Polymerasphaltconcrete together with the use of modified effective components

V E Rozina\(^1\) N I Shestakov\(^2\) and A K Komarov\(^1\)

\(^1\)Irkutsk National Research Technical University, 83 Lermontov str., Irkutsk, 664074, Russia
\(^2\)National research Moscow state University of civil engineering, department of building materials and materials science, 129337, Moscow, Yaroslavl highway, 26, Russia

E-mail: vikt.rozina@yandex.ru

Abstract. In this paper, we consider the possibility of joint use of polystyrene, its block copolymers and transformer oil to produce polymerasphaltconcrete. It is established that the properties of bitumen change when different polymers and their quantity are introduced into its composition. It was found that the introduction of polystyrene together with a plasticizer expands the temperature range of operation, which leads to an improvement in the physical-mechanical and hydrophysical properties of polymerasphaltconcrete. The regularities of the influence of the composition and quantity of polymers on the physical, mechanical and operational properties of asphalt concrete based on modified binders are revealed. It was found that the optimal amount of polymers and plasticizer is 3.5% and 10% of the mass of bitumen.

The road surface must provide maximum resistance to fatigue damage and be resistant to changes in temperature of daily and seasonal cycles. One of the promising areas that allow us to solve these problems is the use of bitumens together with plasticizing polymers (PBB). The cost of PBB is higher than ordinary bitumen by an average of 60-65%, but roads are not built only from bitumen, the share of bitumen in asphalt concrete is only 6%, calculations show that the increase in the cost of building 1 km of road is about one percent [1-4]. Given the increase in the service life of the road in two or three times, the use of PBB is certainly economically justified. Thus, an urgent task is to develop a technology for the production of polymerasphaltconcrete based on a polymer-bitumen binder obtained from ground polystyrene and transformer oil-processing.

The most important advantage of the polymer-bitumen binder (hereinafter referred to as PBB) is the ability to regulate their properties due to the ratio of the polymer content and the plasticizer, which creates a quality material suitable in any climatic conditions for different driving conditions. The most popular modifiers are thermoplastic elastomers of the SBS type: Kraton D (company KratonPolimers), Calprene (Dynasol company) and others. Along with them, synthetic latexes of the Butonal NS series (BASF company) and thermopolymers of the Elvaloy series (du Pont company) are widely used. These polymers reduce the sensitivity of bitumen to temperature changes, increase the cohesive strength and heat resistance of binders, give them elasticity, and improve their behavior at low temperatures. The current trend in Russia, which is to reduce the consumption of expensive polymers for modifying road bitumen, necessitates an in-depth study of bitumen-polymer binders. At the same time, a significant scientific and practical interest is represented by BPP prepared on bitumens of
different brands. When developing PBB compositions, it is necessary to carefully choose the combination of the "bitumen — polymer — plasticizer" system, since there is a possibility of their incompatibility, or use special techniques aimed at reducing their competing ability. [5-7]

There are certain requirements for polymers that determine the effectiveness of their use for modifying bitumens. Thus, the macromolecules of the polymer must have a tendency to association and the ability to immobilize the largest possible volume of the dispersion medium. Also, the polymer must be quickly and well distributed in the dispersion medium of bitumen without destruction, forming a structural grid in the bitumen that retains strength at high and elasticity at low temperatures. The availability and cheapness of the polymer is also important. In this regard, it is very important to study the use of polystyrene as a polymer and oil-processing of transformer plants as a plasticizer of the medium.

The structure of polymers is shown in pictures 1-3.

![Picture 1. Surface structure of styrene-butadiene-styrene SBS](image1)

A) 50x magnification  B) 100x magnification  C) 1000x magnification

Picture 1. Surface structure of styrene-butadiene-styrene SBS

![Picture 2. Surface structure of bead styrene before grinding](image2)

A) 50x magnification  B) 100x magnification  C) 1000x magnification

Picture 2. Surface structure of bead styrene before grinding

The surface of beaded styrene is expressed by clear spherical and low-porosity structures. Such surfaces are most often inactive to sorption processes with organic and organic substances, and adhesive forces can only be formed from the conditions of chemical activity and chemical-sorption capabilities of the surface. Therefore, to ensure the conditions for the formation of a homogeneous binder composite, it is necessary to change the surface type of the structure or its dispersion. In this case, when working with the bitumen melt, the polymer will be more active, which will lead to an increase in the quality characteristics of the resulting PBB. For further work with polymer, it produced its disintegration in vibroeraser. The surface structure is shown in picture 3.
From numerous foreign data, it is known that when polymers are introduced into bitumen without plasticizers, at least 5-6% of the polymer by weight is required to obtain PBB with optimal properties. In this case, the viscosity of the resulting binder is significantly higher than the viscosity of bitumen, which can lead to technological difficulties in the preparation of asphalt concrete mixtures at asphalt plants. Introduction of the plasticizer allows to provide the required temperature regime (no higher than 160°C) and significantly increase the efficiency of the polymer being introduced, i.e. obtain a PBB with a developed spatial structural grid with a minimum polymer content of 2-2.5%, and exclude a colloidal mill from the necessary equipment set.

The selection of prototypes of polymer-asphalt-concrete mixtures for the I-th road-climatic zones carried out in a continuous grading of the grain composition according to the requirements of GOST 9128-2013 “asphalt concrete mixture, polymerasphaltconcrete, polymerasphaltconcrete for roads and airfields. Technical conditions”. Preparation and testing of polymerasphaltconcrete samples was performed in accordance with GOST 12801-98 “Materials based on organic binders for road and airfield construction”.

PBB is a three-component system, so changing the quality of one of the components inevitably leads to a change in the quality of the PBB itself. Since all components are manufactured on an industrial scale, changes in their performance within the specified brands, of course, take place.

To determine changes in the properties of PBB with different polymer and plasticizer compositions, the penetration and softening temperature of the initial bitumen and the resulting PBB of different compositions were determined at the first stage. Variants of compositions are presented in table 1.

| № composition's | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|----------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polystyrene, % | 2 | 3,5 | 5 | - | - | - | 2 | 3,5 | 5 | - | - | - | 2 | 3,5 | 5 | - | - | - |
| Styrene-butadiene-styrene, % | - | - | - | 2 | 3,5 | 5 | - | - | - | 2 | 3,5 | 5 | - | - | - | 2 | 3,5 | 5 |
| Transformer oil, % | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 15 | 15 | 15 | 15 | 15 |

The depth of penetration of the needle at 25°C characterizes the plasticity and viscosity of the binder, its technological properties, and therefore, indirectly, the workability of polymerasphaltconcrete mixtures. Plasticity increases with an increase in the plasticizer content, and with an increase in the polymer content in PBB, this effect is noticeably less pronounced. It is
important to note that if the oil content in the PBB is less than 5%, and even more so without it, the plasticity of the PBB is significantly reduced. Therefore, with a low content of plasticizer in PBB, you should be afraid of a sharp deterioration in the technological properties of polymerasphaltconcrete mixtures, namely, workability and compaction, as well as a decrease in labor productivity at asphalt plants in their manufacture due to the high viscosity of the binder.

The softening temperature is the most important operational indicator and characterizes the heat resistance of bitumens and their transition from the elastic-plastic rheological state to the viscous one, which is characterized by the absence of a spatial structural grid in the binder. The results of determining the softening temperature of the obtained PBB are presented in table 2.

Table 2. The softening temperature of the PBB

|№ composition's | Softening temperature, °C | Needle penetration depth, 0.1 mm, at a temperature of 25°C | № composition's | Softening temperature, °C | Needle penetration depth, 0.1 mm, at a temperature of 25°C |
|-----------------|--------------------------|----------------------------------------------------------|-----------------|--------------------------|----------------------------------------------------------|
|1               | 44,3                     | 111                                                      | 10              | 34,8                     | 147                                                      |
|2               | 46,9                     | 88                                                       | 11              | 36,4                     | 112                                                      |
|3               | 48,3                     | 69                                                       | 12              | 39,2                     | 93                                                       |
|4               | 43,1                     | 116                                                      | 13              | 33,5                     | 247                                                      |
|5               | 45,8                     | 91                                                       | 14              | 35,3                     | 131                                                      |
|6               | 48,1                     | 72                                                       | 15              | 37,0                     | 118                                                      |
|7               | 36,1                     | 141                                                      | 16              | 32,8                     | 258                                                      |
|8               | 38,9                     | 110                                                      | 17              | 34,3                     | 137                                                      |
|9               | 40,1                     | 88                                                       | 18              | 36,8                     | 122                                                      |

According to the results obtained, it is obvious that the softening temperature changes with an increase in the plasticizer content when polystyrene is introduced into the bitumen in an amount of 2% in the same way as when styrene-butadiene-styrene is introduced into the bitumen. As the results of the study show, the introduction of polymers and plasticizers changes the technological properties and composition of bitumen, which should lead to changes in the physical, mechanical and operational properties of polymerasphaltconcrete. The results of determining the basic and hydrophysical properties are presented in table 3.

Table 3. Basic and hydrophysical properties of polymerasphaltconcrete based on various polymers and 10% plasticizer

| Composition of the binder | Polystyrene, mass.% | Styrene-butadiene-styrene, mass.% |
|---------------------------|---------------------|----------------------------------|
| Source                    | 2                   | 3,5                              | 5                  | 2                   | 3,5                              | 5                  |
| The porosity of the mineral skeleton, % | 19,8             | 19,6                             | 19,0               | 18,7               | 19,3                             | 19,1               | 18,8               |
| Residual porosity, %      | 4,01                | 3,69                             | 3,57               | 3,40               | 3,66                             | 3,61               | 3,38               |
| Water saturation, %       | 2,79                | 2,11                             | 1,97               | 1,92               | 2,08                             | 2,01               | 1,98               |
| Swelling, %               | 3,56                | 3,41                             | 3,40               | 3,11               | 3,50                             | 3,21               | 3,07               |
| The coefficient of water resistance | 0,95            | 0,96                             | 0,98               | 1,01               | 0,96                             | 0,96               | 0,99               |
According to the obtained data, it was found that the introduction of the polymer and the plasticizer has a positive effect on hydrophysical properties resulting polymerisation. The main requirement for polymerasphaltconcrete: they must have high structural and mechanical characteristics that determine their durability and reliable performance in engineering design. This can be achieved by bringing their strength as close as possible to that of a defect-free body.

**Table 4. Strength characteristics of the obtained polymerasphaltconcretes**

| Composition of the binder | BND 90/130 Source | Polystyrene, mass.% | Polystyrene, mass.% |
|---------------------------|-------------------|---------------------|---------------------|
| The limit of compressive strength | 2 | 3.5 | 5 | 2 | 3.5 | 5 |
| At t=50°C, MPa             | 1.0 | 1.1 | 1.3 | 1.3 | 1.1 | 1.2 | 1.3 |
| At t=20°C, MPa             | 2.4 | 2.8 | 2.8 | 3.0 | 2.8 | 2.9 | 3.2 |
| At t=0°C, MPa              | 7.4 | 7.9 | 7.9 | 7.9 | 7.8 | 7.8 | 7.6 |

Analyzing the physical and mechanical properties of polymerasphaltconcrete, it should be noted that the mechanical properties of polymerasphaltconcretes with the content of plasticizer in PBB are slightly higher than the standard values.

The dependence of the strength limit of asphalt concrete under compression at 0, 20 and 50°C on the content of the plasticizer in the PBB of the studied polymerasphaltconcrete mixtures meet the requirements of GOST 9128-2013.

Thus, the use of polymer and plasticizer significantly alter the physical and mechanical properties of the PBB by increasing the temperature range of health binder, the work of adhesion of bitumen to mineral materials. The polymer and plasticizer content of 3.5 and 10%, respectively, should be considered the optimal amount for obtaining PBB. The developed compositions of polymerasphaltconcrete using different polymers and different amounts of them are very effective, and the introduction of ground polystyrene together with a plasticizer, leads to an improvement in the strength of asphalt concrete at 20° and 50° C, increasing water resistance and shear resistance.

**References**

[1] Pokrovsky A V 2014 A brief review of the experience of using cast polymerasphaltconcrete on artificial structures in the North-Western region of the Russian Federation *Online journal of science* 5 (24)

[2] Gokhman L M 2017 Substantiation of regulatory requirements for polymerasphaltconcrete according to GOST 9128-2013 *Bulletin of the KNARU* 79

[3] Balabanov V B, Romanov A V and Klimentyev I M 2013 Polymer-bitumen binders, plasticized waste automotive oils *Bulletin of the INRTU* 6 (77)

[4] Akhunova R R, Biglova R Z, Zadkin M A, Talipov R F, Mustafin A G 2012 Butadiene-α-methyl styrene copolymer-modifying additive in the composition of road bitumen *Bulletin of the Bashkir University №3*

[5] Lebedeva K Yu 2013 Research of physical and mechanical characteristics of bituminous-rubber composite binders *JSRP* 2

[6] Mullahmetov N R, Kemalov A F, Kemalov R A and Kostromin R N 2010 Modification of road bitumen with rubber *Bulletin of the Kazan technological University* 7

[7] Doshlov O I and Speshilov E G 2013 Polymer-bituminous binder – a high-tech basis for a new generation of asphalt *Bulletin of the INRTU* 6 (77)

[8] Kazimirov I A and Peshkov V V 2019 Determination of price behaviour in the secondary
residential real estate market using a multidimensional regression model. Proceedings of Universities. Investment. Construction. Real estate 9(3) pp 476–487 DOI: 10.21285/2227-2917-2019-3-476-487

[9] Matveeva M 2018 Synchronization of the activity of participants during the implementation of housing construction projects. Proceedings of Universities. Investment. Construction. Real estate 8 pp 31-41 DOI: 10.21285/2227-2917-2018-2-31-41.

[10] Larina O P and Khalabuda E I 2019 Accident prevention during construction and installation works at height. Proceedings of Universities. Investment. Construction. Real estate 9(4) pp 734–741. https://doi.org/10.21285/2227-2917-2019-4-734-741

[11] Selezneva O I, Radaev S S and Baranova A A The impact of thermal treatment on the granulometric and chemical composition of diatomite of the Kamyshlov field when obtaining a liquid-glass binder. Investment. Construction. Real estate 9(3) pp 550–555

[12] Tyuryukhanov K Yu and Pugin K G 2019 Impact of the surface of particles of moulding sand on the structural formation of asphalt concrete. Proceedings of Universities. Investment. Construction. Real estate 9(3) pp 566–577

[13] Dobruskina M A, Petrov A V and Bat-Erdene Z 2019 Improving the technology of retaining walls in the Irkutsk region using gabion baskets. Proceedings of Universities. Investment. Construction. Real estate 9(2) pp 312–323