Study of Production of Rubber-Bitumen Compounds

F. Austruy[1], Ye. Tileuberdi[2, 3*], Ye. Ongarbaev[2, 3], Z. Mansurov[2, 3]

[1]La Rochelle University, La Rochelle, France
[2]Faculty of Chemistry and Chemical Technology, Al-Farabi Kazakh National University, Almaty, Kazakhstan
[3]Institute of Combustion Problems, Almaty, Kazakhstan

Abstract

In this article were investigated ways of production of Rubber-Bitumen Compounds (RBC). The physico-mechanical characteristics of paving bitumen BND 60/90 modified with rubber crumb from spent tire and spent engine oil. The structure of rubber crumb was characterized by optical microscopy and physico-mechanical characteristics of rubber-bitumen compounds are determined by standard methods. It established that the quantity of entered rubber-oil depending (ratio 3:2) on physical and chemical conditions. 15-25 wt.% rubber-oil modified bitumens were according to variety standard of RBC.

Introduction

Petroleum products play an important role in economic development of any nation. The growth in energy consumption is connected to the growth in the economy of any country; however, the energy demand of the world is increasing while conventional oil reserves are declining. The shortage of oil of known petroleum reserves will make less attended energy resources more attractive. The most feasible way to meet this growing demand is by utilizing such sources as bitumen, which is a huge potential resource to fulfill petroleum requirements of processes significantly. Bitumen is a mixture of organic liquids that is viscous, black and sticky. It is a complex mixture of high boiling point range of compounds and molecules with a relatively low hydrogen-to-carbon ratio [1-3].

The main problem with road building is the poor quality of bitumens used in asphalt-concrete pavements. One of the ways to improve the quality of the binders is their modification with spent rubber crumb from reprocessing of tire industry wastes [4-5]. The production of a qualitative rubber-bitumen binder and modified petroleum bitumen for road pavement is an extremely difficult technological process. Bitumen materials relate to the group of petroleum disperse systems and are colloid systems, in the colloid particle nuclei of which paramagnetic molecules serve as power centers and large molecules of resins, aromatic carbohydrates, and hetero-compounds serve as solvation spheres. The properties of bitumens depend on both the stability and sizes of colloid particles, power interaction of their external solvate layers, quantity, and molecular composition of a medium [6].

To obtain binding bitumen materials with improved qualities, it is important to have a stable disperse system in order to achieve necessary operational characteristics. The utilization of spent rubber materials, including automobile tires, is currently one of the most important environmental problems on a global scale because of the rapid growth of the automobile industry. Scrap automobile tires do not undergo natural degradation and decay; therefore, they are accumulated in open landfills to occupy considerable ground areas or scattered in ravines, forests, and water bodies to pollute the environment. According to available data, the world reserves of scrap tires are estimated at 25 million tons with an annual increment of at least 7 million tons. In Russia and the CIS countries, the annual volume of discarded

*corresponding author. Email: erbol.tileuberdi@mail.ru

automobile tires is greater than 1 million tons. At the same time, scrap tires are valuable secondary raw materials containing 65-70% rubber, 15-25% technical-grade carbon, and 10-15% high-quality metal. Thus, the efficient processing of scrap tires makes it possible not only to solve environmental problems but also to perform economically rational utilization processes [7-8]. According to the European Tire Recycling Association (ETRA), the recovery of tracks for reuse is currently the most widespread process for the utilization of scrap tires. In European countries, retreated tires are responsible for 15 or 46% of the sales of car or heavy-duty tires, respectively.

Crumb rubber modified bitumen can improve the heat-resistance, the crack-resistance at low temperature and the durability of bitumen. Compared with an unmodified bitumen roadway, the service life of a crumb rubber modified bitumen roadway will be prolonged largely. Crumb rubber modified bitumen is made by mixing crumb rubber with bitumen at high temperature for several hours. As is known to all, however, crumb rubber in the sulfurization cannot be dissolved and can only be swelled. But, in fact, because the viscosity of the blend of crumb rubber and bitumen is very low at high temperature, which results in that the sheafing force produced by stirring is small and weak, the swelling of crumb rubber in bitumen is also difficult and a perfect elastic network cannot be formed in the crumb rubber modified bitumen. For these reasons, the elasticity and the stability of crumb rubber modified bitumen are inferior to that of other rubber modified bitumens, such as SBS modified bitumen, SBR modified bitumen. Butbecause of the cheap price of waste crumb rubber and the enormous contribution of its reuse to protecting environment, crumb rubber modified bitumen has attracted a close attention of many countries in the world [9].

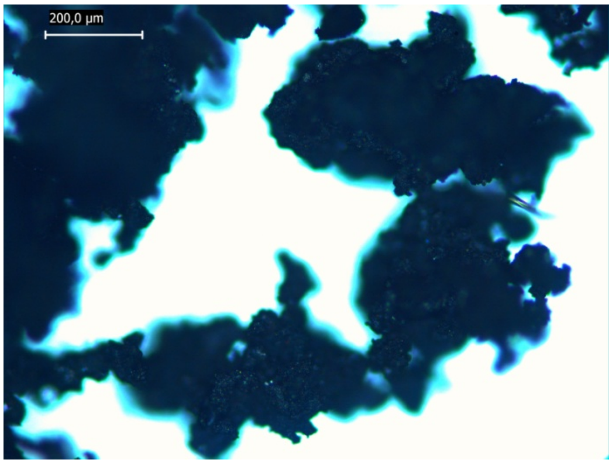
In this study we examined the properties of bitumen compounds prepared with rubber crumb from spent tire and spent engine oil.

Experimental Materials and Methods

When developing Rubber-Bitumen Compounds, it is necessary first to find conditions for introducing rubber crumb into a bitumen or plasticizer, under which the crumb would act not merely as filler but also as a modifier improving the bitumen properties. At work was used standard paving bitumen BND 60/90, which physico-mechanical characteristics according to standard 22245-90 are: penetration at 25ºC – 78·0.1 mm, softening point by method “ring and ball” – 47°C, extensibility at 25ºC – 96 cm. Spent engine oil from Car service.

Rubber crumb from spent tires (from Kazakhstan Rubber Recycling LLP (in Astana)) which have two different particle sizes: one of the rubber crumb is active, particle size less than 0.6 mm. It is showing on the Figure 1. The other one is not active, particle size between 0.6mm and 1mm. It is showing on the Figure 2. These figures took in Laboratory of National Nanotechnology of Kazakh National University by optical microscopy Leica DM 6000 M on optical reflection.

Physico-mechanical characteristics of Rubber-bitumen are established by standard methods: softening temperature (S) is determined by the method “Ring and Boll”, penetration (P) is determined by penetrometer, extensibility (D) is determined by ductilometer.



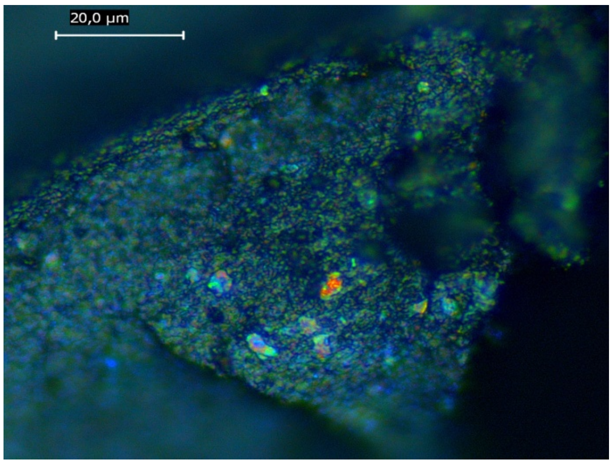


Fig. 1. Optical microscope images of rubber crumb with particle size less than 0.6 mm (active).

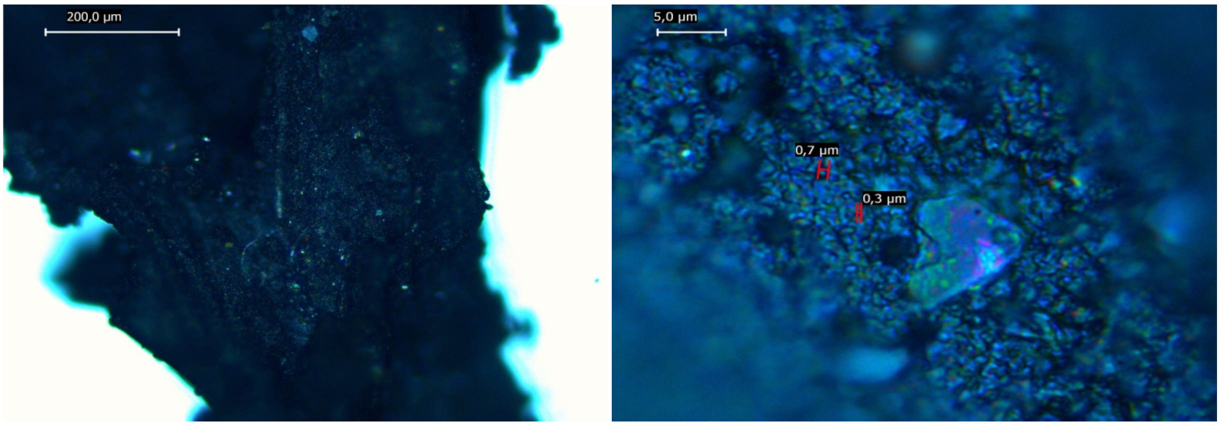


Fig. 2. Optical microscope images of rubber crumb with particle size 0.6-1.0 mm (non active).

Results and Discussion

At first, rubber-oil mixture was prepared. Rubber-oil mixtures were prepared by mixing spent engine oil into rubber crumb with a ratio in 5:6, 1:1 and 3:2. After a day it used for preparing rubber-bitumen compounds. Bitumen samples were heated at 160-170°C and variety content of (10; 15; 20; 25 wt.%) rubber-oil mixtures were added in bitumen. The compound was stirred for 5 minutes at 165-180°C. The Figure 3 shows Scheme of preparation rubber-bitumen compounds.

Physico-mechanical characteristics of Rubber-bitumen compounds with active rubber crumb (Rubber:engine oil = 1:1) are given Table1.

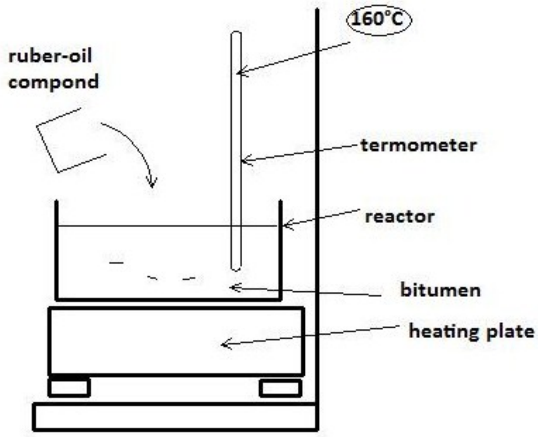


Fig. 3. Scheme of preparation RBC.

Table 1

Physico-mechanical characteristics of Rubber-bitumen compounds with active rubber crumb (Rubber: engine oil=1:1)

Names of indicators	Mark of standard BND 60/90	RBC (a) R:O=1:1 10 wt.%	RBC (a) R:O=1:1 15 wt.%	RBC (a) R:O=1:1 20 wt.%	RBC (a) R:O=1:1 25 wt.%	Method of testing
Penetration at 25°C (0.1 mm)	61-90	90	127	126	170	According to standard 11501
Softening point (°C)	47	51	46	50	48	According to standard 11506
Ductility at 25°C (cm)	55	25	19	26,5	22	According to standard 11505
Standard accordance				RBC 90/130	RBC 130/200	

We can see in Table 1, physico-mechanical characteristics of RBC with 20 wt.% rubber-oil corresponds to grade of paving Rubber-bitumen compounds RBC 90/130 and 25 wt.% is according to standard RBC 130/200. When we use not active rubber crumb (06-1) only one composition is a according to standard RBC 60/90. This is the 15 wt.%, which is shown Table 2.

Table 2
Physico-mechanical characteristics of Rubber-bitumen compounds with not active rubber crumb (Rubber:engine oil = 1:1)

Names of indicators	Mark of standard BND 60/90	RBC (06-1) R:O = 1:1 10 wt.%	RBC (06-1) R:O = 1:1 15 wt.%	RBC (06-1) R:O = 1:1 20 wt.%	RBC (06-1) R:O = 1:1 25 wt.%	Method of testing
Penetration at 25°C (0.1 mm)	61-90	67	71	90	91	According to standard 11501
Softening point (°C)	47	50	59	51	58	According to standard 11506
Ductility at 25°C (cm)	55	12	13.5	12.5	11.5	According to standard 11505
According to standard			RBC 60/90			

Table 3
Physico-mechanical characteristics of Rubber-bitumen compounds with active rubber crumb

Names of indicators	Mark of standard BND 60/90	RBC (a) R:O = 3:2 10 wt.%	RBC (a) R:O = 3:2 15 wt.%	RBC (a) R:O = 3:2 20 wt.%	RBC (a) R:O=3:2 25 wt.%	Method of testing
Penetration at 25°C (0.1 mm)	61-90	75	130	109	150	According to standard 11501
Softening point (°C)	47	58	47	55	46	According to standard 11506
Ductility at 25°C (cm)	55	19	31	17	25	According to standard 11505
According to standard		RBC 60/90		RBC 90/130	RBC 130/200	

The Table 3 is showing Physico-mechanical characteristics of RBC with 10 wt.% rubber-oil corresponds to grade of paving Rubber-bitumen compounds RBC 60/90. Then RBC with 20 wt.% according to standard RBC 90/130 and 25 wt.% rubber-oil corresponds to grade of paving Rubber-bitumen compounds RBC 130/200. Whereas the 15 wt.% crumb rubber modified sample mismatch any standard of RBC. And physico-mechanical characteristics of Rubber-bitumen compounds with not active (06-1) rubber crumb (Rubber:engine oil = 3:2) are given Table 4.

Table 4
Physico-mechanical characteristics of Rubber-bitumen compounds with not active rubber crumb (06-1)

Names of indicators	Mark of standard BND 60/90	RBC (06-1) R:O = 3:2 10 wt.%	RBC (06-1) R:O = 3:2 15 wt.%	RBC (06-1) R:O = 3:2 20 wt.%	RBC (06-1) R:O = 3:2 25 wt.%	Method of testing
Penetration at 25°C (0.1 mm)	61-90	87	160	195	108	According to standard 11501
Softening point (°C)	47	53	45	45	52	According to standard 11506
Ductility at 25°C (cm)	55	17	20	18	13	According to standard 11505
According to standard		RBC 60/90	RBC 130/200	RBC 130/200		

We can see from the Table 4 the products of RBC with 10 wt.% according to standard RBC 60/90, with 15 wt.% and with 20 wt. % rubber-oil samples corresponds to grade of paving Rubber-bitumen compounds RBC 130/200. Thus, all the results are allow knowing in ratio 3:2 rubber-oil mixture modified bitumen better than ratio of 1:1.

Comparisons physico-mechanical characteristics of Rubber-bitumen compounds with active rubber crumb are given Figure 4. As seen from Figure 4, with increasing content of rubber-oil mixture in bitumen, the softening point of RBC decreases, otherwise the penetration increase. It means the bitumen starts to harden. But the extensibility of RBC isn't more changing in any content of rubber-oil mixture.

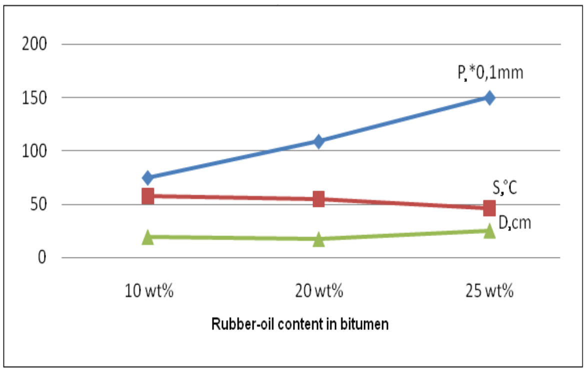


Fig. 4. Characteristics comparison of Rubber-bitumen compounds with active rubber crumb.

Physico-mechanical characteristics of Rubber-bitumen compounds with not active rubber crumb are given Figure 5. There are same conditions as Figure 4, we can see, with increasing content of rubber-oil mixture in bitumen, the softening point of RBC decreases, otherwise the penetration increase. It means the bitumen became harder. But the extensibility of RBC is stable in any content of rubber-oil mixture.

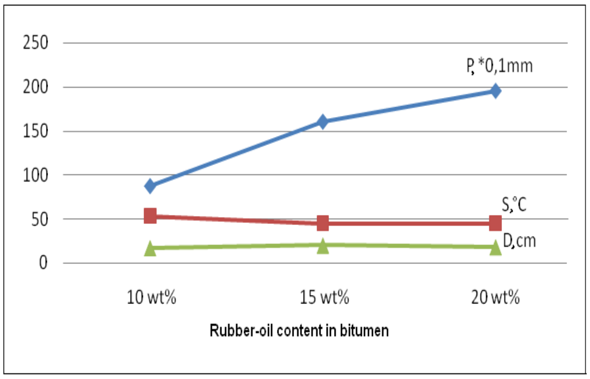


Fig. 5. Characteristics comparison of Rubber-bitumen compounds with not active rubber crumb (06-1)

Conclusion

According to our investigation for production of rubber-bitumen compounds based on spent rubber items and spent engine oil, It established that the quantity of entered rubber-oil depending on physical and chemical conditions. It brings us to optimal composition of rubber-oil ratio 3:2, because when we put the rubber-oil mixture into bitumen for RBC most of time it makes RBC according to standard bitumen. So it allows us to produce high quality rubber-bitumen compounds. Utilization of rubber crumb and spent engine oil in road building will allow the amount of rubber crumb produced by reclaiming facilities to be considerably increased, which will decrease environmental pollution with spent rubber and spent engine oil.

References

1. Songhun Yoon, Sharad Durgashanker Bhatt, Wonkyu Lee, Heung Yeoun Lee, Soon Yong Jeong, Jin-Ook Baeg, and Chul Wee Le. Separation and characterization of bitumen from Athabasca oil sand. *Korean J. Chem. Eng*., 26(1), 64-71 (2009).
2. Mansurov Z.A., Ongarbaev E.K., Tuleutaev B.K., 2000. Utilization of Oil Wastes for Production of Road-building materials, *Eurasian Chemico-Technological Journal, 2(2): 161-166.*
3. E.K. Ongarbaev, Z.A. Mansurov. Oil Wastes and Methods of utilization them. *–Almaty: Kazakh University, 2003. –P. 160. (Russian)*
4. D.G. Shunin, A.G. Filippova, N.A. Okhotina, A.G. Liakumovich, and Ya.D. Samuilov. Possibilities of Production and Use of Rubber-Bitumen Compounds. *Russian Journal of Applied Chemistry, Vol. 75, No. 6, 2002, pp. 1020-1023.*
5. E.K. Ongarbaev, E. Tileuberdi, B.K. Tuleutaev, Z.A. Mansurov. New source of production and and improvement quality of oxidative oil bitumen. *VI International symposium "Combustion and Plasmochemistry", 24-26 august, 2011. -Almaty, the Republic of Kazakhstan. –P. 66-68.(Russian)*
6. B.K. Nefedov, E.E. Gorlova, and E.G. Gorlov. Obtaining a Rubber-Bitumen Asphaltic Concrete Pavement Binder by the Thermocatalytic Processing of Petroleum Residues in a Mixture with Rubber Crumb in the Presence of Zeolites and Organo-Mineral Activators. *ISSN 2070-0504, Catalysis in*

Industry, 2009, Vol. 1, No. 2, pp. 121–127. © Pleiades Publishing, Ltd., 2009.

7. E.E. Gorlova, B.K. Nefedov, and E.G. Gorlov. Manufacture of an Asphalt–Rubber Binder for Road Pavements by the Thermolysis of Tire Chips with Heavy Petroleum Residues. *Solid Fuel Chemistry, 2009, Vol. 43, No. 4, pp. 224–228.*
8. F. Austruy, Ye. Tileuberdi, Ye. Ongarbaev, Z. Mansurov. Use of oil-rubber mixture for production of Rubber-Bitumen Compounds. *VI International symposium "Combustion and Plasmochemistry", 24-26 august, 2011. - Almaty, the Republic of Kazakhstan. –P.137-138.*
9. YE Zhi-gang, KONG Xian ming, YU Jian-ying, WEI Lian-qi. Properties of Desulfurized Crumb Rubber Modified Bitumen. *Journal of Wuhan University of Technology-Mater. Sci.Ed. Mar. 2003 Vol.18 No.1 pp. 83-85.*

Received 24 October 2011