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THE POLYMER EFFECTS ON BITUMEN PERFORMANCE PROPERTIES IN KAZAKHSTAN

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ABSTRACT: The efficacy of polymers on the various performance parameters of modified bitumen was investigated. For PG 64-22, three distinct kinds of polymers with distinct ratios—3.5 %, 8 %, and 1.5 % by weight of base bitumen, respectively—were manufactured, each of which was deemed to have a high effectiveness on properties by local experts. These polymers' ratios were as follows: The four samples, three of which had their physical qualities and storage stabilities examined using traditional methods, were changed using Butonal NS, PR Plast, and Titan Polymers. In addition, experiments for both short-term and long-term aging processes were carried out using a rolling thin film oven as well as a pressure aging vessel. In order to evaluate the bitumens' rheological characteristics, a rotating viscosity and bending beam rheometer was used. Following the rheological analysis, the essential kind of road asphalt mix was developed so that it could be tested for rutting. According to the findings, all three varieties of polymer-modified bitumen give an improvement in the rheological and physical characteristics of bitumen, as well as a strong resistance against rutting. Furthermore, it was discovered that they are very compatible with base bitumen. The viscosity and stiffness of the bitumen were greatly improved by the addition of polymers.

Keywords: Bitumen, Polymer Modified Bitumen, Bitumen Aging, Rutting Test, Performance Grade

1. INTRODUCTION

In many climatic conditions in late autumn, winter and early spring periods there are frequent transitions of air temperature, respectively surface and top part of asphalt concrete pavement of highways through 0°C. According to some data, the number of such transitions of air temperature through 0°C in climatic conditions of Almaty city is 100-120 and more annually. [1]

Rutting, fatigue cracking, and low temperature cracking harm asphalt concrete pavements most often. Bitumen significantly impacts asphalt concrete performance throughout its service life. Modifiers improve binder performance by improving its rheology. Different modifiers exist. In this research, modifiers including rubber, crumb rubber, elvaloy, polypropylene, SBR, SBS, and EVA were employed [2]. It is well known that modifiers vary in usefulness, practicability, performance, availability, and cost.

With the purpose of modifying bitumen to improve the main quality and properties without negatively affecting the performance properties has been chosen styrene-butadiene rubber block polymer latexes (Butanal NS), solids 63.0-65.0%; pH-5.0-5.6; viscosity-250-2000 mPa*s; polyolefin (Titan); mixture of different polymers mainly SBS (PR Plast). Polymers are widely used in studies to improve high-temperature performance, however bitumen's hardening may affect low and intermediate-temperature performance [2].

In this study, for bitumen BND 70/100 was made a modification using modifier polymer additives to examine its impact on the physical and rheological performance properties of the road bitumen.

About 10% of all bitumen used in road construction is modified with polymers of different classes. Polymers are being used more to guarantee pavement resilience under rising vehicle axle loads and traffic intensity. Kazakhstan uses SBS, Kraton D, DST, Elvaloy, Calprene 501, Butonal NS, Butonal NX4190, KUMHO, Zydex, Titan 7686, PR Plast, and PR Flex polymers. Bitumen modification with polymers increases coating shear stability, fracture resistance, and fatigue resistance [2,3].

If we look at the properties of each additive independently, Titan 7686 is a synthetic polymer consisting of a combination of several polymer families, including styrenes, butadiens, polyolefins, etc. Its addition to bitumen boosts resistance to rutting, weathering, and reflected cracking, increases mineral component adhesion, decreases asphalt mix transport and laying temperatures, and reduces roller passes by 33%. It enhances the cohesive strength of asphalt pavements to shear deformation in the warm season, resistance to climatic cracking, and binder elasticity, which promotes road surface durability. PR Flex 20 - 24 mm granules, a blend of polymer and elastomer, coated with a specific bitumen.

Melting 110–130 C. Introduced into an asphalt mixer before, during, or after bitumen. Special bitumen-treated elastomers and plastomers make up the additive. It is a combination of modified bitumen, plastomer, and elastomer: PBB (polymer-bitumen binder) based on styrene-butadiene-styrene block copolymers (SBS, or SBS) and ethylene-butyl acrylate copolymers (EBA), which are similar to ethylene-vinyl acetate copolymers (EVA). Styrene-butadione high filler dispersions (SBR-HSL), such as Butonal NX4190, have improved bitumen performance in road construction for hot (bitumen and asphalt) and cold (bituminous emulsions) paving for years. Bitumen, asphalt concrete, and bituminous emulsions are modified using Butonal NX4190 products in the US and Europe. It's ideal for tough climates. Butonal NX4190 improves asphalt concrete properties:

Firstly, Butonal polymer modification enhances high-temperature viscosity, making the pavement resistant to plastic deformation.

Secondly, at lower temperatures the polymer enhances the resistance of bitumen to low temperature cracking enhancing its rheological characteristics. The international experience and research by KazDorNII demonstrated that Butonal polymer is the most effective in locations with low temperature conditions. Butonal polymer may be utilized independently of the kind of asphalt concrete, whether it is asphalt-mastic or fine-grained dense asphalt concrete.

This research examines bitumen BND 70/100 with modifiers Butonal NS, PR Plast, and Titan. To accomplish bitumen's physical and rheological properties, modified binder test results were compared to basic bitumen.

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2. RESEARCH SIGNIFICANCE

The Kazakhstan road diagnostic examination found thermal fractures in asphalt concrete pavement everywhere. According to the world experience, it is believed that the low-temperature stability of asphalt concrete is mainly determined by the properties of the bitumen in it and with the right choice of binder, it is possible to significantly reduce their number. Thus, as a determination of this it is accepted that binder qualities boost with modifying by polymers. It is essential to research all employed polymers properties with Kazakhstan bitumen.

3. MATERIALS

3.1 Used Materials

The base bitumen with penetration mark BND 70/100 used in this study was supplied from Pavlodar refinery in Kazakhstan. Table 1 presents the results of measurements conducted on the base bitumen BND 70/100 to determine its physical qualities. Styrene-butadiene is a highly concentrated aqueous dispersion (latex) of the brand Butonal NS material supplied by BASF Asphalt in USA Solids content – 63…65 %; pH – 5,0…6,5 %; viscosity – 250…2 000 MPa. c., PR Plast from PR Industrie in France, which melting point 100-130ºC, pellet size 2 to 4 mm, asphalt mixing temperature between 155-175ºC and recommended dosage by company 0.4-0.6% of asphalt mix; Titan 7686 granule diameter (0,1…1,0). 1033mm; styrene content – 31 % mass.; density – 0,94 g/sm^3 ; flexural modulus – 2,9 MPa; elongation at break – 880 % was produced in Honeywell Belgium NV.

Table 1 Physical characteristics of bitumen B

Properties	Results
Penetration (25ºC, 100 gr, 5sec) 0.1 mm	83.2
Softening point, ºC	49.0
Flash point, ºC	250
Specific gravity (25 ºC), gr/cm^3	1.015

3.2 The Samples Preparation

The polymer-modified bitumen was produced by blending base bitumen with the various types of polymers mentioned previously; the percentages of Butonal NS, PR Plast, and Titan were chosen based on the conclusion of the local professors articles, which demonstrated positive results at 3.5 percent, 8%, and 1.5 percent by total bitumen weight, respectively. For this aim, a laboratory high shear mixer IKA Eurostar 40 digital electronically controlled stirrer model, with 30-2000 rpm stirrer speed was used for liquid polymer and IKA Disperser T25 digital with 3000-25000 rpm speed of stirrer for powder polymers to complete the mixing procedure. After 90 minutes of baking at 163 degrees Celsius, the bitumen was placed into the temperature-controlled container of a mixer running at 500 revolutions per minute. Within the first 15 minutes of mixing, the polymers were gradually added to the bitumen by weight, but Butonal NS was added through a 100 ml burette, after which the mixing speed was raised to 1500 rpm. Two hours later, the mixing procedure resumed. The mixing temperature was set at 170℃, and the temperature was monitored using a thermometer every 30 minutes. The basic and polymer-modified bitumens used in this study were designated by the designations B, B+BNS, B+PRPST, and B+Titan [3, 4, 5].

4. TEST METHODS

4.1 Conventional Tests

The penetration, flash point, softening point, elastic recovery, and specific gravity of both the original base and modified bitumens were evaluated. After the thin film oven test, the mass losses, retained penetrations, and softening points of the bitumen were determined to comprehend the effects of the modifier on aging (RTFOT) [5,6]. All tests were conducted in compliance with the local technical specifications of Kazakhstan for polymer-modified bitumens (PMBs).

4.2 Storage Stability Test

To ensure modified bitumen's stability and decomposition resistance throughout handling, mixing, and operation, EN 13399's entire storage stability test included a compatibility test.

The modified bitumen was put into a 35-mm-diameter, 180-mm-tall glass tube. Modified sample tubes were tightly closed with a glass lid with two hooks. Two small springs closed and secured the tube cap. To prevent test evaporation. The tubes were then put vertically in a preheated 180 oC oven for 72 hours. Cooled bitumen samples were cut into three parts. The top and lower half of the samples were evaluated for storage stability. Their penetration and softening temperature influence storage stability [7, 8, 23].

4.3 The Rotational Viscosity Test

Using a rotating viscometer, every bitumen was evaluated for workability (RV). The rotating viscometer measures the torque required to keep a cylindrical spindle immersed in a binder sample at 20 rpm [9,10,11,12].

The AASHTO T316 standard required Brookfield viscometer (DVRVII Pro) tests at 135°C and 165°C. The temperatures for mixing basic and modified bitumen and compacting the mixture for HMA application were also determined. The calculation used 150-190 cP for mixing and 250-310 cP for compacting. Bitumen rotating viscosity should not exceed 3000 cP at 135°C [13, 16].

4.4 The Bitumen Aging process

A rolling thin-film oven test (RTFOT) was used to short-age all bitumen according to EN 12607-1 [14, 15]. Bitumen samples were burned at 163 °C for 85 minutes. After RTFOT simulated bitumen mixing and construction, penetration and softening temperature were examined. To understand short-term aging, bitumen weight loss was estimated. The Superpave standard for RTFOT aged bitumen indicates that the maximum weight loss after short aging should not exceed 1% of the bitumen's total weight, however our local regulation GOST 33140-2014 requires 0.5% weight loss depending on testing temperature for 10 minutes [16]. Soft bitumen has a 1% weight restriction, whereas harder bitumen has 0.8 %. As is known, bitumen is heated and pressured during operation to simulate field age. A pressure aging vessel (PAV) simulates bitumen aging in the field for 7-10 years. [17, 18, 19].

4.5 The Bending Beam Rheometer Test (BBR)

At low temperatures, the bending beam rheometer (BBR) is used to measure the stiffness and consistency of bitumen. The obtained parameters are used to determine the resistance of a bituminous binder to low-temperature cracking. The BBR test is also used to determine bitumen performance grades at low temperatures (PG). At low temperatures, BBR is used to assess the creep stiffness (s) and creep rate (m-value) of bitumen. According to the Superpave standard, to prevent low-temperature cracking, the creep stiffness should not exceed 300 MPa, and the creep rate should not be less than 0.300.

4.6 Rutting Depth Test

20-4000 Wheel track testing equipment tests asphalt concrete for air and water rutting resistance. The equipment works with sector press for sampling asphalt mixes. Two samples may be tested simultaneously, and numerous mould configurations have been designed for testing: 320x260 mm; 340x280 mm; 300x300 mm; 410x260 mm; 400x300 mm. The samples' diameter must be -150 mm in two sections. EN 12697-22 governed testing procedures. First, the samples were manufactured on a 300x300 mm mold in a specific sector compactor to prepare compacted asphalt samples 320 x 260 mm (410 x 260 optional) with a height of 40-120 mm in compliance with EN12697/33, Part 5.2. To conserve material, 300x300 mm and 50 mm samples were made in 10 minutes. After compaction, samples cooled at room temperature for 24 hours, then tested for 20000 passing by 2 samples in parallel in 9 hours. The findings fulfill the criteria for high-temperature and intensive-movement rutting resistance.

4.7 Rheological Characterization

Bitumen viscosity and elastic characteristics were measured using a dynamic shear rheometer

(DSR) at medium to high temperatures. [20, 21] A tiny bitumen sample was subjected to oscillatory shear stresses between parallel plates in the DSR machine in stress-controlled mode at 10 rad/s to measure its complex shear modulus (G^*) and phase angle (δ). Non-aged and RTFOT samples were examined on 25 mm plates with 1 mm gaps. RTFOT+PAV-aged samples are tested on 8 mm x 2 mm plates. The high-temperature rutting parameters ($G^*/\sin\delta$) and intermediate-temperature fatigue parameters are obtained for each sample. Original bitumen should not exceed 1 kPa, while RTFOT aged bitumen should not exceed 2.2 kPa. Additionally, RTFOT+PAV aged bitumen must not exceed 5000 kPa $G^*\sin\delta$ pressure [21].

5. RESULTS AND DISCUSSION

Determine the PG grade of the bitumen first, and then compare the conventional test results and rheological characteristics obtained with the requirements polymer-modified bitumen (PMB) at the given PG grade of each bitumen in this study to examine the influence of different polymers on base bitumen. It is vital to determine the PG grade of modified bitumen in advance of evaluating its qualities in line with the ST RK 2534 standard. As a result, the results of the modified bitumen conventional tests, both before and after short-term aging, were included in Table 2.

Table 2 Evaluation of modified bitumen according to ST RK 2534 local standard for (PMB)

Tests / Binder types	B	B+BNS	B+PRPST	B+Titan
Penetration (25ºC, 100 gr, 5sec) 0.1 mm	83.2 (70-100)	68.9 (51-70)	57.9 (51-70)	50.4 (35-50)
Softening point, ºC	49.0 (≥47)	60.4 (≥62)	62.8 (≥62)	67.4 (≥65)
Flash point, ºC	270 (≥230)	280 (≥235)	285 (≥235)	285 (≥240)
Specific gravity (25 ºC), gr/cm^3	1.015 (1.0-1.1)	1.028 (1.0-1.1)	1.031 (1.0-1.1)	1.036 (1.0-1.1)
Elastic recovery (25 ºC) %	-	81.2 (≥60)	82.6 (≥60)	80 (≥60)
Storage stability:				
Difference in softening point, ºC	-	1.4 (≤5)	1.5 (≤5)	1.2 (≤5)
Difference in penetration, 0.1 mm	-	1	1	1
Dynamic shear rheometer (DSR) ($G^*/\sin\delta \geq 1$ kPa) Failure temperature, (ºC)	66.5 (≥64)	77	77.1	80
Rolling thin oven test (RTFOT):				
Weight loss, %	0.601 ≤0.6	≤0.5 0.204	≤0.5 0.197	≤0.5 0.156
Change in softening point:				
Increase, ºC	5.5 (≤6)	5.5 (≤6)	5.5 (≤6)	5.0 (≤6)
Decrease, ºC	- (≤5)	- (≤5)	- (≤5)	- (≤5)
Bending beam rheometer (BBR) Stiffness (s≤300MPa, m≥0.300) Failure temperature, (ºC)	28	22	22	22
Dynamic shear rheometer (DSR) RTFOT aged ($G^*/\sin\delta \geq 2.2$ kPa) Failure temperature, (ºC)	67 (≥64)	77.4	77.5	81
Dynamic shear rheometer (DSR) RTFOT+PAV aged ($G^*/\sin\delta \leq 5000$ kPa) Failure temperature, (ºC)	27 (≤31)	26.2 (≤31)	26.1 (≤31)	26.6 (≤31)

()Requirements of binders according to standard.

5.1 Conventional Bitumen Tests Results

Table 2 shows the results of penetration and softening point tests performed on bitumen. As can be seen in Table 3, the penetration tended to decline in different ways depending on the kind of polymer added, with the Titan additive having the lowest penetration with a value of 50.4 mm. Polymers raised bitumen's softening point, confirming penetration test findings. These studies imply that polymers harden bitumen substantially. Elastic recovery decreases as bitumen hardens. Polymers affected bitumen's elastic properties, boosting elastic recovery by 85-95% with Butonal NS. Both basic and polymer modified bitumen samples exceeded the 220 °C flash point requirement.

Table 2 shows that polymers improved aged bitumen's aging potential. The modified bitumen's weight loss was minor and within normal limits. Every bitumen's softening point before and after aging is within specification.

5.2 Storage Stability Test Results

Storage of bitumen for a lengthy period of time could generate phase separation and stability concerns. This is a major modified bitumen concern. Table 3 provides storage stability test results. The bottom and top of Polymer-modified bitumen assessed for storage stability exhibited very comparable softening points and penetration. This finding may be viewed as a good indicator of the modified bitumen polymers' homogeneity and consistency.[22]

Table 3 Storage stability test results of Polymers Modified Bitumen

Property / Bitumen types	B+BNS	B+PRPST	B+Titan
Penetration bottom part, 0.1 mm	64.0	53.6	47.2
Penetration top part, 0.1 mm	64.8	54.1	48.0
Difference in penetration between bottom and top part, 0.1 mm	0.8	0.5	0.8
Softening point bottom part, °C	58.4	60.0	65.1
Softening point top part, °C	57.6	59.2	64.0
Difference in Softening point between bottom and top part, °C	0.8	0.8	1.1

5.3 Rotational Viscosity Test Results

The bitumen's rotational viscosity (RV) was measured at 135 and 165 degrees Celsius, and the the mixing and compaction temperatures, as well as the modification indices ($\eta_{modified}$ / η_{base}) of all bitumen for use in HMA are given in Table 4. Polymers increased basic bitumen viscosity at 135 and 165 °C. Polymer treatment hardened bitumen. However, mixing and densification temperatures climbed like polymer kinds.

Table 4 Rotational viscosity test results of the base and Polymer Modified Bitumen

Binder types	Rotational viscosity (cP)		$\eta_{modified}$ / η_{base}		Temperature range (°C)	
	135 °C	165 °C	135 °C	165 °C	Mixing	Compaction
B	312	101	1	1	150-155	135-145
B+BNS	814	237	2.61	2.35	167-171	162-165
B+PRPST	660	175	2.12	1.73	163-165	157-159
B+Titan	400	120	1.28	1.19	155-160	145-155

Figure 2 calculated bitumen mixing and compaction temperatures. Mixing and compaction occurred between 150 and 165 °C. Although modified bitumen workability decreased, RV was less than 3000 cP and satisfied ASTM D6373 workability requirements.

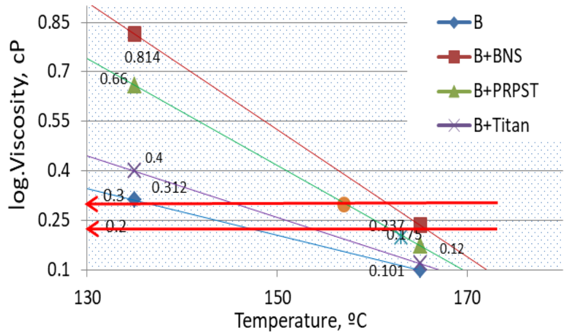

Fig. 2 Viscosity temperature relationships for the base and Polymer modified bitumen

5.4 Bending Beam Rheometer (BBR) Test Results

BBR equipment tested bitumen at -22°C and -28°C. Figures 3 and 4 indicate that all bitumens' creep stiffness and m-values exceeded the Superpave criterion at -22°C. B+Titan had similar creep stiffness as B and a low m-value. As the temperature dropped, the samples stiffened but the m-value fell. At -28°C, all bitumens failed the Superpave criterion, suggesting that all were PG X-22.

Titan, a polymer with a high temperature performance grade of PG 64-28, was ideal for adding by weight of bitumen. Thus, the optimal usage of polymers is 3.5 percent, 8%, and 1.5 percent, as their m-values at -22°C were all at least 0.300, meeting the criterion. PG grade was unaffected by polymer modification at -28°C. B's S-stiffness was 357 MPa, B+BNS 493 MPa, B+PRPST 521 MPa, and B+Titan 690 MPa, showing a maximum of 300 MPa. Polymer additives reduced creep and stiffened bitumen at -28°C. Table 3 compares polymer-free bitumen characteristics.

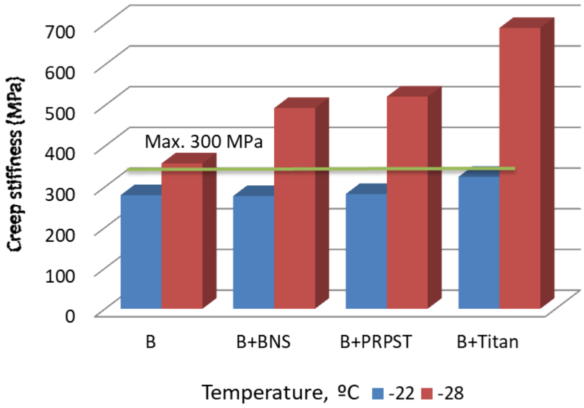

Fig.3 Creep stiffness of the base and PMB

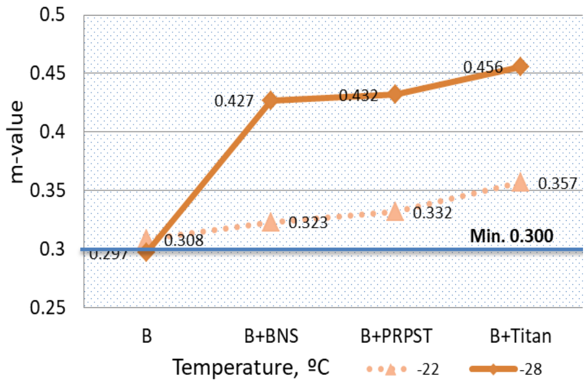

Fig.4 The m-value of the base and PMB

5.5 Rutting Resistance Test Results

EN 12697-22 required two parallels on a 60 °C preheated 20-4000 Wheel Track Testing Machine for each sample with different polymer additives. In Figure 5, all bitumens test results with polymer addition match the standard in 20000 passage, however B+Titan had a greater average rutting depth of -2.17 mm than B+BNS and B+PRST, which had -2.20 and -2.38 mm, respectively. Bitumen B without addition attained the needed threshold of -3.24 mm and stopped after 12000 passes, showing that it could not endure a high load of transport movement at high temperatures.

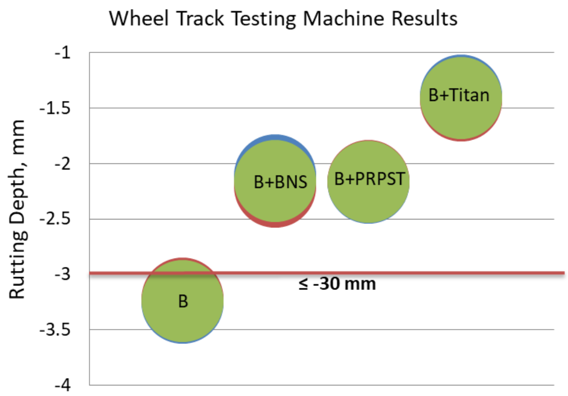

Fig. 5 Rutting depth results of the base and PMB

5.6 Rheological Characterization Results by DSR

The DSR test assessed each bitumen type's PG grade and examined how polymers impact bitumen's rheology. [23] Figure 6 shows all bitumens' viscoelastic characteristics, complex shear modulus (G*) and phase angle (δ), including the effect of polymers on G*, for original and RTFOT-aged bitumens. Figure 7 illustrates the rutting parameter (G*/sin δ) for basic and modified bitumen samples.

Figure 6 shows that the G* parameter for the original bitumen base (B) at 67 °C was 1.12 kPa, but it increased to 1.02 kPa at 77°C at B+BNS, 77.1°C at B+PRPST, and 81°C at B+Titan. Polymers stiffen bitumen over 100%. Polymers improved bitumen's rigidity and rheology, especially at high temperatures.

Figure 6 shows that adding polymers reduced δ values, both in original and aged bitumens. At 64°C, δ of native bitumen B had 82.27 and polymers B+Titan, B+BNS, and B+PRPST had 61.14, 63.03, and 63.05. Polymers B+BNS and B+PRPST were almost similar. Polymers increased bitumen's elastic component in varying proportions.

Bitumen's stiffness regulation at high temperatures helps the pavement resist permanent deformations. Original and RTFOT aged bitumens were tested for rutting (G*/sin**δ**) at high temperatures starting at 40 °C. As G*/sin**δ** increased, bitumen stiffened, making rut-resistant blends possible.

Figure 7 presented unaged and aged RTFOT G*/sin**δ** values. B+Titan has 7.14kPa, B+BNS 4.06kPa, and B+PRPST 4.36kPa. Polymers stiffened bitumen. Traditional testing provided this result.

The aged bitumen sample had a higher G*/sin**δ** than the first sample. At 64 °C, original B had 1.83 kPa G*/sin**δ** and aged B 3.67 kPa. At the same temperature, G*/sin was 7.14 kPa for original B+Titan, 9.04 for aged, 4.06 for original B+BNS, 8.14 for aged, 4.36 for original B+PRPST, 8.44 for aged.

G*/sinδ (Figure 7) reveals that B+Titan enhances stiffness by 320.2% compared to base bitumen, whereas B+BNS and B+PRPST increased stiffness by 189.7% and 210.8%. As expected, the rise in temperature leads G* to decrease and δ to increase. B+Polymers resists persistent deformation better than B. As indicated in Figure 4, every Polymer fulfilled the rutting parameter norms for both old and unaged situations, but B+Titan up to 82°C and other Polymers up to 76°C. Superpave limits bitumen B to 64℃.

Figure 8 shows the complex shear modulus (G*) and phase angle (δ) for PAV-aged bitumen at different temperatures and polymers to evaluate polymer-modified bitumen fatigue performance. Figure 9 shows the Polymers modification's fatigue characteristics (G*sinδ) for all bitumen types. Table 3 shows how polymer kinds affect bitumen rheology.

Due to the rise in (G*) and reduction in (δ), the fatigue parameters (G*sinδ) of modified bitumens increased with adding Polymers relatively to the basic bitumen. Note that the fatigue parameter was obtained at the intermediate test temperature by combining the high-grade and low-grade temperatures, dividing the result by 2, and adding 4. The comparison between bitumen B and B+Titan should thus be based on the PG grade of each bitumen, since stiffness varies from one bitumen to the next. The PG grade of B was 64-22, therefore the intermediate test temperature of RTFOT+PAV aged bitumen utilized in the DSR test was determined to be 25 ℃ (using the previously indicated calculation, which corresponds to (64-22)/2+4 = 25). Using the same technique, the intermediate test temperature was derived from Table 5 for B+Titan, which is PG 82-22 graded bitumen, to be 34 ℃ and B+BNS and B+PRPST's grade is PG 76-22 and their temperature will be 31℃.

G*sinδ of B was determined to be 2406kPa at 25 ℃, 1985 kPa and 2142kPa at 31 ℃ for B+BNS and B+PRPST, respectively, 1983 kPa at 34 ℃ for B+Titan, indicating that Polymer-modified bitumen satisfied the standard requirement of fatigue parameter (G*sin<5000 kPa). When RTFOT+PAV aged bitumens are compared to base bitumen at an intermediate temperature (25 ℃; Fig. 6), the phase angle is reduced by 25.8 percentage points with modification, from 46.06 to 34.59 degrees. The same holds true for other Polymers too, B+BNS phase angle δ decrement was 21.5 % and B+PRPST decreased for 19.6%. At the newly acquired intermediate performance temperatures, the elastic behavior of Polymer-modified bitumens predominated due to the drop in δ value accompanied by an increase in G*.

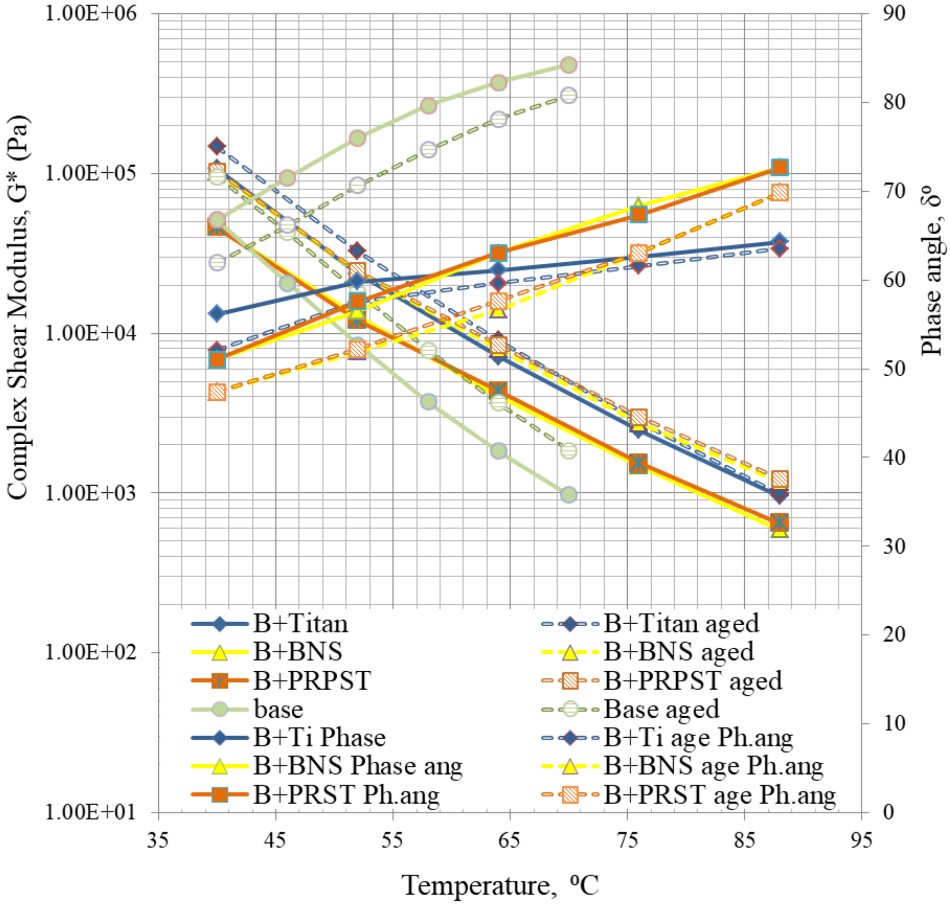

Fig.6 Effects of both original and aged base B and PMBs complex shear modulus (G*) and Phase angle (δ)

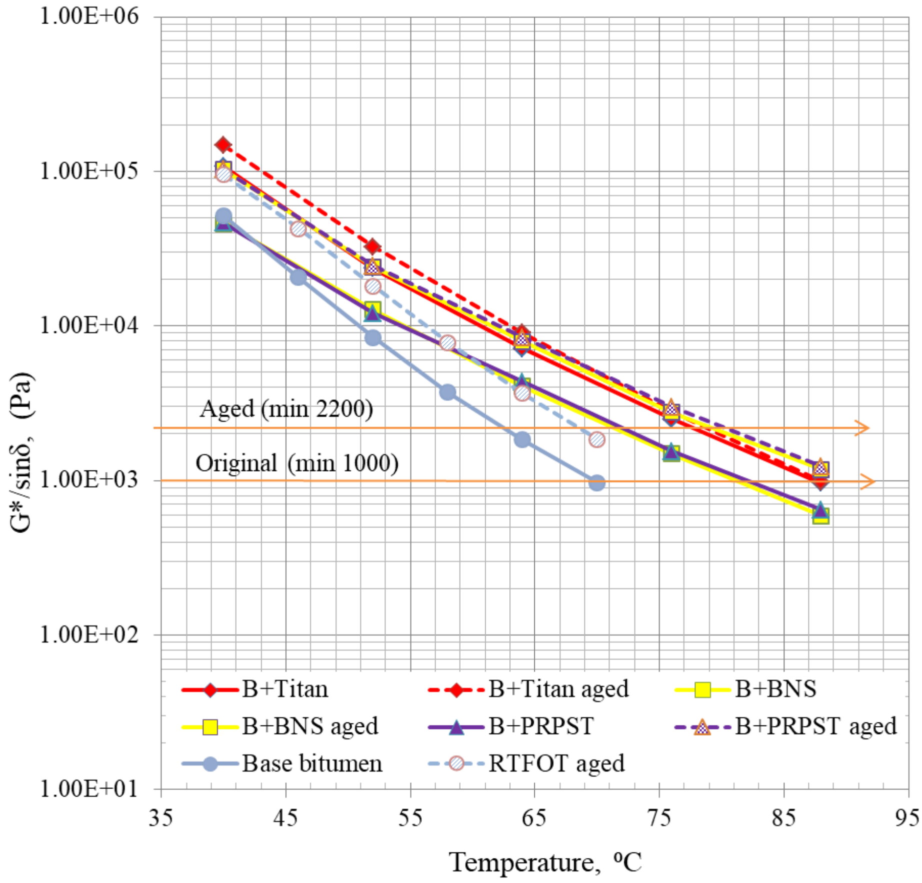

Fig.7 The PMB Rutting Performance

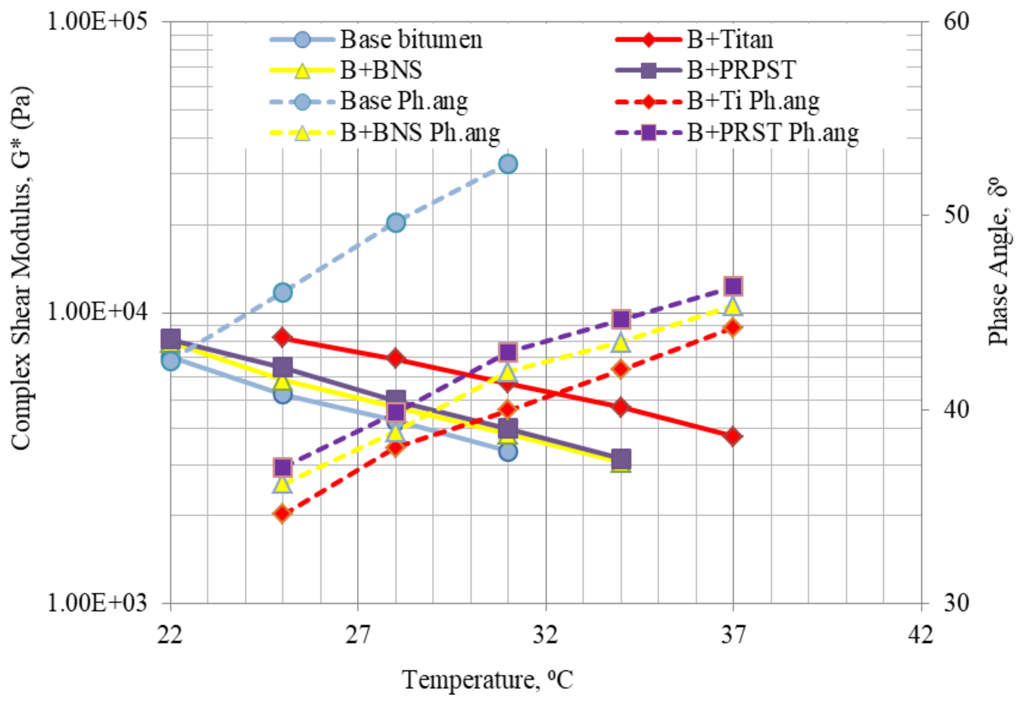

Fig.8 Polymers effect on complex shear modulus (G*) after PAV aged test

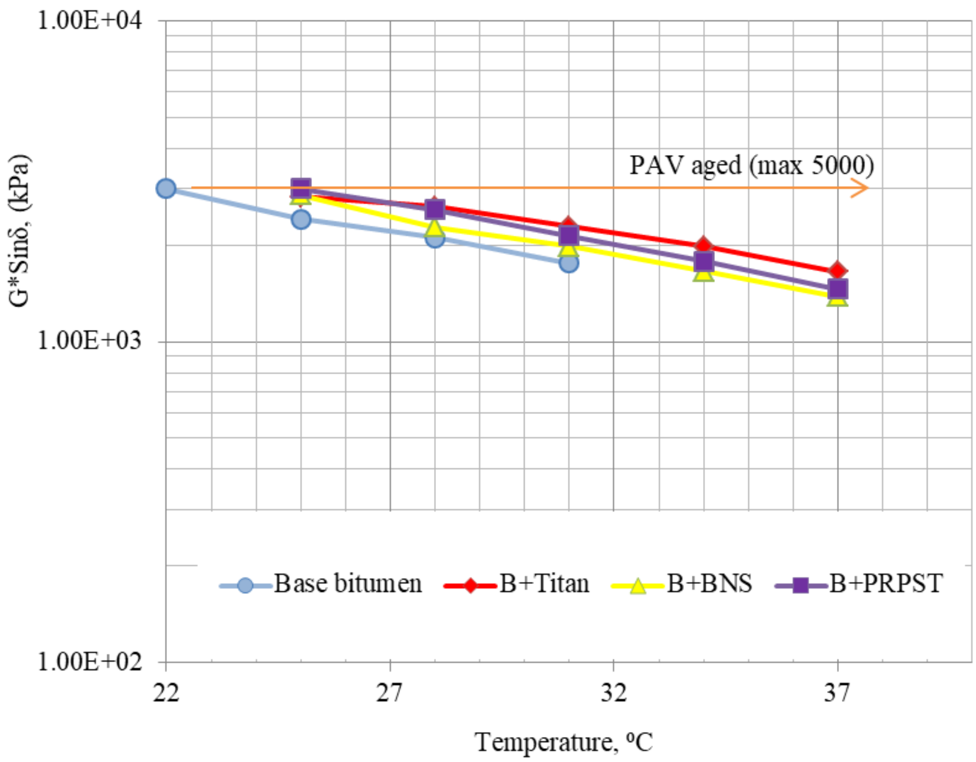

Fig.9 The PMBs fatigue performance

6. CONCLUSION

In this study, the effects of different polymers were investigated on the performance properties of bitumen and the following conclusions were made.

Polymers improve base bitumen viscosity and stiffness following traditional test findings. RV data may indicate that polymers stiffen bitumen. Polymers were considered to be an effective modifier for modifying, despite its relatively low mixing and compacting temperatures.

The elastic recovery findings also vary with modification, depending on the polymers used. For example, the Butonal NS water-based latex stiffened the bitumen yet made it elastic and reversible. Although, Titan had not demonstrated the recovery due of its plasticity but it was still that polymer that could present the best outcomes in all tests.

The storage stability test with Polymers was stable and compatible with bitumen and had no phase separation in the bitumen during fairly long time at storage process.

BBR test results showed that Polymers additive had no positive effect on low-temperature cracking resistance of bitumen at -28℃ with taken ratio. Although, on less low temperature at -22 ℃ was shown positive effect facing to standard.

Rutting depth results of the base bitumen failed with -3.24 mm at 12000 passes and modifying with polymers reveals that could resist to 20000 passage with low rutting depth and meet the standard. B+Titan lead the other polymers with the results -2.17 mm, B+BNS -2.20 mm and B+PRPST -2.38 mm.

According to the findings, Polymers has shown positive effects on physical properties of bitumen in stiffening after the modification which means the pavements become more resistant to permanent deformation and become more capable for large loads.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] Teltayev B., Kaganovich E. Bitumen and asphalt concrete requirements improvement for the climatic conditions of the Republic of Kazakhstan /Proceedings of the XXIVth World Road Congress Mexico, 2011.-13 p.

[2] Zolotarev V.A.. Bitumens modified by polymers and additives. Selected works book. Volume 2. St. Petersburg, 2013, pp. 75-120.
[3] Teltayev B.B. Temperature dependence of bitumen binders mechanical characteristics., Reports of the National Academy of Sciences of the Republic of Kazakhstan, ISSN 2224-5227, Vol.2, Number 300 (2015), pp.30-37.
[4] Teltaev B.B., Amirbaev E.D., Begalieva S.T., Alizhanov D.A. Mechanical characteristics of road compounded bitumen at low temperatures. Collection of Proceedings of Second International Joldasbek Symposium "Mechanics of the Future", 1-5. March 2021 (Reports digest Second International Joldasbekov Symposium "Future Mechanics" 1-5. March 2021, Almaty), ISBN 978-601-08-0953-6, pp. 54-58.
[5] The Ministry of Transport and Communication Republic of Kazakhstan. RK 218-80-2010. RECOMMENDATIONS on the application of Elvalloy polymer for bitumen and asphalt concrete modification. pp.1-63.
[6] Zhi, S., Gun, W.W., Hui, L.X., Bo, T., Evaluation of fatigue crack behavior in asphalt concrete pavements with different polymer modifiers, Construction and Building Materials, 27, 2012, pp. 117-125.
[7] Fu, H., Xie, L., Dou, D., Li, L., Yu, M., Yao, S., Storage stability and compatibility of asphalt binder modified SBS graft copolymer, Construction and Building Materials, 21, 2017, pp.1528-1533.
[8] Yilmaz, M., Yamaç, Ö.E., Evaluation of Gilsonite and styrene-butadiene-styrene composite usage in bitumen modification on the mechanical properties of hot mix asphalts, J. Mater. Civ. Eng., 29:9, 04017089, 2017. pp. 546-558.
[9] Bahia, H.U., Hanson, D.I., Zeng, M., Zhai, H., Khatri, M.A., Anderson, R.M., Characterization of modified asphalt binders in Superpave mix design (Project No. 9-10 FY′ 96), NCHRP, Washington, 2001. pp. 978-993.
[10] Tang, N., Huang, W., Zheng, M., Hu, J., Investigation of Gilsonite-, polyphosphoric acid- and styrene–butadiene–styrene-modified asphalt binder using the multiple stress creep and recovery test, Road Materials and Pavement Design, 18:5, 2017, pp.1084–1097.
[11] Widyatmoko, I., Elliott, R., Characteristics of elastomeric and plastomeric binders in contact with natural asphalts, Constr. Build. Mater., 22, 2008, pp.239–249.
[12] Spadoni, S.,Ingrassia, L. P.,Mariani, E.,Cardone, F.Canestrari, F., Long-term performance assessment of a warm recycled motorway pavement, Case Studies in Construction Materials,17, 2022, e01451. pp.1009-1024.
[13] Babagoli, R.,Nasr, D.,Ameli, A.,Moradi, M. R., Rutting and fatigue properties of modified binders with polymer and titanium dioxide nanoparticles, Construction and Building Materials, 345, 128423, 2022.pp.774-791.
[14] Mahali, I., Sahoo, U.C., Rheological characterization of Nanocomposite modified asphalt binder, International Journal of Pavement Research and Technology, 12 (6), 2019, pp. 589-594.
[15] Zhang, C.; Wang, H.; You, Z.; Gao, J.; Irfan, M. Performance test on Styrene-Butadiene-Styrene (SBS) modified asphalt based on the different evaluation methods. Appl. Sci. 2019, 9, 467p.
[16] AASHTO: AASHTO T 316- Viscosity determination of asphalt binder using rotational viscometer, Washington D.C., 2004. pp.1-6
[17] D. S. Mabui, M. W. Tjaronge, S. A. Adisasmita, Mubassirang Pasra. Performance of porous asphalt containing modificated buton asphalt and plastic waste. International Journal of GEOMATE, Jan., 2020, Vol.18, Issue 65, pp. 118-123
[18] AASHTO: AASHTO T 240- Effect of heat and air on a moving film of asphalt (Rolling Thin-Film Oven Test) standard test methods, Washington D.C., 2013.pp.1-12.
[19] AASHTO: AASHTO R 28- Accelerated aging of asphalt binder using a pressurized aging vessel (PAV) standard test methods, Washington D.C., 2012.pp.1-29.
[20] ASTM D 6521-13. Standard Practice for Accelerated Aging of Asphalt of Asphalt Binder Using a Pressurized Aging Vessel (PAV), 2008.-12 p.
[21] AASHTO: AASHTO T 315- Determining the rheological properties of asphalt binder using a dynamic shear rheometer (DSR) standard test methods, Washington D.C., 2012.pp.1-32.
[22] EN 13399, Bitumen and Bituminous Binders - Determination of Storage Stability of Modified Bitumen, European standard, 2010.pp.1-23.
[23] Shirakawa, Tatsuo;Tada, Akio;Okazaki, Noriyasu. Development of functional carbon nanotubes-asphalt composites. International Journal of GEOMATE.Volume 2.Ed.1.2012. pp.161-165.