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THE EFFECT OF POLYMER SULFUR OBTAINED FROM TECHNICAL SULFUR ON BITUMEN ADHESION

[1] *Yusupov Farkhod,1 Khursandov Bobomurod,1 Yuldashov Fazliddin*

[1] Institute of General and Inorganic Chemistry of the Academy of Sciences of Uzbekistan. Tashkent, Uzbekistan

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Abstract

The article investigates the optimal conditions, structure, and properties of polymer sulfur obtained from local sulfur raw materials. A composition was developed using secondary phenol and sulfur. Sodium hydroxide was utilized as an initiator in creating the composition. IR spectroscopy was employed to determine the optimal conditions for polymer sulfur. Based on the research results, the interactions between bitumen and mineral material were studied, focusing on the mechanical theory and electrostatic theory of adhesion properties.

Keywords: Composition, polymer, adhesion, destruction, modifier. modification, plastomers, thermoplastic elastomers, copolymer, dispersion, cohesion, viscosity

Introduction

Currently, the chemical, petrochemical, metallurgical, and gas processing industries produce over 70 million tons of elemental sulfur as a by-product. Due to the high corrosive properties of sulfur compounds and their significant environmental impact, processing them is of great practical importance. One of the areas where sulfur and its compounds are widely used is in construction and road building. Therefore, synthesizing polymer sulfur based on elemental sulfur and developing effective methods for producing polymer sulfur-containing bitumen products using this compound are of great importance. Although sulfur is widely used in many areas of chemical production, it is the construction industry that can consume such large quantities of sulfur (W. J. Chung, 2013). In particular, one of the promising directions is the production of sulfur-containing binding materials used in road surfaces. The inclusion of sulfur in road coating binders, on one hand, reduces the cost of road coatings, while on the other hand, it serves to improve the rheological properties of the coating (N. P. Tarasova, 2021). Sulfur does not conduct electricity. It dissolves well in organic solvents such as carbon disulfide, toluene, and pure ammonia. However, it is practically insoluble in water and most inorganic acids. The main physical and mechanical properties of sulfur are shown in the following table (M. Porto, 2019).

Table 1. *The properties of technical sulfur*

Indicators	Temperature, °C		
	20	122	150
Density, g/cm³	2,1	1,96–1,99	1,6–1,81
Durability, MPa	12–22	–	–
Stiffness on a matching scale	1–2	–	–
Viscosity, Pa·c	–	0,011–0,012	0,0065–0,0070
Surface tension, Н/м	–	–	0,055
Heat capacity, kJ/kg	0,7	1,47	1,84

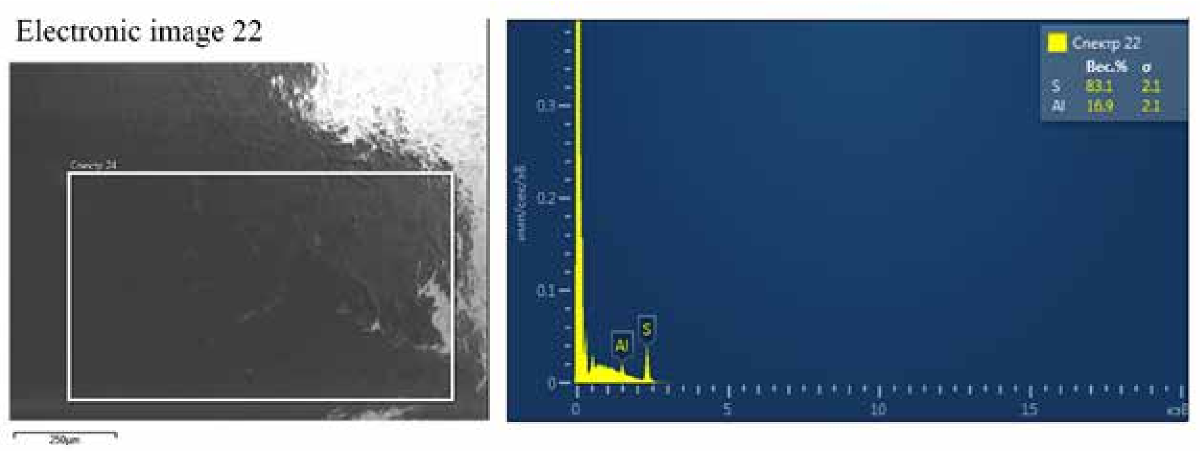
Numerous studies are also being conducted on bitumen modification to obtain high-quality bitumen. Among all bitumen modification methods, polymer modification is considered one of the most popular.(S. Pyshev, 2016) Polymer modification of bitumen involves introducing polymers into bitumen through mechanical mixing or chemical reaction.(V. Gunka, 2021) Among the various polymers studied are plastomers (e.g., polyethylene (PE), polypropylene (PP), ethylene vinyl acetate (EVA), ethylene butyl acrylate (EBA)) and thermoplastic elastomers (e.g., styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), and styrene-ethylene/butylene-styrene (SEBS)).(G. Polacco, 2005) It has been reported that these polymers can improve certain properties of bitumen, such as high stiffness at high temperatures, high crack resistance at low temperatures, good moisture resistance, or extended lifespan.(B. Sengoz, 2009) Polymer modification of bitumen is the introduction of polymers into bitumen by mechanical mixing or chemical reaction.(V. Gunka, 2021) Among the various polymers studied are plastomers (e.g. polyethylene (PE), polypropylene (PP), ethylene vinyl acetate (EVA), ethylene butyl acrylate (EVA)) and thermoplastic elastomers (e.g. styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), and styrene-ethylene/butylene-styrene (SEBS)). It has been shown that these polymers may improve some of the bitumen's properties, such as high hardness at high temperatures, high crack resistance at low temperatures, good moisture resistance, or increased lifespan (B. Sengoz, 2009).

EVA (ethylene vinyl acetate) is a thermoplastic substance formed by copolymerization of ethylene and vinyl acetate monomers. These binders are produced by dispersing the polymer in bitumen at a specified temperature. The modification of bitumen with EVA has the following advantages: increased adhesion of the binder to the mineral filler, improved cohesion (over a wider temperature range), increased resistance to deformation (due to increased viscosity of the binder), increased tensile strength, and reduced temperature sensitivity (C. Rodriguyes, 2015).

Method

Technical sulfur from the Mubarek Gas Processing Plant, secondary phenol, BND 60/90 grade bitumen from the Jarkurgan district of Surxondaryo Region, marble, granite, and gravel were selected as materials for the study. Infrared (IR) spectroscopy was used to examine the structure of polymer sulfur. Elemental analysis was conducted using a scanning electron microscope (SEM) to determine the purity level of technical sulfur, which is a waste product of the Mubarek Gas Processing Plant.

Figure 1. *SEM results of technical sulfur*



Results

Technical sulfur is heated at 125 °C while being rotated at a speed of 60 rpm. During heating, secondary phenol was added in an amount of 4% of the sulfur mass. Sodium hydroxide was used as the initiator. The mixture of sulfur and secondary phenol was stirred for one hour until it reached a homogeneous state. Without stopping the stirring, the temperature was raised to 165 °C, and the mixture was stirred for another 2 hours. Afterward, the liquid sulfur was cooled to room temperature and solidified.

The obtained polymer sulfur was studied based on physicochemical investigations. The interaction between sulfur and phenol was examined using IR spectroscopy, which revealed significant changes in the O-H group region (V_{max}, cm^{-1}: 3374). Peaks at 2917 cm^{-1} and 2850 cm^{-1} indicated the presence of methyl (CH_3) and methylene (CH_2) groups in the composition of aliphatic hydrocarbons. Peaks at 2101 cm^{-1} and 1993 cm^{-1} indicated the presence of triple bond (C=C) groups. The presence of aldehyde or ketone groups was shown by peaks in the region of 1740.72 cm^{-1}. C=C bonds, which are part of the aromatic ring, formed peaks at 1586 cm^{-1} and 1486 cm^{-1}. C-H deformation vibrations in the region of 842 cm^{-1} and 756 cm^{-1} confirmed the existence of a benzene ring. The low-frequency peaks presented in the spectrum at 756 cm^{-1} and 465 cm^{-1} were found to correspond to S-S bonds.

Figure 2. *IR spectrum of polymer sulfur obtained from phenol (secondary phenol) containing additional substances*

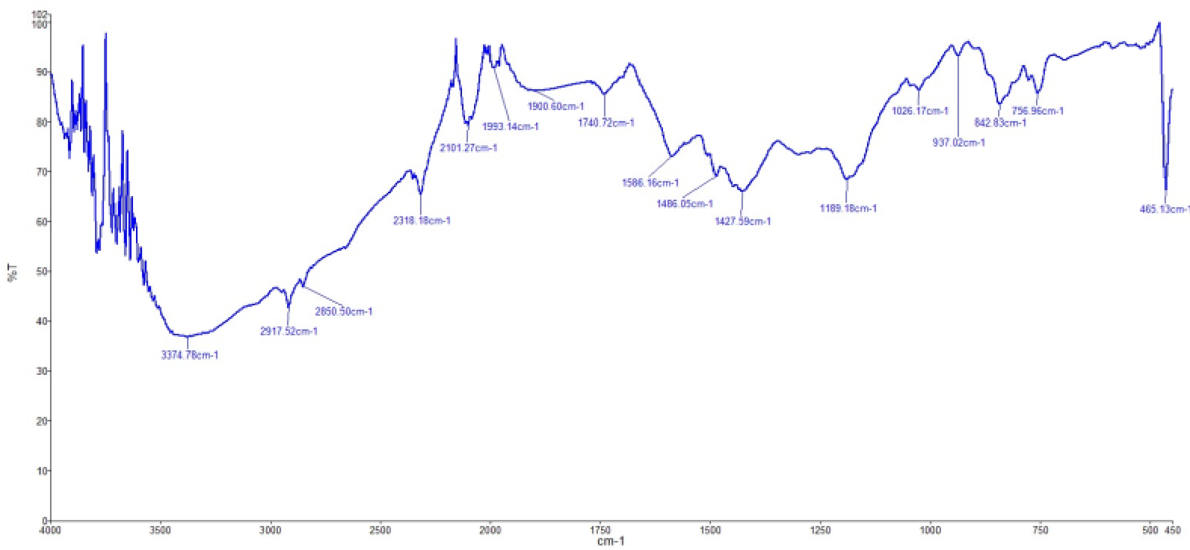


Table 2. *Study and evaluation of the adhesive properties of BND-60/90 bitumen and polymer sulfur-based binders to mineral materials*

The binder	Mineral material					
	Granite stones		Granite gravel		Marble	
	% cover	score	% cover	score	% cover	score
BND-60/90	76	3	74	2	78	3
BND-60/90 + 3% (PO)	82	3	77	3	86	3
BND-60/90 + 5% (PO)	86	3	84	3	90	4
BND-60/90 + 10% (PO)	92	4	90	4	93	4
BND-60/90 + 15% (PO)	89	3	87	3	89	3
BND-60/90 + 20% (PO)	91	4	89	3	93	4
BND-60/90 + 25% (PO)	93	4	90	4	95	5
BND-60/90 + 30%(PO)	96	5	92	4	97	5
BND-60/90 + 35%(PO)	92	4	88	3	91	4

Based on the data in Table 1, dependency graphs shown in Figures 3 and 4 have been constructed. The highest level of adhesion to granite, gravel, and marble was achieved when the polymer sulfur content was added up to 10%. As we increased the amount of polymer sulfur beyond 10%, the degree of adhesion to the materials decreased.

Note: Explanation of scores: 2 – "unsatisfactory" – the binding film covers less than 75% of the pebbles' surface; 3 – "satisfactory" – the binding film covers up to 90% of the pebbles' surface; 4 – "good" – the binding film covers up to 95% of the pebbles' surface; 5 – "exemplary" – the binding film covers more than 96% of the pebbles' surface (P. Kumar, 2014).

Figure 3. *Adhesion of BND 60/90 road bitumen to mineral materials by adding polymer sulfur in amounts of 3, 5, 10, and 15%*

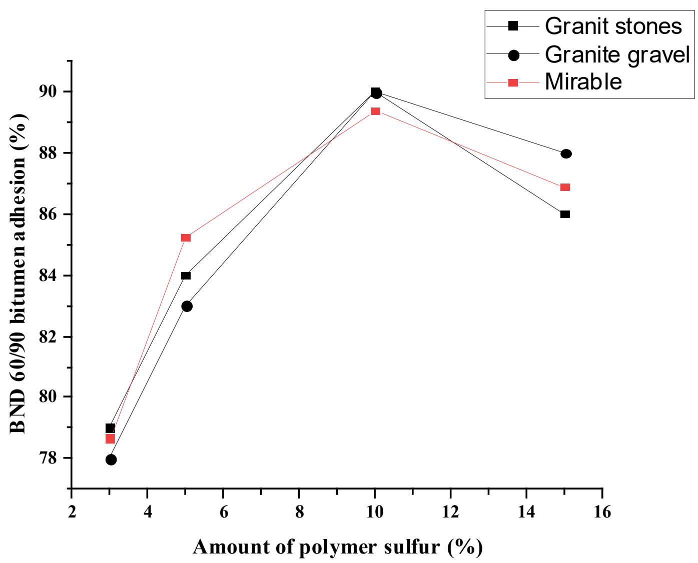
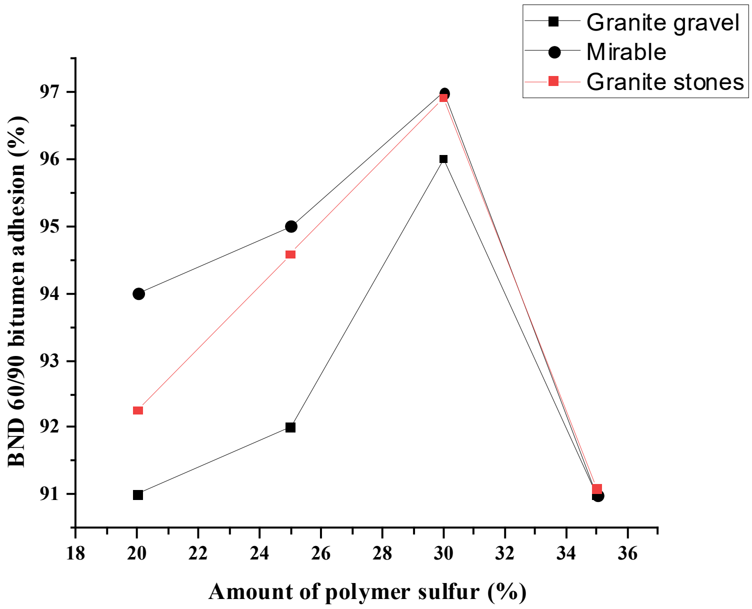


Figure 4. *Adhesion of mineral materials to road bitumen BND 60/90 with the addition of polymer sulfur in amounts of 20, 25, 30, and 35%*



As the amount of polymer sulfur increased, the degree of adhesion to granite stones, granite gravel, and marble increased. The highest adhesion level was achieved when the sulfur content reached 30%. As the amount of polymer sulfur exceeded 30%, its adhesion began to decrease. When we increased the amount of polymer sulfur to 35%, the quality of adhesion with granite, gravel, and marble decreased.

Conclusion

According to the research results, the studied mechanical theory and electrostatic theory demonstrate the importance of the physical properties of granite stones and granite gravel for studying adhesive properties: the surface morphology promotes adhesion and induces selective adsorption, and the nature of the mineral material's surface interacts with adhesive properties. The theories of chemical bonding and thermodynamics have also been thoroughly studied, and the following conclusions have been drawn.

According to the theory of chemical bonds, insoluble stable complexes are formed in bitumen, ensuring adhesive strength in the interphase region of the mineral. Based on the thermodynamic theory, the necessary conditions for adhesive properties and the establishment of a close connection between the two phases have been determined. Based on the two theories of studying adhesive properties considered, the following conclusion was drawn. The smoothness, roughness, surface chemisorption of mineral materials, and various other approaches were observed, and their interaction with bitumen was determined.

References

Chung, W. J. (2013). The use of elemental sulfur as an alternative feedstock for polymeric materials. *Nature Chemistry,* – 5. – P. 518–524.
Tarasova, N. P. (2021). Elemental Sulphur in the synthesis of sulfur-containing polymers: Reaction mechanisms and green prospects. *RSC Advances,* – 11.
Porto, M. (2019). Bitumen and bitumen modification: A review on latest advances. *Applied Sciences,* – 9.
Pyshev, S. (2016). Polymer modified bitumen. *Chemistry & Chemical Technology,* – 10.
Gunka, V. (2021). Application of phenol-cresol-formaldehyde resin as an adhesion promoter for bitumen and asphalt concrete. *Road Materials and Pavement Design,* – 22.

Polacco, G. (2005). Asphalt modification with different polyethylene-based polymers. *European Polymer Journal,* – 41.

Sengoz, B. (2009). Morphology and image analysis of polymer modified bitumens. *Construction and Building Materials,* – 23.

Rodriguyes, C. (2015). Polymer modified bitumen's and other modified binders. In *The Shell Bitumen Handbook* (6th ed., – P. 45). ICE Publishing.

Kumar, P. (2014). Rheological investigations of sulfur modified bitumen. *Proceedings of the International Conference on Sustainable Civil Infrastructure (ICSCI 2014)*, Hyderabad, Telangana, India (P. 703–713).

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Contact: temirovgolib1995@gmail.com