

RESEARCH PAPER

Study of the Rheological Properties of Asphalt Modified with Polymer Additives

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ABSTRACT

In the current research, polyvinyl alcohol (PVA) and sulfur were applied in order to improve the rheological performance of asphalt as well as strengthen its ability toward standing up against severe weathering as well as repeated heavy loads. The research was done in a number of steps. In the first step, the best conditions for the reaction process were ascertained by identifying the favorable temperature as well as the best reaction time. In the subsequent step, the best quantity of sulfur was ascertained, and it was discovered that incorporating 0.5% by weight of nano-sulfur yielded the most desirable outcomes. Then, different ratios of PVA and 0.5% by weight of nano sulfur were mixed with the asphalt. The use of modified asphalt in paving was determined based on the measurements conducted (ductility, penetration, softening point, percentage of separated asphaltene, chemical immersion, and Marshall test). These measurements revealed good asphalt models that can be used in paving.

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INTRODUCTION

Asphalt is the most widely used paving material due to its properties in terms of stability, durability, and water resistance. Asphalt is produced from the direct distillation of crude oil. Asphalt is primarily composed of paraffinic, naphthenic, and aromatic hydrocarbon compounds, and also contains cyclic and acyclic compounds containing nitrogen, oxygen, and sulfur. It is a highly used material. Paving the road is a must to its excellent adhesion with various metals, acceptable viscosity properties, and relatively low cost [1,2]. Therefore, many researchers have been keen on improving the specifications of asphalt through various chemical and physical treatments and the use of numerous additives, particularly polymeric additives, due to its huge effect on enhancing

the rheological properties of asphalt and making it more suitable for different uses, particularly in paving [3].

The researcher Li et al. (2018) had the possibility of investigating how a styrene-butadiene-styrene copolymer with thermochromic powders affects the physical constant and rheological properties of asphalt. The thin-film oven test (TFOT) was performed, indicating how much the asphalt was affected by the aging conditions. Accordingly, the study improved the temperature stability of asphalt and also showed high resistance to the aging test [4]. Yu.J et al. [5] had the opportunity to investigate the effect of TPU addition. The study confirmed that this polymer improves thermal properties, stabilizes storage at high temperatures. IR analysis revealed improvement in resistance to

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aging.

Yan et al. (2020) [6] investigated the impact of the WTR mixture with EVA waste on asphalt properties through various measurements that turned out to be improved, manifested by reduced penetration and increased softening points and viscosity. Shan et al. (2020) used SBS to modify the rheological properties of asphalt and observed its effect on the flow behavior of the asphalt binder and improved its specifications [7]. Researchers [8] (Ahmed & Hamdoon, 2020) were able to study the rheological properties of asphalt modified with a commercial adhesive composed primarily of [(EVA) ethylene-vinyl acetate], aerobic oxidation, and the presence of anhydrous aluminum chloride. The results showed that samples with specifications qualify for use in various fields, such as moisture barriers and surfacing, in addition to their most important use, paving [8]. Ezzat and Abed, 2020 [9] studied the effect of using a polymer blend of PVC (Polyvinyl Chloride) and SBS (Styrene Butadiene Styrene) and evaluated its rheological properties, taking into account short-term aging. The results of the study revealed that the modified asphalt binder had a positive effect on the aging process compared to the original asphalt [10]. The asphalt-prepared charcoal was used in a study [11,12] as a raw material for the synthesis of graphene oxide [13], which introduced several reactions to prepare new nanocatalysts as a support material [14]. Many minerals have been used as nanocatalysts for numerous applications [15], including environmental [16] and reduction ratios [17]. Hussein et al., 2022 [18] altered the rheological characteristics of the asphalt employing a polymeric mixture of styrene butadiene rubber (SBR) with ethylene vinyl acetate (EVA). Many theoretical studies have confirmed the above statement [19]. The mixture was applied with varying weights of both polymeric materials, in weight as a presence of 0.5% of (AlCl₃) anhydrous as catalyst in the treatment with the temperature being maintained at a constant value. The modified samples showed good rheological characteristics based on the readings made.

MATERIALS AND METHODS

1- Determining the Optimal Ratio of Sulfur to Treat with Asphalt

Asphalt was treated with changes in percentages of sulfur in an asphalt treatment device at a temperature ranging between 160-170°C to determine the optimal ratio of sulfur that could be used for modifications with the addition of polymer.

Treating Asphalt with Polyvinyl Alcohol (PVA)

A sample of asphalt weight was introduced and set in the asphalt treatment equipment, added various ratios of polyvinyl alcohol to the given percentage of sulfur, which was 0.5% by weight. By mixing the reactants in the temperature of 160-170°C under continuous agitation for 60 minutes [20,21], softening point [22], penetration [23], and asphalt separation [24] were then carried out, as well as the Marshall stability test [25] and chemical immersion [26-28].

RESULTS AND DISCUSSION

The researchers have shown rising concerns to enhance the performance of the pavements made of asphalt by the addition of various additive types that enhance its resistance to the various atmospheric conditions and enhance the resistance to repetitive loads. In the current work, an attempt has been made by the authors by using polyvinyl alcohol with certain percent of sulfur to enhance the properties of asphalt. The above was achieved in the following steps.

Determining the rheological specifications of the base asphalt

The rheological properties of the asphalt in basic medium were measured as shown in Table 1.

Determining the optimal percentage of nano sulfur added to asphalt

To determine the best percentage of nano sulfur added to asphalt under the conditions used in the reaction, asphalt was treated with changes in percentages of sulfur, and then the necessary

Table 1. Rheological properties of base asphalt.

Properties	Results
Ductility	+100
Softening point C°	45.3
Penetration	51
Asphaltenes %	20.3

measurements were performed to determine the optimal percentage of sulfur. Table 2 shows the results obtained.

It can be seen from the table that the best ratio adopted is 0.5% sulfur by weight. By heating the asphalt with sulfur at 180 °C, the eight rings in the sulfur get converted into free radicals, which then get attached to the asphalt, thereby providing flexibility to the residing in between the chains

[29,30].

Treatment of asphalt with polyvinyl alcohol and sulfur

Asphalt was treated with different ratios of polyvinyl alcohol and 0.5% sulfur by weight, as explained in the practical section. Table 3 and Fig. 2 illustrate the results occur.

From the results obtained in Table 3 and Fig. 2,

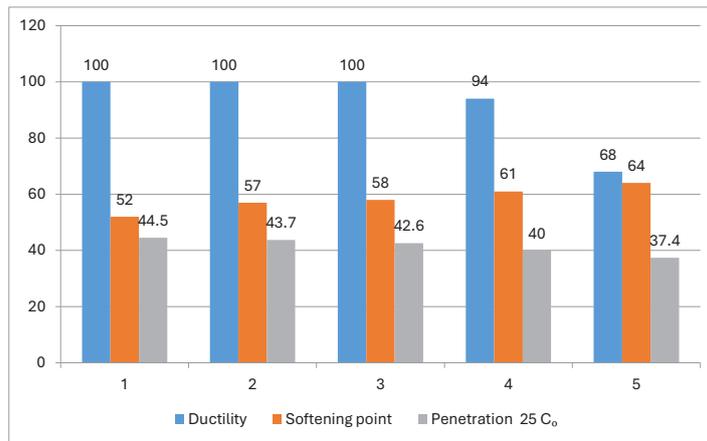


Fig. 1. Rheological properties of asphalt treated with different sulfur contents.

Table 2. Asphalt treated with different percentages of sulfur.

Sample no.	percentage of sulfur %	Ductility	Softening point	Penetration 25 C°	Asphaltenes %
AS ₁	0.25	+100	52	44.5	25.4
AS ₂	0.5	+100	57	43.7	27.3
AS ₃	1	+100	58	42.6	28.4
AS ₄	2	94	61	40	35.2
AS ₅	3	68	64	37.4	39.7

Table 3. Rheological properties of modified asphalt (polyvinyl alcohol and sulfur) with 0.5% sulfur by weight.

Sample no.	Polyvinyl alcohol percentage %	Ductility cm.	Softening point	Penetration 25 C°	Asphaltenes %
AS6	0.5	+100	53	48.1	20.6
AS7	1	+100	54	46.3	21.4
AS8	2	+100	54	47.3	23.8
AS9	3	+100	57	45	25.5
AS10	4	90	58	41.8	27.8
AS11	5	34	71	38.6	28.4

we note that the properties of modified asphalt with the polymer additive were improved through ductility, ductility, and penetration values. It was noted that the ductility values were excellent up to 4% of the additive weight, while the penetration and ductility values were excellent, then began to deteriorate at 4%. The results also showed that the asphaltene ratio gradually increased with increasing additives due to the increased molecular weight with increasing polymer additive ratio [31].

Chemical Immersion

This kind of testing shows how resistant asphalt is to high temperatures and acid rain after being mixed with gravel. It is a measure or number that indicates the extent of asphalt’s adhesion to the aggregate. Table 4 shows the results of asphalt delamination from the aggregate for the original

asphalt and some modified asphalt models (AS7, AS8, AS9, AS10, and AS6) [32]. Chemical immersion measurements were performed and compared with the base asphalt model to determine the resistance of the base and core asphalt to acid rain and high temperatures, by comparing the results as shown in Table 4.

Analysis of the outcomes from the chemical immersion test presented in Table 4 indicates that the asphalt modified with polyvinyl alcohol and nano sulfur commenced separation from the aggregate (gravel) at a higher concentration of (Na₂CO₃) than the original asphalt, as shown in Table 4 in detail. The results of this chemical test for the polymer-modified asphalt and its comparison with the basic asphalt indicate that polyvinyl alcohol led to the production of asphalt that is well resistant to environmental factors, including acid rain, and thus the polymer-modified

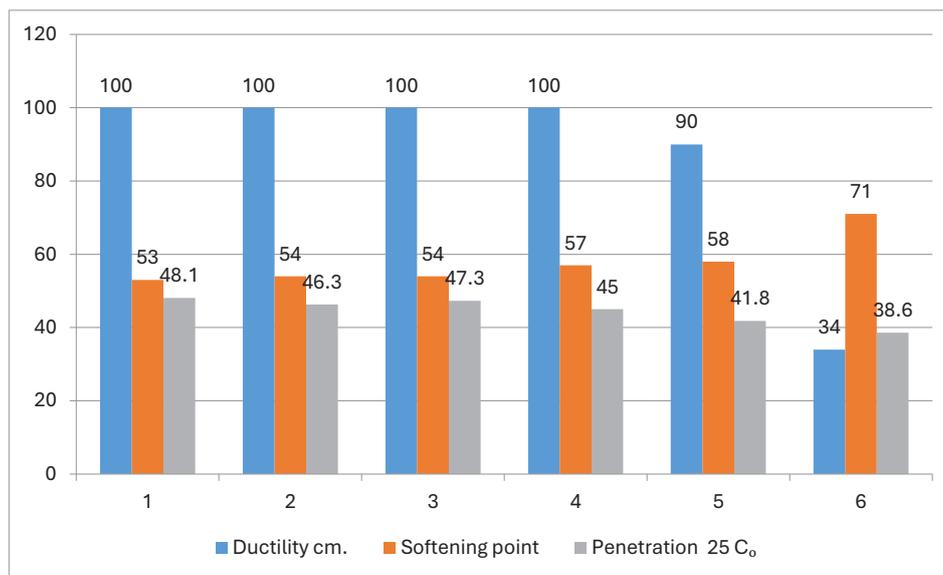


Fig. 2. Rheological Properties of Modified Asphalt (Polyvinyl Alcohol and Sulfur).

Table 4. Chemical immersion test values.

No. of modified sample	Percentage of Na ₂ CO ₃ gm	Riedel&Weber number	R&WNO Original asphalt	R&WNO Modified samples
	0.025	1		
AS0	0.041	2	2	
AS9	0.082	3		
AS10	0.164	4		4
AS6, AS7	0.328	5		5
AS8	0.656	6		6
	1.312	7		
	2.624	8		



Table 5. Marshall test values.

Marshall test values			Percentage of asphalt added to aggregate (%)
Model	Stability (KN)	Flow (mm)	
AS ₀	11.7	5.3	4.5
AS6	14.4	3.1	
AS7	16.3	2.8	
AS8	13.6	3.3	
AS9	16.7	3.1	
AS10	16.2	3.5	
AS*	7 Minimum	2-4	

AS* Specifications of the Iraqi Roads and Bridges Authority

asphalt can be used in road paving [33-35].

Marshall Stability Test

To determine the success of the modified polyvinyl alcohol samples with a sulfur content of 0.5% by weight for use in paving, samples AS7, AS8, AS9, AS10, and AS6 were selected for the Marshall test (asphalt paving).

It is clear from the results obtained from Table 5 that all modified models are better than the original model when used as paving asphalt. These results reinforce the results we obtained in Tables 2 and 3 and confirm the stability of modified asphalt and its resistance to different conditions, whether high temperatures or continuous traffic loads.

CONCLUSION

After completing the study and following up on the results, the following was demonstrated:

1. Asphalt samples with excellent rheological properties were obtained by using a mixture of polyvinyl alcohol and sulfur.
2. The optimum sulfur content used to improve asphalt properties was 0.5% by weight of sulfur.
3. Asphalt modified with polyvinyl alcohol and sulfur has higher separation values than original asphalt, meaning that the modified asphalt is more resistant than original asphalt to acid rain and high temperatures. This is a very important characteristic of asphalt quality, enabling modified asphalt to adhere better to the aggregate, providing longer operational life for roads and greater resistance. Furthermore, modified asphalt possesses good stability values, making it resistant to high temperatures and frequent traffic loads.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this

manuscript.

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