



STUDY THE EFFECT OF THE)SBR/BET(POLYMER BLEND ON THE THERMAL AND RHEOLOGICAL PROPERTIES OF MODIFIED ASPHALT

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Abstract. This study aims to evaluate the effect of a binary polymer blend comprising styrene-butadiene rubber (SBR) and polyethylene terephthalate (PET) on the thermal and mechanical properties of Iraqi asphalt. The polymer blend was prepared using an equal weight ratio (50:50) of SBR and PET and subsequently added to the asphalt at incremental weight percentages of 1%, 2%, 3%, 4%, and 5% relative to the asphalt weight. Blending was conducted at temperatures ranging from 150°C to 160°C for 60 minutes to ensure a homogeneous distribution of the polymer components within the asphalt matrix.

The prepared samples underwent a series of physical tests and chemical analyses to assess the impact of the polymer blend on the asphalt's thermal and mechanical properties, as well as its resistance to degradation caused by operational and environmental conditions. The results demonstrated significant improvements in several properties compared to unmodified asphalt, indicating that the combination of SBR and PET yields a synergistic effect that balances flexibility, deformation resistance, and thermal stability.

These findings highlight the potential of using this binary polymer blend to enhance the performance of asphalt mixtures intended for use in harsh climatic conditions, particularly in high-temperature environments. The study also highlights the potential of utilizing polymers particularly recycled PET in asphalt applications, thereby contributing to the use of plastic waste and the achievement of environmental sustainability.

Introduction

Crude oil is the primary source of asphalt, which is obtained through the direct distillation of crude oil. Asphalt is characterized by its black or dark brown color, high molecular weight compared to other petroleum fractions, and high density, ranging from 1.0 to 1.1 g/cm³ (1, 2). Chemically, asphalt consists of condensed aromatic, paraffinic, and naphthenic hydrocarbon compounds that exhibit high solubility in carbon disulfide (CS₂). It also contains cyclic and non-cyclic compounds incorporating nitrogen, oxygen, and sulfur, alongside trace amounts of

elements such as aluminum, iron, and silicon. Asphalt is a crucial material for road paving due to its strong adhesion to various materials, acceptable viscosity, and low cost (3, 4). Consequently, many researchers have focused on studying paving-grade asphalt and improving the specifications of asphaltic materials through chemical and physical treatments specifically by incorporating various additives. Polymeric additives are particularly significant in this regard, as they substantially alter asphalt's rheological properties, enhance its adhesion to aggregates, improve its resilience against diverse environmental conditions, traffic flow, and repeated loading, and ultimately render it suitable for road paving applications. One such study was conducted by Diab et al., who investigated the effects of rubber, styrene-butadiene-styrene (SBS), and ethylene-vinyl acetate (EVA) on asphalt mixtures based on various rheological tests. The physical and mechanical properties of polymer-modified asphalt binders both before and after aging as well as their fracture and cracking characteristics, were examined and discussed, resulting in asphalt with favorable properties (7).

Yan et al. studied the potential use of waste tire rubber (WTR) and ethylene-vinyl acetate (EVA) to modify and improve asphalt properties. Rheological tests including penetration, softening point, viscosity, and dynamic shear rheometry were performed to evaluate physical properties, alongside FTIR spectroscopy and Environmental Scanning Electron Microscopy (ESEM) analysis; the results indicated that the WTR and EVA blended completely with the asphalt (8).

Furthermore, researchers Ahmed and Hamdoon (2020) successfully modified and improved the rheological properties of Iraqi asphalt using ethylene-vinyl acetate (EVA) combined with aerobic oxidation. Test results demonstrated the production of asphalt samples with favorable specifications, making them suitable for various applications such as asphalt paving, surfacing, and moisture-proofing (9).

Liu et al. (2020) investigated the chemical and physical properties of asphalt modified with waste cooking oil (WCO) and an SBS/SBR polymer blend; the results and measurements revealed a distinct improvement in the modified asphalt's properties, although storage stability was compromised (10).

Jarjees et al. utilized polymer blends specifically polyvinyl acetate (PVA) and polyvinyl chloride (PVC) to modify and enhance the rheological properties of asphalt, thereby increasing its resistance to environmental factors such as acid rain and aging in road paving applications (11).

Additionally, Che et al. presented a research paper examining the effect of styrene-butadiene rubber (SBR) on the performance of asphalt binders. The rheological properties and performance of the asphalt binder were evaluated using various tests, most notably the Dynamic Shear Rheometer (DSR). DSR test results indicated that the addition of SBR latex increased the asphalt's viscosity, suggesting that SBR played a significant role in enhancing the asphalt's resistance to cracking and fatigue (12).

Joni et al. (2022) (13) investigated the use of waste plastic (Low-Density Polyethylene LDPE) as a modifier for asphalt's thermal properties. The study results demonstrated improvements in the thermal and mechanical performance of asphalt mixtures across various temperatures, identifying an optimal polymer additive content of 4% by weight of the asphalt; furthermore, the use of this LDPE percentage enhanced the asphalt's stability.

Experimental Part

A 100 g sample of asphalt was weighed and placed in the asphalt processing apparatus. Subsequently, varying proportions of the (SBR:BET) mixture were added, and the reactants were thoroughly blended at a temperature of 150°C under continuous agitation for 60 minutes. . Subsequently, measurements were conducted for ductility (14), softening point (15), penetration (16), asphaltene content (17), chemical immersion (18), and the Marshall test (19) on certain samples.

Results and Discussion

Researchers are increasingly interested in improving the performance of paving asphalt by using various additives that enhance its resistance to diverse environmental conditions and repeated loading. This study employed a polymer blend consisting of Styrene-Butadiene Rubber (SBR) and Polyethylene Terephthalate (PET). The process involved the following steps:

First: Treating the asphalt with the polymer blend

The asphalt material was treated with varying proportions of the SBR/PET polymer blend using an asphalt processing unit. The blend was gradually added to the asphalt at concentrations ranging from 1% to 5% of the asphalt's weight at temperatures between 160°C and 170°C for a duration of 60 minutes

Second: Measurement of rheological properties and asphaltene content for base asphalt and polymer-modified asphalt

To determine the rheological properties of the polymer-modified asphalt and compare them with the base asphalt, measurements were conducted on both the base asphalt and the polymer-modified asphalt across the various additive concentrations. Table (1) and Figures (1, 2, and 3) illustrate the results obtained from treating the asphalt material with the (SBR: BET) blend.

Table 1. Rheological properties of asphalt treated with various proportions of the (SBR: BET) blend

Sample	Polymer %	Ductility (cm, 25 °C)	Softening point (°C)	Penetration, mm	Asphaltene ratio%
AS ₁	1	+100	54	44.2	21.2
AS ₂	2	+100	57	43.6	23.4
AS ₃	3	+100	56	42.5	25.7
AS ₄	4	95	59	40	27.8
AS ₅	5	85	61	37.2	31.3

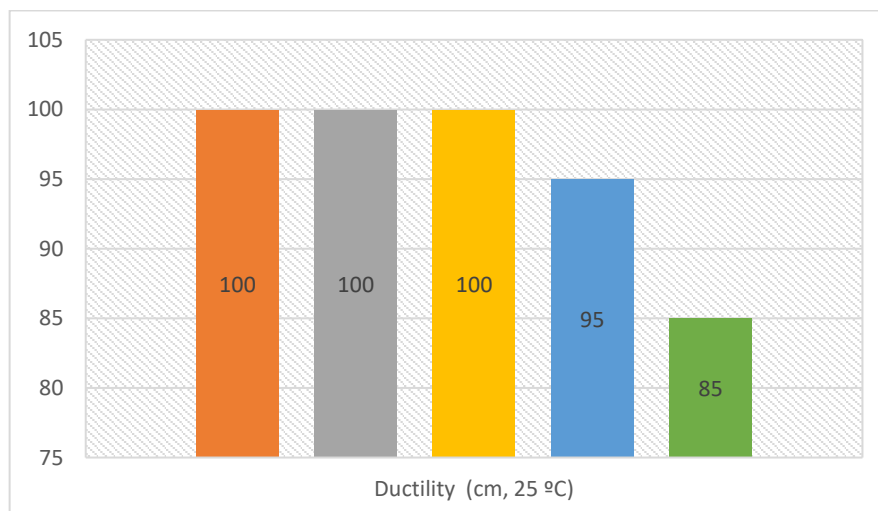


Figure 1. Ductility values for asphalt treated with the (SBR_BET) blend

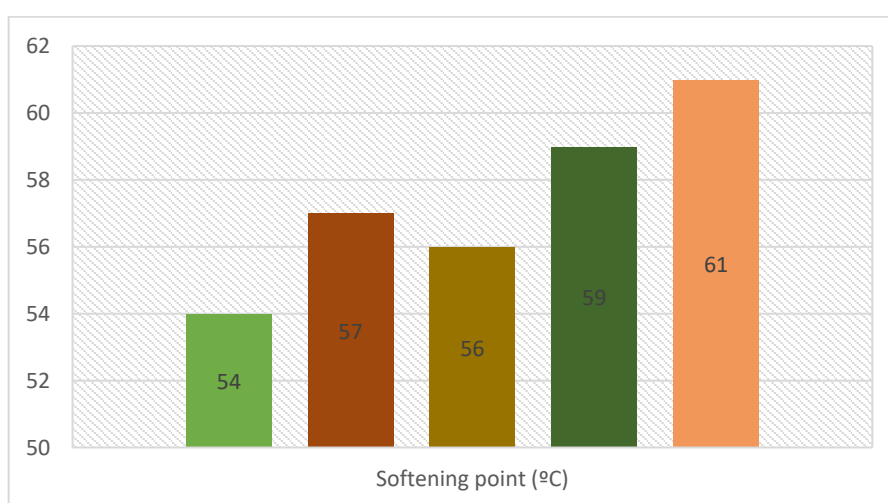


Figure 2. Softening point values for asphalt treated with the (SBR_BET) blend

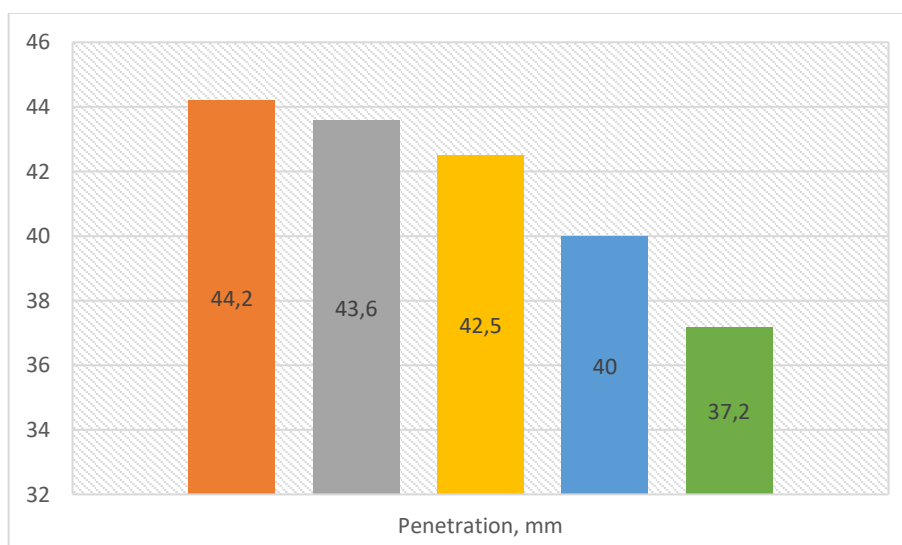


Figure 3. Penetration values for asphalt treated with the mixture (SBR_BET)

From Table (3) and Figures (1, 2, and 3), it is evident that adding the polymer blend resulted in favorable rheological properties up to a concentration of 3% of

the polymer additive in the asphalt. Values for ductility, penetration, and softening point fell within the specifications required for paving-grade asphalt. Furthermore, a distinct improvement in the ductility of the modified asphalt was observed compared to the base asphalt; the polymer blends effectively stiffened the asphalt to a degree that met paving specifications. This compatibility between the polymer blends and the asphalt stems from chemical reactions and physical changes occurring during heating at temperatures exceeding 160°C.

As for asphaltenes, they are the material that precipitates when asphalt is dissolved in certain solvents. Asphaltene molecules consist of condensed aromatic and naphthenic nuclei bearing various alkyl substituents. The state of the asphaltenes depends on the quantity and quality of the resin and oil fractions within the asphalt. A high aromatic content in the resins and oils leads to the formation of "Sol asphalt," where asphaltenes are dispersed throughout the oily components. Conversely, a high paraffinic content in the resins and oils results in "Gel asphalt," where asphaltenes exist as gelatinous aggregates. Upon separating the asphaltenes using petroleum ether from both the base asphalt and the polymer-modified samples, we observed an increase in the separated asphaltene content corresponding to the increase in the additive percentage; this is attributed to an increase in molecular weight. The addition of the polymer resulted in an increase in the molecular weight of the asphalt, due to the bonding of high-molecular-weight polymer molecules with the asphalt.

The rheological properties of the asphalt suitable for paving operations were determined based on the Iraqi standard specifications for paving asphalt outlined in Table (2) (22).

Table 2. Iraqi paving asphalt

Rheological properties	Minimum	Maximum
Softening point (°C)	54	60
Penetration (100gm.5sec.25°C)	40	50
Ductility (cm.25°C)	100	----

Third: Chemical Immersion (Separation)

To determine the resistance of polymer-modified asphalt after mixing with aggregates—to acid rain and high temperatures, a chemical immersion test was conducted on both the polymer-modified mixture samples and the control sample. Table (4) shows the results of asphalt-aggregate separation for the original asphalt and the modified samples.

Table 4. Chemical Immersion results

No. of modified sample	Percentage of Na ₂ CO _{3gm}	R&WNO	R&WNO For the original asphalt	R&WNO For the modified samples
	0.025	1		
AS ₀	0.041	2		
AS ₅	0.082	3	3	
AS ₄	0.164	4		4

-----	0.328	5		
AS ₃ AS ₁	0.656	6		6
AS ₂	1.312	7		7
-----	2.624	8		

Table (4) and the chemical immersion values defined as the amount of sodium carbonate at which the asphalt begins to separate from the aggregate reveal that the modified samples required a higher quantity of sodium carbonate to initiate separation compared to the base asphalt. The values ranging from (0) to (8) correspond to the Riedel and Weber (R&W) scale; specifically, a value of (1) indicates a sodium carbonate quantity of 0.025 g in 50 ml of distilled water, while a value of (8) represents the maximum quantity of 2.624 g. Furthermore, the chemical immersion test results identified sample AS2 containing 2% of the polymer blend as exhibiting the highest resistance to stripping. The fact that the modified asphalt demonstrates higher separation values than the base asphalt indicates superior adhesion to the aggregate, resulting in enhanced resistance to acid rain, high temperatures, and temperature fluctuations. Consequently, the polymer blend significantly improved the asphalt's rheological properties, increasing its resilience against environmental conditions and repeated loading. The study also demonstrates the potential for utilizing the BET material for the rheological modification of asphalt, alongside SBR for asphalt modification.

Fourth: Marshall Test

The Marshall test was conducted on samples modified with the polymer blend (SBR/BET), as well as on the base asphalt. This was done to compare the modified samples with the base asphalt and thereby determine their suitability for paving applications, particularly in the context of the country's climatic conditions.

Stability and flow values were determined through this test, and the Marshall Quotient was calculated by dividing Marshall stability by the flow value (23, 24).

Table (3) presents the Marshall values specifically stability and flow obtained for the selected samples and compares them with the base sample, in accordance with the specifications of the Iraqi State Commission for Roads and Bridges (S.C.R.B) (25, 26).

Table 3. Marshall values for original and modified (S.C.R.U.B) asphalt.

Sample	Modified asphalt (best samples)			Percentage of asphalt added to aggregate (%)
	Stability (KN)	Flow (mm)	MQ	
AS ₀	11.6	5.4	2.1	4.5
AS ₁	14.4	3.2	4.5	
AS ₂	16.7	3.2	5.2	
AS ₃	15.4	2.7	5.7	
AS ₄	13.4	3.8	3.5	
AS ₅	15.6	3.3	5.0	
Standard values	7 Minimum	2-4	3.5 Minimum	

The table above shows that all samples modified with the polymer blend outperform the base sample when used as paving asphalt. The AS2 sample

utilizing a 2% polymer additive exhibits the highest stability. Additionally, the MQ values for the modified samples exceed that of the base asphalt, indicating superior resistance to permanent deformation and repeated loading.

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Conclusions

1. The use of an (SBR:BET) polymer blend as an asphalt additive resulted in a distinct change in the asphalt's thermal properties, driven by chemical changes occurring during the blending process.
2. Utilizing the (SBR:BET) polymer blend as a modifier under specific reaction temperature and time conditions yielded asphalt samples with rheological properties that align with standard specifications for paving-grade asphalt.
3. Marshall test results demonstrated that the asphalt samples exhibited high stability and resistance to repeated loading.
4. Chemical immersion test results indicated that the asphalt samples possessed high resistance to acid rain.

References

1. Asphalt Institute Inc and European Bitumen Association, Eurobitume, (2015), The Bitumen Industry, A Global Perspective, 3rd ed., USA
2. Dabouni, A.A.; and Ali, L.H.", (1986), "Origin Oil, Composition, and Technology." Mosul University, pp. 10-13, 63-72, 65, 69, 70-72, 166-174, 232-236, 292, 293, 294, 298, 301-312, 621, 622.
3. Jarjees, Q. S., Ahmed, S. S., & Hamdoon, A. A. (2025). Enhancing Asphalt Performance with Polymer Blends: A Rheological Study. *Journal of Nanostructures*, 15(2), 499-507.
4. Vargas X.A., Fanasjeve N., alvares M., marchal P.H. and choplin L.,(2008). "Asphalt rheology evolution through thermo-oxidation (Againg) in arheo-reactor", Elsevier. *Fuel*, 87(13-14), 3018-3023
5. Alsolieman, H. A., Babalghaith, A. M., Memon, Z. A., Al-Suhaibani, A. S., & Milad, A. (2021). SBRIuation and comparison of mechanical properties of polymer-modified asphalt mixtures. *Polymers*, 13(14), 2282.
6. Mashaan, N. S., Chegenizadeh, A., Nikraz, H., & Rezagholilou, A. (2021). Investigating the engineering properties of asphalt binder modified with waste plastic polymer. *Ain Shams Engineering Journal*, 12(2), 1569-1574.
7. Diab, A., You, Z., Adhikari, S., You, L., Li, X., & El-Shafie, M. (2020). Investigating the mechanisms of rubber, styrene-butadiene-styrene and ethylene-vinyl acetate in asphalt binder based on rheological and distress-related tests. *Construction and Building Materials*, 262, 120744.
8. Yan, K., Chen, J., You, L., & Tian, S. (2020). Characteristics of compound asphalt modified by waste tire rubber (WTR) and ethylene vinyl acetate (SBR): Conventional, rheological, and microstructural properties. *Journal of Cleaner Production*, 258, 120732.

9. Ahmed, S. S., Hamdoon, A. A., (2020) "The Rheological Properties of Asphalt by Commercial Adhesive (Ethylene-Vinyl Acetate) and Air Blowing Process" *Journal of Education and Science* , Vol.29, No.3, pp.102-118, ISSN 1812-125X.
10. Liu, S., Zhou, S., Peng, A., & Li, W. (2020). Investigation of physiochemical and rheological properties of waste cooking oil/SBS/SBR composite modified petroleum asphalt. *Journal of Applied Polymer Science*, 137(26), 48828 .
11. Hamdoon, A. A., Ahmed, S. S., & Saleh, M. Y. (2022). Modifying the rheological properties of asphalt using waste additives and air blowing and studying the effect of time aging on the modified samples. *Egyptian Journal of Chemistry*, 65(5), 447-453.
12. Mashaan, N. S., Chegenizadeh, A., Nikraz, H., & Rezagholilou, A. (2021). Investigating the engineering properties of asphalt binder modified with waste plastic polymer. *Ain Shams Engineering Journal*, 12(2), 1569-1574.
13. Che, T., Pan, B., Li, Y., Ge, D., Jin, D., & You, Z. (2022). The effect of styrene-butadiene rubber modification on the properties of asphalt binders: Aging and restoring. *Construction and Building Materials*, 316, 126034.
14. Joni, H. H., & AL-Rubaie, A. H. (2022). Enhancement of the Rutting Resistance of Asphalt Mixtures at Different High Temperatures Using Waste Polyethylene Polymer. *Engineering and Technology Journal*, 40(11), 1-9.
15. ASTM D113-99, " Standard test method for ductility of bituminous materials", section 4, vol. 04. 03 Road and paving materials- vehicle- pavements systems, Newyork, Ny
16. ASTM D36-95]Reapproved 2000[, "Standard test method for softening point of bituminous materials(Ring and Ball Apparatus",Section 4,Vol .04 .04,Roofing and waterproofing ,New york,Ny.
17. ASTM D5- 97 " Standard test method for penetration of bituminous materials", Section 4, vol. 04. 03 Road and paving materials- vehicle- pavement systems New York, Ny.
18. Yoder E. J. and Witczak M. W., (1964), "Principle of pavement design" 3rd ed., John Willy and Sons., PP. 269 – 27.
19. ASTM D 6560- 17 " Standard test method for determination of asphaltens (heptane in soluble) in crude petroleum and petroleum production.
20. Speight, J. G., (2015), "Asphalt Materials Science and Technology" Butterworth-Heinemann. PP.232-233.
21. ASTM D 1559- 89, " Test method for resistance of plastic flowak Bituminous mixtures using marshal Apparatus", (With draw standards until 2006), (With drawn standards until 1998), New York, Ny.
22. Kaiser, M. J., de Klerk, A., Gary, J. H., & Handwerk, G. E. (2019). Petroleum refining: technology, economics, and markets. CRC Press.
23. Ahmed, S., Hamdoon, A. A., & Abdulla, M. (2024). Residues from The Mishraq Sulfur Mine and The Nano_Sulfur Derived from Them as Modifiers for The Mechanical and Thermal Characteristics of Iraqi Asphalt. *Journal of the Turkish Chemical Society Section A: Chemistry*, 11(3), 1055-1064. <https://doi.org/10.18596/jotcsa.1386031>
24. Lesueur, D. (2009). The colloidal structure of bitumen: Consequences on the rheology and on the mechanisms of bitumen modification. *Advances in colloid and interface science*, 145(1-2), 42-82.
25. Zoorob, S. E. and Suparma, L. B., "Laboratory Design: an Investigation of the Properties of Continuously Graded Asphaltic Concrete Containing

- Recycled Plastic Aggregate Replacement (Plastiphalt)", Cement and Concrete Composites; Elsevier. 22: 233-242. (2000)
26. State Cooperation of Road and Bridges (S.C.R.B.), " Hot Mix Asphaltic Concrete Pavements". Iraqi Standard Specification , Ministry of Housing and Construction . Department of Design and Study, Section R9. (2003)