

Increasing the Durability of Asphalt Pavement - the Road to Road Safety

*Valentina Yadykina*¹, *Anatoly Gridchin*¹, *Anna Trautvain*^{1*}, *Rashid Sharapov*², and *Christina Pashkova*¹

¹Belgorod State Technological University named after V.G. Shukhov, 46 Kostyukova str., Belgorod, 308012, Russia

²National Research Moscow State University of Civil Engineering, 26 Yaroslavskoye Shosse, Moscow, 129337, Russia

Abstract. Based on literature data, the paper analyzed the impact of transport operational indicators related to the quality of road surface coverage on road safety. It presented the results of experimental studies on the effect of the road adhesion cationic thermostable additive on the properties of bitumen and asphalt concrete. The authors identified that the introduction of this additive leads to an increase in the viscosity and softening temperature of bitumen, its adhesion to mineral materials, which has a positive effect on strength, water resistance, shear stability, crack resistance, fatigue durability of asphalt concrete. The conclusion was made about the regularity of improving road safety, related to the improvement of the quality of the pavement, arranged from asphalt concrete with the application of the tested additive.

1 Introduction

The successful and safe operation of road transport depends to a large extent on the condition of existing highways and their technical parameters [1, 2, 3]. Actual conditions for the operation of highways differ from the calculated ones. As a consequence, the technical and economic indicators of the road transport work decreases, and traffic safety deteriorates. Every motor vehicle collision (MVC) is usually caused by an unfavorable combination of several factors closely related to each other, which makes it difficult to identify the true reasons for the analysis. One of the contributing factors is the unsatisfactory state of highways and streets [2, 4, 5]. From 10 to 15% of road accidents occur due to unsatisfactory road conditions. Studies show that drivers' mistakes in driving and traffic violations are the main cause of most accidents. But these violations can also be related to the shortcomings of highways, which in 50-80% of cases are one of the active causes, and in 15-20% of cases, the main cause of road accidents.

* Corresponding author: trautvain@bk.ru

2 Material and methods

The physico-mechanical characteristics of bitumen were investigated according to the State General Education standard (SGE) number 22245-90, samples of asphalt concrete - according to SGE 9128-2013, the cohesive strength of bitumen - according to EN 13588-2013.[17-19]

3 Theory

The main material for covering roads in most countries is asphalt concrete. It is known that many characteristics of asphalt-concrete mixtures depend on the quality of bitumen. The basis for a real increase in the physico-mechanical properties and durability of road asphalt concrete was the introduction of modified bitumens [7, 8, 9].

For the production of road bitumens, which meet high standards, in many countries the modification with their polyphosphoric acid is actively used, and also in combination with polymers [10].

Considerable interest is shown in the study of the mechanism of its interaction with various bitumens, which contributes to the development of new technologies. Scientific work in this field is represented by a large number of publications [11, 12, 13, 14, 15].

The purpose of this work was to study the effect of bitumen, modified by the addition of RACThA (road adhesion cationic thermostable additive), developed and produced by "Selena" company on the basis of phosphoric acid esters and synthetic phospholipids, on the physical, mechanical and operational characteristics of asphalt concrete.

Based on the composition of the additive, it can be assumed that the mechanism of its action is the destruction of associates of asphaltenes into smaller particles; thanks to these processes, the fine-dispersed associates of asphaltenes interact more closely with the surface of the stone material. In addition, slowing the formation of a rigid spatial structure of asphaltenes will help reduce the aging rate of bitumen. Due to the presence of phosphoric acid esters in the additive composition, it is possible to expect that the bitumen rigidity will increase at high temperatures and decrease at low temperatures, it is also likely that the softening temperature of the modified bitumen will increase, and a significant increase in adhesion to the stone material is expected.

4 Results and Discussion

To conduct the study, bitumen oil road BND 60/90 of Saratov Refinery was used, the properties of which are presented in Table 1.

As one can see, bitumen meets the requirements of regulatory documentation.

The influence of the tested additive on the change in the rheological, adhesive and cohesive properties of bitumen as well as on the properties of asphalt concrete on the variation in the compressive strength of the samples at test temperatures of 0, 20 and 50 ° C, as well as water saturation and prolonged water resistance after 15, 30, 60, 90 and 120 days, was studied. Concentration of the additive in accordance with the manufacturer's recommendations was 0.4%.

The results of the bitumen tests with additives shown in Table 2 indicate that the introduction of the additive into the bitumen results in a significant change in the properties of the bitumen, such as penetration, softening temperature and extensibility.

Table 1. Characteristics of bitumen, which is used

Indicators	Requirements of GOST	Actual indicators
The penetration depth of the needle is 0.1 mm: at 25 °C at 0 °C	61 – 90 not less than 20	64 22
Extensibility, cm: at 25° C at 0° C	55, not less 3.5, not less	71.4 3.5
Softening temperature, ° C	47, not lower	48
Brittleness temperature, ° C	-15, not higher	-22
Flash temperature, 0 C	230, not lower	302

Table 2. Change in the properties of bitumen when adding an additive

№	Additive	Penetration		Softening temperature, °C	Extensibility	
		25 °C	0 °C		25 °C	0 °C
	Requirements of GOST	61-90	not less than 20	not lower than 47	not less than 55	not less than 3,5
1	Without additive	64	22	48	71,4	3,5
2	RACThA	52	24	52	93,7	4,0

As can be seen from Table 2, the addition of the additive leads to an increase in viscosity and softening temperature. It is important to note that at a temperature of 0 °C, the penetration values increase slightly. Extensibility with the addition of RACThA also increases. All this indicates that bitumen with the addition of RACThA becomes somewhat more severe at high temperatures, while maintaining the required softness at low temperatures.

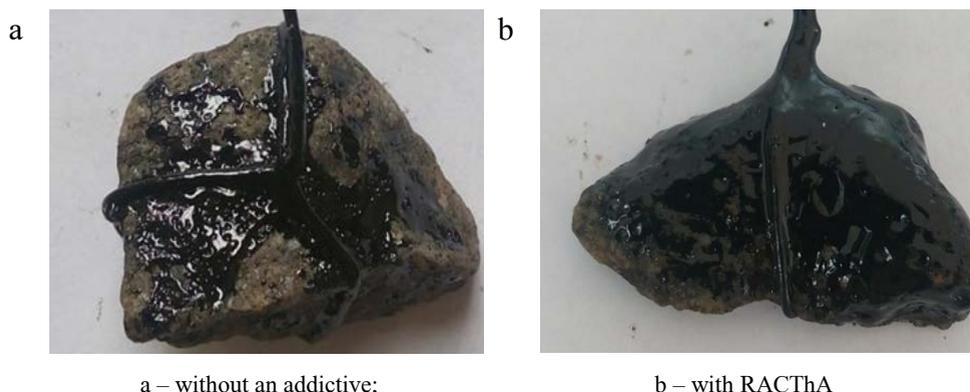
The influence of the additive on the adhesion of bitumen to stone materials was also studied. Figure 1 shows the effect of modified bitumen on adhesion to granite gravel.

It follows from the figure that the use of the additive positively affected the adhesion of bitumen to mineral material.

The effect of the additive was also evaluated by the change in bitumen cohesion, which was determined in accordance with EN 13588-2013. The results indicate an increase in bitumen cohesion when using the tested additive by 80%.

In connection with the growth of adhesion and cohesion of bitumen, modified RACThA, asphaltic concrete prepared using this binder should be characterized by increased values of water, heat and frost resistance, as well as resistance to rutting.

Table 3 shows the effect of the additive on the physical and mechanical characteristics of asphalt concrete.



a – without an additive;

b – with RACThA

Fig. 1. Bonding of bitumen with granite gravel surface after boiling

The study of the influence of the additive on the physical and mechanical characteristics of asphalt concrete shows a positive effect on the properties of the latter. So the strength of asphalt concrete at 20 °C increased by 7% relative to the composite on bitumen without an additive, the strength at 50°C – by 17%, the strength at 0 °C decreased by 12%. The water saturation decreased by 39%, which indicates a decrease in the porosity of asphalt concrete and an increase in resistance to seasonal temperature changes. In turn, the water resistance increased from 0.90 to 0.98.

Table 3. Physical and mechanical characteristics of asphaltic concrete modified by the addition of RACThA

Physical and mechanical characteristics	Requirements of GOST 9128-2013	Without an additive	RACThA
The limit of compressive strength, MPa: at 20oC at 50oC at 0oC	from 2.2 from 1 to 12	3.9 1.2 11.3	4.2 1.4 9.9
The limit of the strength of water-saturated samples, MPa	-	3.5	4.1
Water saturation	1.5-4.0	3.3	2.0
Water resistance	0.85	0.90	0.98

The change in the long-term water resistance after 0, 15, 30, 60, 90 and 120 days of asphalt concrete with additives is shown in Figure 2.

In general, the long-term water resistance of asphalt concrete with the use of the additive significantly increased, which can be explained by the improvement of the adhesion of bitumen to the mineral materials of the composite. So, compared with the initial value, the water resistance after 15 days of asphalt concrete on the original bitumen and bitumen with the additive decreased by 15.6 and by 8.2%, respectively.

After 30 days, the water resistance value of the composite with the additive was 0.86, whereas without the additive was only 0.67. With the continuation of the test, the trend persisted. Water resistance after 120 days of testing of asphalt-concrete samples on the original bitumen decreased by 44%, while on bitumen, modified by RACThA, only by 30%.

Thus, the RACThA additive significantly increased the water resistance of asphalt concrete, which should positively affect the durability of the road surface.

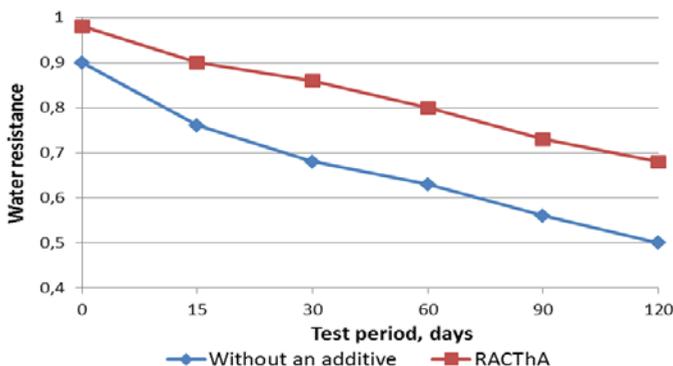


Fig. 2. The effect of additives on the long-term water resistance of asphalt concrete

The presence of ruts and cracks in the road surface can make it difficult to maintain a safe trajectory along the road [16]. Water accumulating in ruts and cracks in the road surface increases the risk of slipping. Large potholes on the road surface can lead to premature deterioration or breakdown of the car, or loss of driver control over driving.

In this regard, the indicators of asphalt concrete are very important from the viewpoint of ensuring the strength and reliability of pavement, shear resistance and crack resistance.

The results of determining these indicators are given in Table 4.

Table 4 shows that the shear stability indicators: the coefficient of internal friction and shear adhesion at 50°C of asphalt concrete on the modified binder increased in comparison with asphalt concrete on bitumen BND 60/90 without an additive. Figure 3 shows the change in these indicators in percent.

Table 4. Characteristics of asphalt concrete

Characteristics	Characteristics of GOST 9128-2013	BND 60/90	Bitumen with RACThA
Shear resistance: coefficient of internal friction, not less than adhesion at shear at +50 oC, MPa, not less than	0.81 0.35	0.83 0.37	0.94 0.42
Crack resistance	3.0-6.5	4.36	4.63

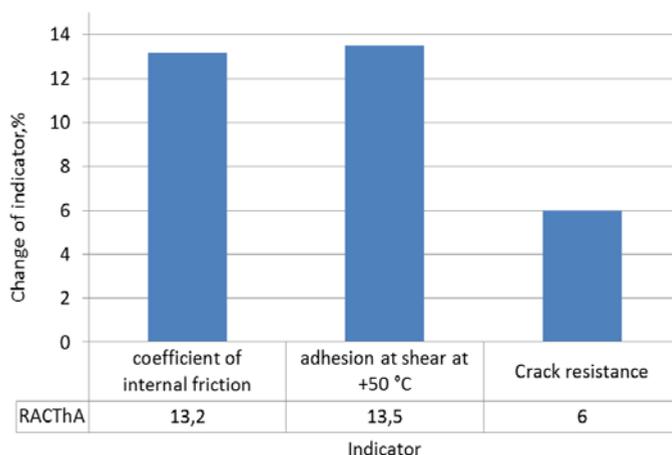


Fig. 3. Change in shear stability and crack resistance

Figure 3 shows that the shear stability indicators increased by 13%, which should positively affect the quality of the asphalt-concrete covering. Shear resistance is the ability to resist tangential stresses, and, consequently, with an increase in the shear stability indicator, the asphalt concrete will be more resistant to rutting. This was to be expected, since in previous studies of standard physical and mechanical properties of asphalt concrete, the strengths at 20 and 50°C increased by 7 and 17%, respectively.

Crack resistance, which characterizes the resistance to tensile strength at low temperatures, increased by 6%, which is quite logical, since the strength of asphalt concrete at 0°C decreased by 12%. It follows that asphalt concrete will be less susceptible to mechanical deformations at negative temperatures, which will positively affect the operational properties of asphalt concrete on the modified binder. The growth of these indicators can be explained by the presence of phosphoric acid in the composition of the RACThA.

The next stage of the research was the testing of fatigue durability, the rigidity modulus and the resistance to rutting. These characteristics, in particular, the index of fatigue durability, will allow to predict an increase in the operational properties of the asphalt-concrete covering.

Table 5. Characteristics of asphalt concrete

Indicator	Value	
	BND 60/90	BND 60/90 with the addition of RACThA
Hardness module, MPa	4660	4392
Fatigue durability	81000	130000
Depth of track, mm	20	14

As can be seen from Table 5, the asphaltic concrete strength modulus with RACThA added decreased by 5% compared to asphalt concrete on the original bitumen. Fatigue durability increased 1.6 times, which suggests that the overhaul durability of the asphalt covering will increase. The depth of track through 20 thousand passes was reduced by 30%, compared to asphalt on the original bitumen of BND 60/90.

5 Conclusion

Thus, the use of the RACThA additive improves such operational characteristics of asphalt concrete as water resistance, rigidity module, resistance to rutting, fatigue durability, which will lead to improved road surface quality.

From the results of the research it is known that a general improvement in the state of the road reduces the number of road accidents with injuries by approximately 20%. The number of accidents with material losses is reduced by 5%. In this regard, it is reasonable to assume that improving the quality of the road covering, constructed from asphalt concrete with the application of the additive to be tested, will lead to an increase in road safety and a reduction in the number of accidents.

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