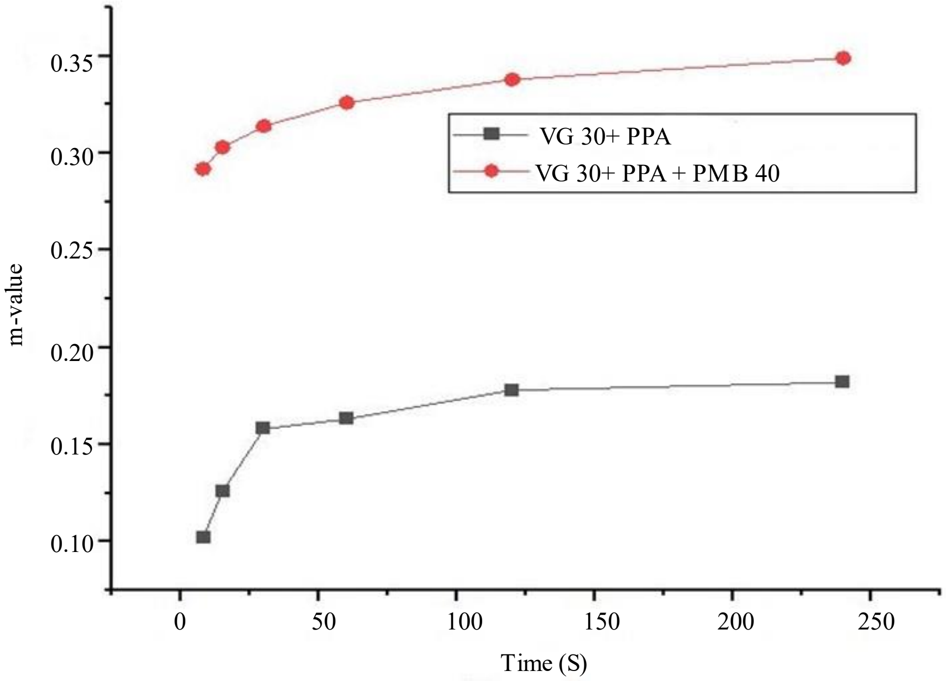

Figure 6. m-Value v/s time.

Based on the specifications outlined by AASHTO T313 and the Superpave TM specification, the stiffness and m-values of the dual modified binder asphalt were assessed at -12ºC utilizing the Bending Beam Rheometer test. According to the criteria provided, the stiffness should be below 300 MPa, and the m-values should exceed 0.300 at -12ºC. These requirements serve as benchmarks to evaluate the performance and suitability of the dual modified binder asphalt under low-temperature conditions.

By analyzing Figure 5 and Figure 6, it becomes evident that the stiffness and m-values of the dual modified binder asphalt remain within the specified limits. This observation indicates that the dual modified binder asphalt meets the prescribed criteria for low-temperature climatic conditions. The ability of the dual modified binder asphalt to stay within the defined range demonstrates its capacity to perform reliably under cold temperature conditions.

Compliance with these requirements signifies that the dual modified binder asphalt is well-suited for regions or applications where low temperatures are a concern. The dual modified binder asphalt possesses the necessary characteristics to withstand the challenges posed by low-temperature environments. Its ability to maintain appropriate stiffness and m-values within the specified limits ensures its suitability for road construction and pavement applications in areas with cold climates. The findings validate the effectiveness of the dual modified binder asphalt in meeting the desired performance standards in low-temperature conditions.

Therefore, based on the stiffness and m-values obtained from the Bending Beam Rheometer test, it can be concluded that the dual modified binder asphalt is suitable for use in low-temperature climates.

CONCLUSIONS

1. Dual modification asphalt binder (VG 30 + PPA 1.5% + Polymer Modified Bitumen 40) is suggested to use, as Marshall Stability value is high (25.43kN) compared with VG30 and VG30 + PPA 1.5%.
2. As G* modules is high and phase angle values are lower for dual modification (VG 30 + PPA 1.5% + Polymer Modified Bitumen 40) asphalt binder, it can be used for high temperature i.e., 76ºC.

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3. For dual modification (VG 30 + PPA 1.5% + Polymer Modified Bitumen 40) asphalt binder, Jnr @ 3.2 kPa, kPa-1value is 1.8202 which is less than 2 and minimum recovery is > 30%. For other binder Jnr @ 3.2 kPa, kPa-1value is greater than 2 and it is not applicable.
4. At -12ºC Stiffness and m-value for dual modification (VG 30 + PPA 1.5% + Polymer Modified Bitumen 40) are 139Mpa and 0.326. As per AASHTO T313 stiffness must be < 300 MPa and m-value must be > 0.300. For other binder is not meeting basic requirement, so dual modified asphalt binder (VG 30 + PPA 1.5% + Polymer Modified Bitumen 40) can be used for low temperate climatic conditions i.e., is -12ºC.
5. Based on low temperature and high temperature values performance grade is decide as PG 76-12.

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