# Adhesion and wetting of road bitumen on mineral materials

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**Abstract.** The article covers the results of a study of adhesive and wetting (wetting edge angle) characteristics of road bitumen compositions. New ingredients for road bitumen have been selected to increase its adhesive ability. Based on additives such as oil sludge, gossypol resin and technical sulfur, bitumen compositions with improved adhesive characteristics have been obtained. The influence of oil sludge, gossypol resin and industrial sulfur on the structural properties of road bitumen has been studied. Based on the chemical theory that provides adhesion of additives with mineral materials, a number of scientific studies of bituminous compositions on the strength of adhesion to the surface of various mineral materials have been carried out. Based on the results obtained, it was revealed that on the basis of the finished road bitumen grade BND 60/90 and the D-7 additive, a bituminous composition that has the highest adhesion strength to the surface of various mineral materials has been obtained.

## 1 Introduction

Nowadays, a number of scientific studies on development of new ingredients for the production of road bitumen and improve their properties are being carried out in the world. In this regard, special attention is paid to the creation of obtaining the composition of bituminous compositions with improved physical, mechanical and operational properties based on the residues of the oil and gas, chemical and food industries, as well as improving the adhesive properties, with the joint introduction of oil residues and sulfur, the development and testing of production technologies road construction bitumen [1,2].

According to the results [3,4] of the standard method obtained when evaluating the adhesive properties of a composite bituminous binder, as well as the values of wetting angles, the obtained bituminous binder has better adhesive properties than oil (consisting of carbonyl and hydroxyl groups).

The purpose of research is to evaluate the effect of additives on the contact angle and adhesion properties of the developed bitumen composition.

Based on the study of the nature of adhesive additives in the contact of bitumen with the surface of a mineral material, i.e., adherence, adhesion of bitumen and mineral material occurs in its interfacial layer. Because the theory that ensures the adhesion of additives with

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mineral materials that increase the adhesive properties of bitumen is subject to the chemical theory of adhesion [5,6].

The structure of tar (gossypol resin) contains a polar carbonyl group, a small amount of carboxyl and hydroxyl functional groups. Complex substances containing nitrogen, i.e., adhesive additives improve adhesive properties, since there is a chemical reaction of binding with the surface of the mineral material from which the polar nitrogen-containing substance is selected [7,8].

## 2 Materials and methods

The following were used as an object of research:

- road bitumen grades BND 60/90 and BND 90/130 from the Djarkurgan oil refinery;
- as additives, tar (gossypol resin) from the Urgench oil and fat plant, oil sludge from the Bukhara oil refinery and technical sulfur from the Mubarek gas processing plant, according to GOST 127.1-93;
- mineral materials (granite, gravel, marble) to evaluation of the wetting and adhesion of bitumen.

The choice of bitumen grades is explained by the fact that they have found the greatest application for the preparation of road binders and, accordingly, asphalt concrete.

## 3 Results and discussion

In order to study the mechanism of action of adhesive additives on the adhesion strength of bitumen with mineral material, the following additives were chosen: oil sludge, tar (gossypol resin) and ground industrial sulfur.

Oil sludge is a lipophilic surfactant, insoluble in pure water, but dispersible in hot water to form an emulsion. Dehydrated oil sludge is used in the road industry as a surfactant [9-11].

The effect of adhesive additives on the adhesion strength of bitumen BND 60/90 with mineral material is shown in Figure 1.

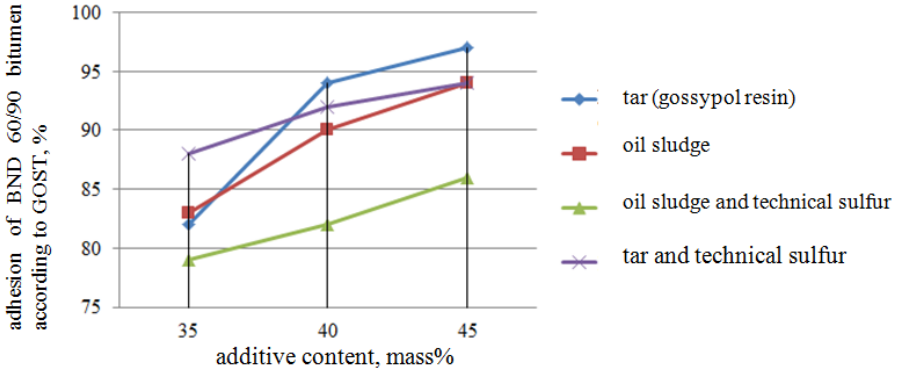


**Fig. 1.** Dependence of the adhesive ability of BND 60/90 on the content of additives.

From the above analyzes and surfactant theory, tar (gossypol resin) has a higher value on the adhesive properties of bitumen than oil sludge, because the composition of the tar contains resinous substances that improve the binding properties of bitumen.

Based on the graphs presented in Figure 1 and 2, it can be seen that all the considered additives have a positive effect on the adhesion of bitumen to the surface of the mineral material, and with an increase in their content in bitumen, adhesion improves according to

GOST 11507-74 by the "passive" adhesion method. It is known that the wetting of mineral material with bitumen is a necessary condition for their adhesive interaction.

Experimental results on estimates of the adhesion strength of bitumen to the surface of various mineral materials are presented in Tables 1 and 2.

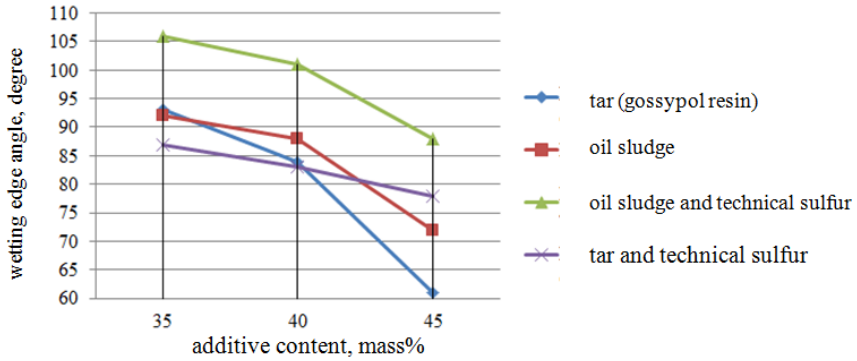


**Fig. 2.** Dependence of the wetting ability of BND 60/90 on the content of additives.

Note: decoding of points: 2 - "unsatisfactory", less than 75% of the surface of crushed stone particles is covered with a binder film; 3 - "satisfactory", up to 90% of the surface of crushed stone particles is covered with a binder film; 4 - "good", up to 95% of the surface of crushed stone particles is covered with a binder film; 5 - 96% and above of the surface of crushed stone particles is covered with a binder film.

**Table 1.** Adhesion strength of bitumen BND 60/90 with the surface of various mineral materials.

| **Additive, mass%** | **Mineral materials** | | | | | |
|---|---|---|---|---|---|---|
| | **Granite crushed stone** | | **Granite gravel** | | **Marble** | |
| | **Covering, %** | **Points** | **Covering, %** | **Points** | **Covering, %** | **Points** |
| **BND-60/90** | **76** | **3** | **74** | **2** | **78** | **3** |
| BND 60/90 +35%(D-1) | 82 | 3 | 77 | 3 | 86 | 3 |
| BND 60/90 +40%(D-2) | 86 | 3 | 84 | 3 | 90 | 4 |
| BND 60/90 +45%(D-3) | 92 | 4 | 90 | 4 | 93 | 4 |
| BND 60/90 +50%(D-4) | 89 | 3 | 87 | 3 | 89 | 3 |
| BND 60/90 +35%(D-5) | 91 | 4 | 89 | 3 | 93 | 4 |
| BND 60/90 +40%(D-6) | 93 | 4 | 90 | 4 | 95 | 5 |
| BND 60/90 +45%(D-7) | 96 | 5 | 92 | 4 | 97 | 5 |
| BND 60/90 +50%(D-8) | 92 | 4 | 88 | 3 | 91 | 4 |

In the Table: D-1 composition (tar (gossypol resin) 30% and sulfur 5%); D-2 composition (tar (gossypol resin) 30% and sulfur 10%); D-3 composition (tar (gossypol resin) 30% and sulfur 15%); D-4 composition (tar (gossypol resin) 30% and sulfur 20%); D-5 composition (tar (gossypol resin) 15%, oil sludge 15% and sulfur 5%); D-6 composition (tar (gossypol resin) 15%, oil sludge 15% and sulfur 10%); D-7 composition (tar (gossypol resin) 15%, oil sludge 15% and sulfur 15%); D-8 composition (tar (gossypol resin) 15%, oil sludge 15% and sulfur 20%).

According to Table 1, graphical dependencies were built, which are presented in Figure 3 and 4.

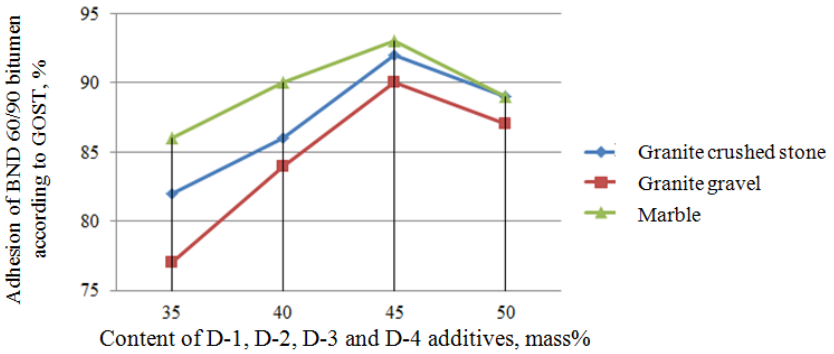


**Fig. 3.** Dependence of adhesion of BND 60/90 bitumen with D-1, D-2, D-3 and D-4 additives to various mineral materials.

Figure 3 shows that addition of 45 mass% D-3 additive to BND 60/90 grade bitumen gives the best adhesive indications. Since the surface of the mineral material of marble has a roughness, the adhesion of the bituminous composition to the marble mineral material showed the highest percentage than with crushed granite and gravel. Further, BND 60/90 + D-3 bituminous composition is well wetted and adheres to crushed granite and then to granite gravel.

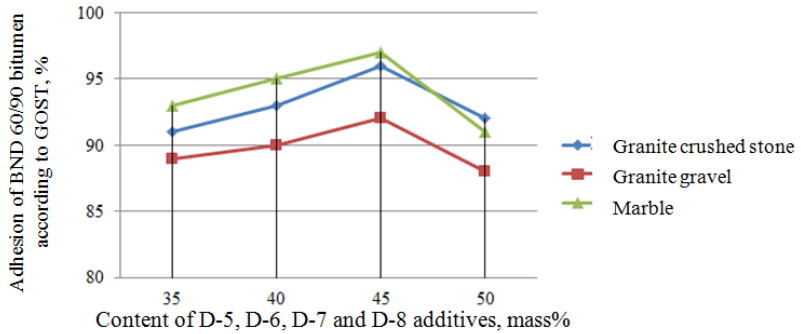


**Fig. 4.** Dependence of adhesion of bitumen BND 60/90 with D-5, D-6, D-7 and D-8 additives to various mineral materials.

**Table 2.** Adhesion strength of bitumen BND 90/130 with the surface of various mineral materials.

| **Additive, mass%** | **Mineral materials** | | | | | |
|---|---|---|---|---|---|---|
| | **Granite crushed stone** | | **Granite gravel** | | **Marble** | |
| | **Covering, %** | **Points** | **Covering, %** | **Points** | **Covering, %** | **Points** |
| **BND-90/130** | **69** | **2** | **67** | **2** | **70** | **2** |
| BND 90/130 +35%(D-1) | 79 | 3 | 77 | 3 | 78 | 3 |
| BND 90/130 +40%(D-2) | 84 | 3 | 83 | 3 | 85 | 3 |
| BND 90/130 +45%(D-3) | 90 | 4 | 90 | 4 | 90 | 4 |
| BND 90/130 +50%(D-4) | 87 | 3 | 88 | 3 | 89 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| BND 90/130 +35%(D-5) | 82 | 3 | 79 | 3 | 84 | 3 |
| BND 90/130 +40%(D-6) | 90 | 4 | 90 | 4 | 91 | 4 |
| BND 90/130 +45%(D-7) | 92 | 4 | 91 | 4 | 93 | 4 |
| BND 90/130 +50%(D-8) | 89 | 3 | 88 | 3 | 90 | 4 |

According to Table 3, graphical dependencies were built, which are presented in Figure 5 and 6.

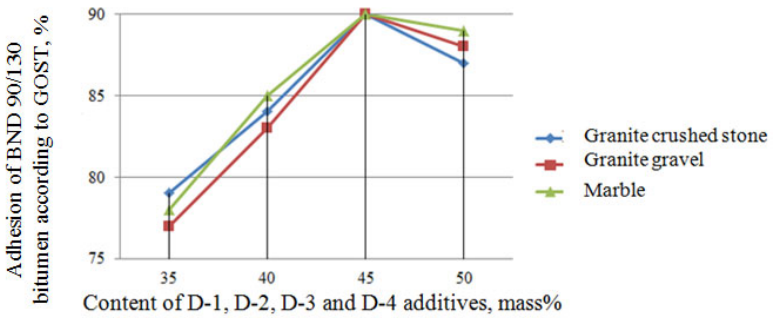


**Fig. 5.** Dependence of adhesion of BND 90/130 bitumen with D-1, D-2, D-3 and D-4 additives to various mineral materials.

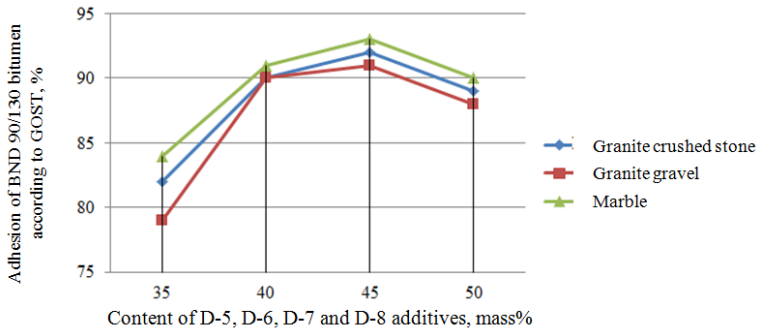


**Fig. 6.** Dependence of adhesion of bitumen BND 90/130 with D-5, D-6, D-7 and D-8 additives to various mineral materials.

According to Tables 1, 2 and graphs presented in Figures 3-6, we can conclude that the adhesion of bitumen decreases in the following order: marble - crushed granite - granite gravel. In other words, the adhesion strength of bitumen to basic rocks (marble) is better than to acidic rocks (granite materials). Besides, according to the Table, it can be seen that with the same acid-base characteristics of mineral materials, the adhesion strength of bitumen to the surface of a rough material (granite crushed stone) is greater than to the surface of a smoothly rolled material (gravel).

## 4 Conclusion

It has been shown that the introduction of tar (gossypol resin) into the developed compositions significantly increases their wetting and adhesive ability. Based on additives

such as oil sludge, gossypol resin and technical sulfur, bitumen compositions with improved adhesive characteristics have been obtained. Based on the obtained results, the bituminous composition BND 60/90 + D-7 has the highest adhesion strength to the surface of various mineral materials. This allows intensifying the process of adhesion of the bituminous binder with mineral materials and will allow obtaining a high-quality road mix for covering the motor roads.

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