Budownictwo o Zoptymalizowanym Potencjale Energetycznym **Vol. 7, Nr 2/2018, s. 25-33**
DOI: 10.17512/bozpe.2018.2.03

V.T. EROFEEV (orcid id: 0000-0001-8407-8144) **A.L. SALNIKOVA** (orcid id: 0000-0002-7782-2817)
A.A. PIKSAYKINA (orcid id: 0000-0001-8008-8898)
National Research Mordovia State University, Saransk, Russia

O.V. STARTSEV (orcid id: 0000-0003-0810-2055)
Russian Scientific Research Institute of Aviation Materials» State Research Center of the Russian Federation, Moscow, Russia

V.I. RIMSHIN (orcid id: 0000-0002-9084-4105)
Moscow State University of Civil Engineering, Moscow, Russia

INVESTIGATION OF BITUMEN COMPOSITES DURABILITY IN CONDITIONS OF IMPACT OF VARIOUS CLIMATIC FACTORS

The results of researching the influence of ultraviolet irradiation factors, the damp climate of the Black Sea coast and sea water on the physical and mechanical characteristics of asphalt binders made on the basis of bitumen and bitumen--polymer composites are presented in this article. Medium density, water saturation, compressive strength at the temperature of 50 ±2°C and mass change of asphalt binders were defined. It was found that sea water has a negative effect on the majority of physical and mechanical characteristics of asphalt binders. The compositions of asphalt binders resistant to the impact of climatic factors were found. The optimal composition of asphalt binders was selected. The investigation results can be used in the manufacture of durable road asphalt and waterproofing materials exploited in the climatic conditions of the sea coast and sea water.

Keywords: **bitumen, asphalt binder, bitumen-polymer binder, bitumen composites, aging**

INTRODUCTION

Increasing the durability of waterproofing materials and asphalt-concrete coatings is an urgent task, the solution of which provides a significant economic effect by increasing the service life of buildings and structures, reducing the costs of repair work in service and improving the transport-operational condition of roads during their service life. During operation, waterproofing materials and asphalt--concrete coatings are subjected to aging under the influence of various factors [1-5]. S.V. Shestoperov gives the following definition of aging - it is the property of the material to transfer from one state to another as a result of the course of physicochemical processes. At the same time, the ability of materials to resist loads and aggressive environments is lost. For example, asphalt-concrete coatings due to the aging of organic binders as the road service life elapses and elastic-viscoplastic deformations decrease, the material becomes more brittle, and cracks gradually develop in the coatings [6]. S.S. Sayenko in his work [7] indicates that the aging of bitumen occurs continuously, and not only in the composition of asphalt concrete in the exploitation of motor roads. Moreover, in the process of preparing bitumen in asphalt plants, its properties may deteriorate. The greatest changes in the bitumen properties during its preparation take place at the storage stage in the storage tanks before being fed into the mixer. As a result, an astringent is included in the composition of asphalt concrete, significantly changing its initial properties, which leads to a reduction in the service life of motor roads. To improve the quality of the structure and properties of road bitumen, they are modified by various additives, polymers or modifiers.

The following materials were used in the studies: non-activated mineral powder MP-1 from carbon at a rocks with a true density of 2.71 g/cm^3 and an average density of 1.71 g/cm^3 in accordance with GOST R 52129-2003 (LLC "Issinskiy Combine of Building Materials", Issa); bitumen of BND grade 60/90 according to GOST 22245-90 (OJSC "Lukoil-Nizhegorodnefteorgsintez", Kstovo); modifiers Olazol, Telazbrand L5, Telazbrand L7 - specially synthesized additives (NP OJSC "Synthesis-SAW", Shebekino, Belgorod region); bitumen modifier and thermoplastic polymer Kraton D-1101 is a pure linear block copolymer based on styrene and butadiene with a styrene content of 31% by weight (Kraton Polymers, USA); industrial grade I-20A oil in accordance with GOST 20799-88.

It is known that the degree of structuring of the bitumen with a minimum content of mineral powder in the asphalt binder, is negligible. In this case, the mineral powder particles with the oriented inner bitumen layers formed on them do not interact with each other and the strength of the microstructure is negligible. With an increasing mineral powder content, the distance between individual particles becomes smaller and, with its optimum content, the bituminous types of the mineral grains are completely in an oriented inner state. The strength of the microstructure is the maximum. With an increasing amount of mineral powder above the optimum in the asphalt binder, the number of pores sharply increases, the amount of bitumen to envelop the mineral grains becomes insufficient, which leads to a sharp reduction in the strength of the microstructure. Thus, determining the optimum ratio of bitumen and mineral powder is the main issue in forming an asphalt binder [8]. The optimal content of mineral powder in the asphalt binding agent was chosen according to GOST R 52129-2003 "Mineral powder for asphalt-concrete and organomineral mixtures. Technical conditions". In accordance with paragraph 7.6.3 of the state standard, the required ratio in the mixture of powder and bitumen should be such that the water saturation of the samples is from 4 to 5%. In view of this, several mixtures with a bitumen content ranging from 14 to 17% by weight of the non-activated powder were successively prepared.

1. RESULTS

Three samples were prepared from each mixture, for which water saturation was determined not earlier than the day after production in accordance with

Section 13 of GOST 12801-98 "Materials based on organic binders for road and airfield construction. Methods of testing". The essence of this method was to determine the amount of water absorbed by the sample under a given saturation mode. The water saturation was determined on samples of a cylindrical shape (d = 50 mm), the compositions of which are given in Table 1.

In accordance with paragraph 7.6.3 of GOST R 52129-2003, based on the obtained data, a graph of water saturation versus bitumen content in the mixture was plotted (Fig. 1), by which the amount of bitumen required to obtain water saturation W [%] was determined within 4 to 5% by volume.

Table 1. **Test results**

Composition number	Bitumen content in asphalt binder [%]	Average density ρ_m [g/cm^3]	Water saturation W [%]
1	14	2.03	7.25
2	15	2.01	6.28
3	16	2.05	2.52
4	17	2.07	0.12

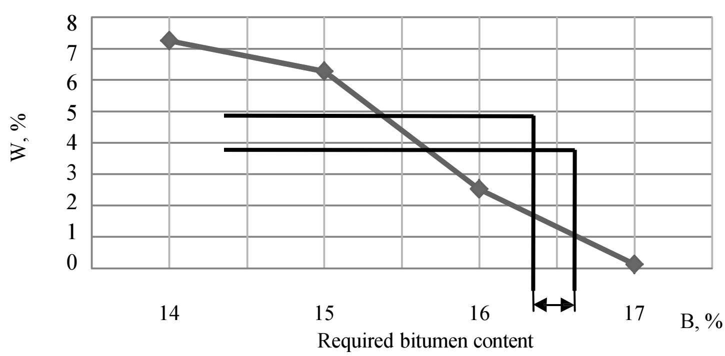

Fig. 1. Dependence of changes in water saturation of bitumen compositions on bitumen content

The required bitumen content, based on the plotted graph (Fig. 1), was taken to be 15.5%, with W = 4.4% and ρ_m = 2.03%. An important characteristic of mineral powders, reflecting their interaction with water (and, consequently, peculiarities of interaction with bitumen) is the degree of swelling of a mixture of powder with bitumen in water. The swelling of a mixture of powder with bitumen (for a sample residual porosity of 5÷6%) should not exceed 2.5% for unactivated mineral powders [9]. Furthermore, the ultimate strength of asphalt binders was determined in compression in accordance with GOST 12801-98, section 15. Three samples were prepared from the mixture of mineral powder and bitumen to determine the strength, with a final content of 15.5%. The essence of the method was to determine the load required to break the sample under the given conditions, namely at water temperatures: 0±2, 20±2 and 50±2°C. The results of the tests are given in Table 2.

The obtained samples of asphalt binders on the basis of bituminous and polymer bituminous composites (Table 3) were maintained under the conditions of the Black Sea climate on the site of the Gelendzhik Climate Research Center G.V. Akimova (STCI VIAM, Gelendzhik, Krasnodar Territory). Samples of asphalt binders were kept under the following conditions: on an open atmospheric platform, on an at- mospheric platform under a tent, and in sea water. The period of incubation of the samples was 12 months. After aging in the media under study, the samples as well as the control variants of the samples were examined for changes in the basic physical and mechanical properties, among which were: density ρ_m [g/cm^3], water saturation W [%], and compressive strength R_{aw} [MPa] at 50 ±2°C. In addition, the sample mass change Δm [g], was analyzed after 12 months of testing. In Table 4 the results of physical and mechanical tests of control samples of asphalt binders are shown, and in Table 5 - the results of physical and mechanical tests of samples aged under the conditions of an open atmospheric platform, in Table 6 - in the conditions of an atmospheric platform under a tent, in Table 7 - in sea water.

Table 2. **Test results**

Composition number	Bitumen content in asphalt binder [%]	Water temperature [°C]	Compressive strength R_{com} [MPa]
5	15.5	0	11.07
6		20	5.14
7		50	2.42

Taking into account the results obtained at the second stage of the study, samples of asphalt binders from a mixture of mineral powder and bitumen with a final content of 15.5% were made. The content of the components in the formulations is given in Table 3. For clearer of consideration of the results of the climatic tests of asphalt binders, histograms were constructed (Figs. 2-4).

Table 3. **Content of components in asphalt binder**

Components	Content of components in formulations [% by weight]					
	8	9	10	11	12	13
Mineral powder	84.5	84.5	84,5	84.5	84.5	84.5
Bitumen of BND grade 60/90	15.5	13.5	13.5	13.5	7.5	9.5
Olazole	–	2.0	–	–	2.0	–
Telas L5	–	–	2.0	–	–	–
Telas L7	–	–	–	2.0	–	–
Kraton D-1101	–	–	–	–	3.0	3.0
Industrial grade I-20A oil	–	–	–	–	3.0	3.0

Table 4. **Test results of control samples**

Properties	Indicators for compounds					
	8	9	10	11	12	13
Average density ρ_m [g/cm^3]	1.99	2.02	2.05	2.01	1.98	1.97
Water saturation W [%]	4.94	3.62	5.29	2,95	4.74	10.13
Compressive strength R_{com} [MPa]	3.32	3.65	2.90	3.01	3.55	3.16
Change in sample weight Δm [g]	+0.27	–0.26	+0.53	+0.61	+0.34	+0.58

Table 5. **Test results of samples aged under open atmospheric platform conditions**

Properties	Indicators for compounds					
	8	9	10	11	12	13
Average density ρ_m [g/cm^3]	2.00	1.98	2.03	2.05	1.95	1.97
Water saturation W [%]	5.85	8.10	4.31	2.55	7.41	2.01
Compressive strength R_{com} [MPa]	3.80	3.99	3.37	3.66	2.43	3.41
Change in sample weight Δm [g]	–0.16	+0.28	+0.34	+0.11	–0.33	–0.09

Table 6. **Test results of samples held in conditions of atmospheric platform under a tent**

Properties	Indicators for compounds					
	8	9	10	11	12	13
Average density ρ_m [g/cm^3]	1.99	2.04	2.05	2.00	1.94	1.91
Water saturation W [%]	5.77	2.79	3.30	5.07	6.82	8.65
Compressive strength R_{com} [MPa]	3.19	4,14	3.37	3.15	3.31	3.66
Change in sample weight Δm [g]	+0.30	+0.35	+0.42	+0.38	+0.17	+0.21

Table 7. **Test results of samples aged in sea water conditions**

Properties	Indicators for compounds					
	8	9	10	11	12	13
Average density ρ_m [g/cm^3]	2.06	2.04	2.04	2.02	2.05	1.96
Water saturation W [%]	0.40	1.93	2.62	2.01	0.94	1.82
Compressive strength R_{com} [MPa]	2.85	2.77	1.97	2.21	2.39	2.16
Change in sample weight Δm [g]	+3.95	+3.47	+6.63	+6,87	+4,.65	+8.65

The density of the asphalt binders is the main indicator for evaluating the structure of the material. Usually the higher density, in other identical conditions, corresponds to a highest strength and less water saturation. In Compositions 10 (Table 6) and 11 (Table 5), these dependencies are preserved, that is, when the density values are increased or maintained, the compressive strength at 50°C is increased, and the water saturation is reduced. In other compositions, this dependence is somewhat violated. In this case, the following regularities are observed.

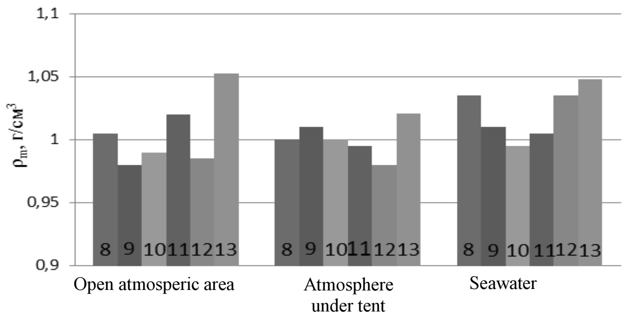

Fig. 2. Changes in relative density of asphalt binder samples, aged in open area, under tent and in sea water

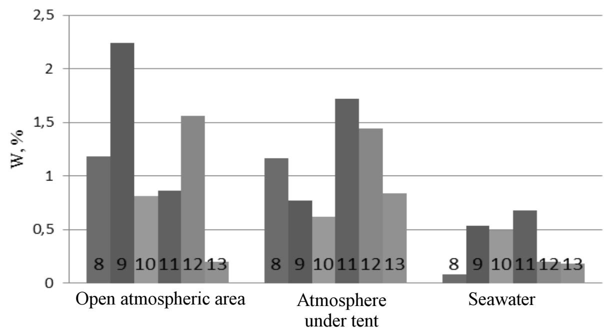

Fig. 3. Changes in relative water saturation of of asphalt binder samples, aged in open area, under tent and in sea water

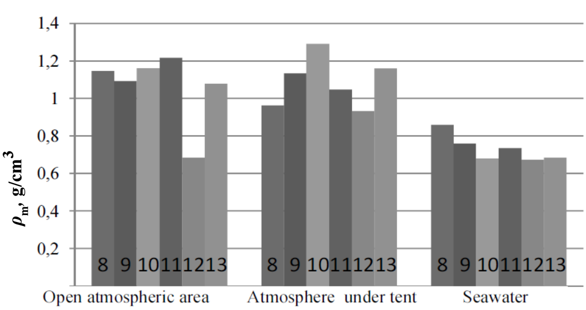

Fig. 4. Changes in relative compressive strength of asphalt binder samples at 50 ±2°C, sustained in conditions of open area, platform under tent and in sea water

2. DISCUSSION

In the group of samples held under the conditions of an open atmospheric platform (Table 5), the following changes were observed: the density is practically unchanged for all the compositions in comparison with the control samples (Table 4). The density increases only by 5% in Composition 13 (Table 5, Fig. 2).

The introduction of Telaz L5, Telaz L7, and Kraton D-1101 modifiers (Formulations 10, 11 and 13) contributes to a reduction in the water saturation index by 18.5, 14 and 80%, respectively, compared with the control compositions. In addition, these compositions increase the compressive strength at 50°C, by 14, 18 and 7%, respectively. Compositions 8-11 and 13 show an increase in compressive strength at 50°C by 7÷18% (Table 5, Fig. 4). At the same time, Composition 12 shows the greatest decrease in strength at 50°C (31.5%). The test results showed that Compositions 10, 11 and 13 are the most resistant to weathering on an open air site; they have decreased water saturation and increased compressive strength at 50°C. The research data show that the properties of asphalt binders with a polymeric additive (Composition 13) in terms of water saturation and strength are higher than those of asphalt binders on polymer-bitumen composites with an additionally introduced Olazol modifier (Composition 12). It can be concluded that the modifier Olazol leads to an increase in water saturation, which is also observed in Composition 9, where the asphalt binder consists only of bitumen and the above modifier.

In the group of samples held under the conditions of the atmospheric platform under a tent (Table 6), the following changes are observed: stable density values are observed for all the compositions. Introducing bitumen modifiers Olazol, Telaz L5 and Kraton D-1101 allows water saturation to be reduced by 23, 38 and 15% respectively, in comparison with the control samples. It should be noted that in the samples without additives kept under a tent, as in an open atmospheric site, there is an increase in water saturation and a decrease in R50. The compressive strength at 50°C for Compositions 9-11 and 13 rises from an insignificant 4% (Composition to 22% (Composition 10). In all the samples tested under the conditions of the atmospheric platform under the tent, an increase in their mass after the test was observed. Compositions 9, 10 and 13 are resistant to the effects of the atmospheric environment under the tent. In these formulations, properties such as density, water saturation and strength at 50°C improved. By analyzing the properties of polymer-bituminous composites, it is possible to trace analogous regularities as in a group of samples aged under the conditions of the open atmospheric platform, that is a higher strength and low water saturation are characteristic of Composition 13, and in Composition 12 with the modifier Olazol, the indices are inferior to the control samples c Composition 12, Table 4).

In the group of samples kept under sea water conditions (Table 7), the following changes are observed: in all the samples the water saturation decreases from 32 to 92%, and the compressive strength at 50°C also significantly decreases (14÷33%). The negative impact of sea water on asphalt binders can be noted. Composition 8 is relatively stable, where the strength at 50°C drops slightly (14%) and Composition 9 the loss of strength is 24%. It can be seen from the results that in all the samples tested in sea water, an increase in mass after the test was observed. In Compositions 8, 12 and 13, which sustained 12 months in sea water, an increase of density was observed (Fig. 2). As a rule, the chemical aging of bitumen, accompanied by an increase in its density, causes shrinkage stresses in it when shrinkage is not possible.

CONCLUSIONS

Thus, as a result of the research it was established that the climatic factors of the Black Sea coast affect asphalt binders made on the basis of bituminous and polymer-bituminous composites. The conclusions from the research are:

– Tests of bitumen and polymer bituminous composites under conditions of variable humidity, ultraviolet irradiation of the sea coast and sea water, as well as the durability of asphalt binders in these environments were conducted.
– The effect of climatic factors on the density, water saturation and strength at 0, 20 and 50°C of asphalt binders based on bituminous and polymer bituminous binders was established.
– The physical and mechanical properties of bitumen composites with modifying additives were studied.
– The data showing changes in the physical and mechanical parameters of bituminous and polymer-bituminous composites, depending on the conditions for aging of the samples were:
  • on the open air site it was found that introducing Telaz L5, Telaz L7 and Kraton D-1101 modifiers in bitumen allows one to obtain more durable compositions;
  • in the conditions of the open atmospheric platform, an increase in the relative density, water saturation and strength in compositions with modifiers Olazol, Telaz L5, as well as a polymer bitumen composite consisting of bitumen, Kraton D-1101 modifier and industrial oil was determined under a tent;
  • a significant reduction in water saturation and compressive strength of bituminous and polymer bituminous composites was found in the samples kept in sea water.
– The results of the research can be used to create durable asphalt concrete suitable for the manufacture of various coatings, and waterproofing materials used in the climatic conditions of the sea coast and sea water.

REFERENCES

[1] Erofeev V.T., Petrunin D.A., Smirnov V.F., Likomaskin A.I., Pron'kin S.P., The asphalt concrete mix, Patent of RF No 2308430. 2005. B. No 29.

[2] Kalgin Ju.I., Erofeev V.T., Development and research of molded asphalt concrete on the bitumen-rubber binder, Building Materials 2007, 1, 60-63.

[3] Lavruhin V.P., Kalgin Ju.I., Erofeev V.T., Fatigue durability of asphalt concrete on the base of modified bitumen, News of Mordovian University, 2001, 3-4, 128.

[4] Lesnov V.V., Boriskin A.S., Erofeev V.T., Dispersive-reinforced composites for road surface and transport facilities, Transport Building 2007, 5, 24.

[5] Solomatov V.I., Erofeev V.T., Kalgin Ju. I., Epoxide-bitumen polymer concretes, 2000, 7-8, 34.

[6] Shestoperov S.V., The road-building materials, M. Higherschool, Moscow 1969.

[7] Sajenko S.S., The methods of minimization of bitumen aging in a work boiler in a preparation of hot asphaltobitumen mixtures, Rostov on/D. 2008.

[8] Erofeev V.T., Bazhenov Ju.M., Kalgin Ju.I., The road bitumomineral materials on the base of modificated bitumen (technology, qualities, durability), Saransk 2009.

[9] Gezencvej L.B., Gorelyshev N.V., Boguslavskij A.M., Korolev I.V., The Road Asphalt Concrete, Transport, Moscow 1985.

BADANIE TRWAŁOŚCI KOMPOZYTÓW BITUMICZNYCH W ZMIENIAJĄCYCH SIĘ WARUNKACH KLIMATYCZNYCH

Przedstawiono wyniki badań wpływu promieniowania ultrafioletowego, w warunkach wilgotnego klimatu czarnomorskiego i wody morskiej, na fizyczne i mechaniczne właściwości spoiw asfaltowych wykonanych na bazie mieszanek bitumicznej i bitumiczno-polimerowej. Wyznaczono średnią gęstość, nasycenie wody, wytrzymałość na ściskanie w temperaturze 50±2°C i zmianę masy spoiw asfaltowych. Stwierdzono, że woda morska ma negatywny wpływ na większość fizycznych i mechanicznych właściwości spoiw asfaltowych. Odporne na działanie czynników klimatycznych okazują się struktury kompozytowe spoiw asfaltowych. Dobrany został optymalny skład spoiw asfaltowych. Wyniki badań mogą być wykorzystane do produkcji drogowych mas asfaltów o podwyższonej trwałości, materiałów odpornych na działanie wilgoci, eksploatowanych w warunkach oddziaływania klimatu morskiego i wody morskiej.

Słowa kluczowe: **bitum, spoiwo asfaltowe, spoiwo bitumiczno-polimerowe, kompozyty bitumiczne, starzenie**