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Article

Properties of modified bitumen in road construction

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Abstract. The increase in the construction of asphalt concrete roads in Kazakhstan has led to the development of research on raw materials in this industry. Bitumen binder as the main component affecting the deformation properties, as well as the physical and mechanical properties of coatings, in general, is of the greatest interest to builders. The analysis of scientific sources in the field of the application of various modifiers of bitumen binders is carried out. Polymer-based additives have been widely used in road construction. The use of half-dimensional additives contributes to the improvement of asphalt concrete indicators: strength properties, water resistance, deformative stability of the coating at high and low operating temperatures, wear resistance, and resistance to rutting, which generally increases the repair time and contributes to a corresponding reduction in operating costs. This article presents a study of the properties of bitumen modified with an additive based on rubber crumbs. Indicators such as penetration depth and softening temperature by the ring and ball method are investigated in the article. The samples with different content of additives were taken: control sample without additives, and samples with the addition of modifiers in the amount of 5%, 10%, 12%, and 15% out of bitumen weight. The highest viscosity is shown by the sample with a modifier of 12%. Bitumen samples with a modifier content of 12% and 15% correspond to the standard indicators regarding softening temperature.
Keywords: bitumen, modifier, polymer additive, crumb rubber, bituminous binder.

1. Introduction

Bitumen modifiers for asphalt concrete are used to improve their basic properties such as strength, water resistance, fatigue resistance, and durability. Several types of modifiers can be added to asphalt bitumen such as polymers, rubber particles, plasticizers, adhesion additives, nanotechnology-based additives, and modified bitumen itself [1]. For example, polymers are added to the bitumen to improve its resistance to ultraviolet radiation and fatigue with the potential to increase the strength and durability of the asphalt concrete [2]. Rubber particles are added in the form of crumb rubber or powder from recycled tires to improve the elasticity and fatigue resistance of the asphalt concrete [3]. Plasticizers improve bitumen performance at low temperatures by increasing flexibility. Adhesion additives improve adhesion between bitumen and mineral aggregates, thereby increasing the strength of the asphalt concrete [4]. Modified bitumen is already modified with polymers or other additives to provide specific properties related to temperature resistance or chemical resistance. Nanotechnology-based additives use nanoparticles to improve bitumen properties [5]. All of the above modifiers can be combined depending on the project. However, the main purpose of these modifiers is to create durable and stable asphalt pavements [6].

Polymers were found to be an effective bitumen modifier despite relatively low mixing and compaction temperatures [7]. Tests have shown positive effects on the physical properties of bitumen: an increase in stiffness after modification, meaning that pavements become more resistant to permanent deformation and become more resistant to heavy loads.

Another additive is a composite thermoplastic elastomer, which is used to modify bitumen to improve resistance to plastic deformation, increase the shear stability of asphalt concrete, and reduce the effect of temperature during the technological process when working with bitumen [8].

In this paper, we consider the possibility of using modified crumb rubber as an additive for bituminous binder [9]. It is assumed that the use of this modifier will increase the deformation resistance of the material [10].

2. Methods

For testing of materials, samples of bitumen of Pavlodar petrochemical plant grade BND 70/100 and modified rubber crumb, were obtained as a result of processing of automobile tires. Tests of material samples were carried out by the approved methods in compliance with the current regulatory documents in the Republic of Kazakhstan.

2.1 Sample preparation

Bitumen sampling was carried out by ST RK 1809-2008 [11]. Two-point samples of bituminous mastic weighing at least 0.5 kg were selected and poured into the mold for casting.

2.2 Method for determining needle penetration depth

Bitumen samples to determine the penetration depth of the needle are taken by the requirements of Interstate standard 2517-2012 [12]. The test sample is heated to a mobile state, in the presence of moisture, it is dehydrated by heating to a temperature 90 °C above the softening temperature, but not higher than 160 °C. The heating time should not exceed 30 minutes (Figure 1).

Figure 1 – Heating samples

Further, the bitumen samples are filtered, poured into two penetration cups, and thoroughly mixed until the air bubbles are completely removed (Figure 2).

Figure 2 – Pouring bitumen samples into penetration cups

The studied bitumen samples are cooled in air at a temperature of 15-30 °C for 60-90 minutes. After cooling, the cups with the samples are placed in a bath.

Bitumen consistency is determined by the method of determining the depth of needle penetration according to ST RK 1226-2003 [13]. The essence of the method is to measure the depth of penetration of the penetrometer needle into the bitumen sample under certain conditions: a given load, temperature and time interval (Figure 3). The accuracy of the needle penetration depth is 0.1 mm.

Figure 3 – Testing samples in a penetrometer

2.3 Determination of the softening point by the ring and ball method

Bitumen sampling is carried out by Interstate standard 2517-2012 [12]. Bitumen is poured with a small excess into two stepped rings placed on a plate lubricated with dextrin. Samples must be dehydrated and free of air bubbles (Figure 4).

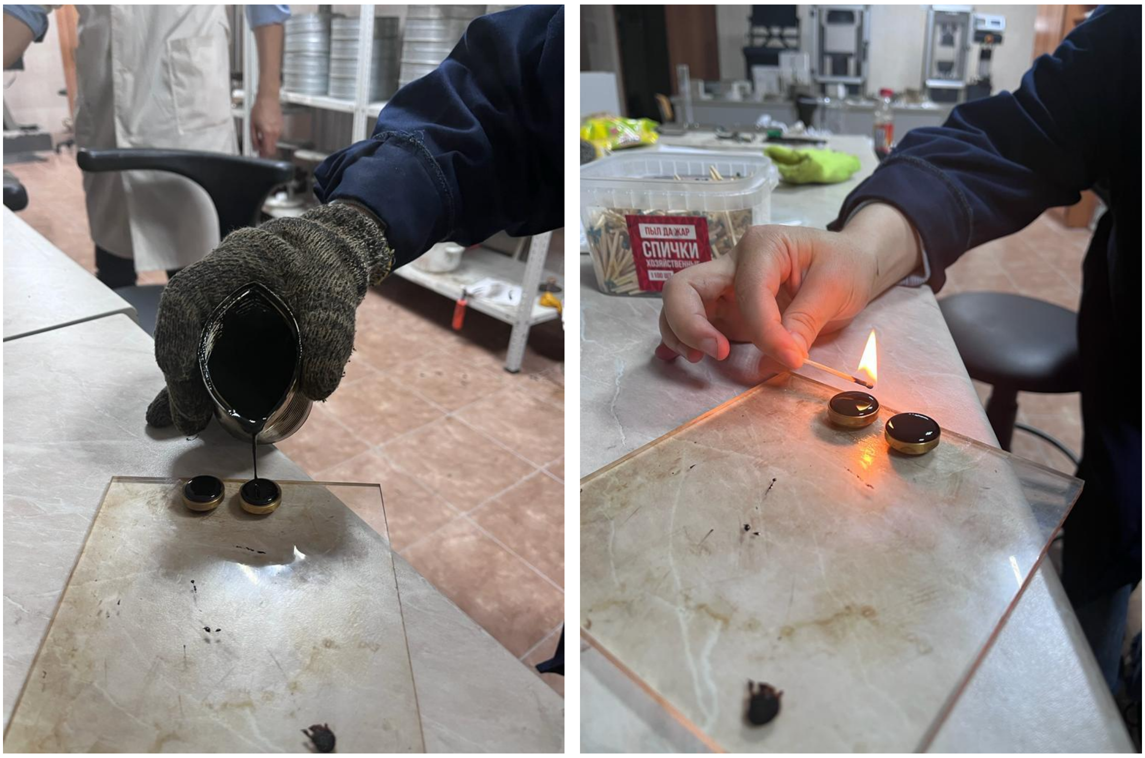

Figure 4 – Pouring bitumen samples into stepped rings

After cooling the sample rings for 30 minutes, the excess bitumen is cut off with a heated knife (Figure 5).


Figure 5 – Cutting of excess bitumen

When testing samples, rings with bitumen are placed in the holes of the upper plate of the device. A tripod with test samples in rings is placed in a bath filled with distilled water with a temperature of 5±1 °C. After 15 minutes, the tripod is removed from the bath, a steel ball is placed on each ring in the center of the surface, pre-cooled in the bath to a temperature of 5±1 °C, and lowered back into the bath on the heating device. The water temperature after the first three minutes should rise at a rate of (5.0 ± 0.5) °C per minute. For each ring and ball, the temperature at which the bitumen squeezed out by the ball touches the light beam of the device is noted (Figure 6).

Figure 6 – Testing of samples

3. Results and Discussion

In order to determine the effectiveness of using modifier for bitumen, samples with different content of additive were taken: control sample without additive, samples with addition of modifier 5%, 10%, 12% and 15% of bitumen weight. The tests carried out on laboratory equipment showed different results. Processing of results and comparative analysis of indicators was carried out in accordance with the requirements of the National standard [14]. According to Table 2 of this standard, physical-mechanical and performance indicators of binder samples were evaluated for PMB (polymer modified bitumen) 70/100 grade.

3.1 Needle penetration depth

The results of the tests carried out by this method allow us to judge the consistency of bitumen binders. High accuracy of the results is provided by calibrated laboratory equipment (Figure 7).

Figure 7 – Testing of the sample on the Infratest penetrometer

The obtained indicators of the penetration depth of the needle of the test device into the bitumen samples are shown in the following graph (Figure 8):

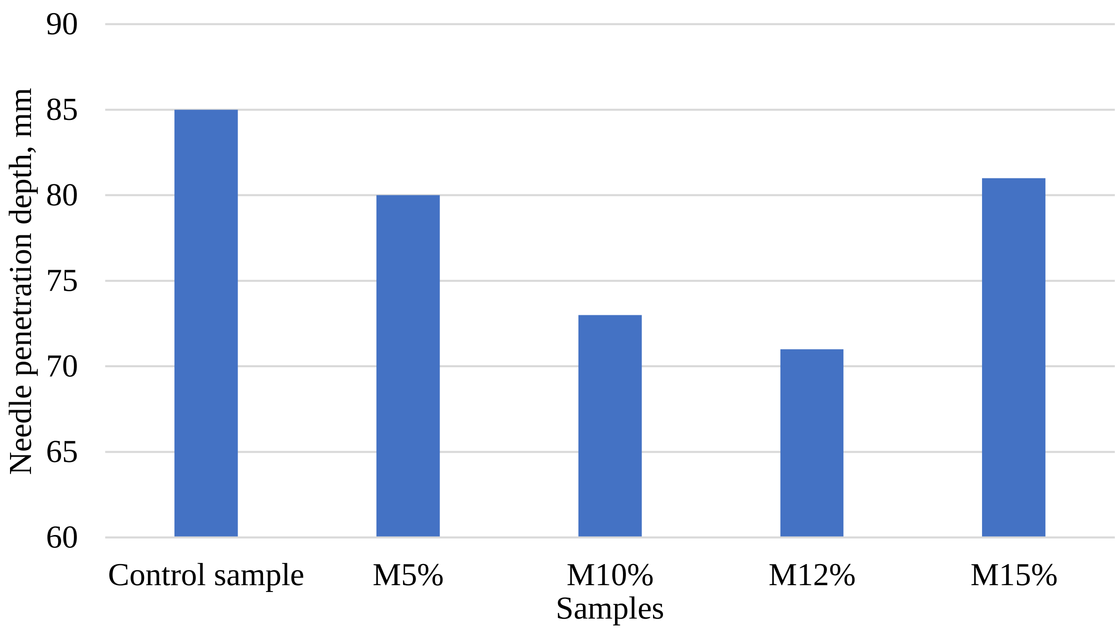

Figure 8 – Indicators of penetration of bitumen samples

As we can see, the samples of the modified binder have sufficient viscosity for mobility. The highest indicator is a sample with a modifier content of 12 %.

3.2 Determination of the softening temperature of bitumen

Determination of the softening temperature of bitumen characterizes the upper temperature limit of its application. This indicator also indirectly characterizes the adhesion of bitumen and is related to the nature of its components. The data obtained experimentally are summarized and shown in the Figure 9.

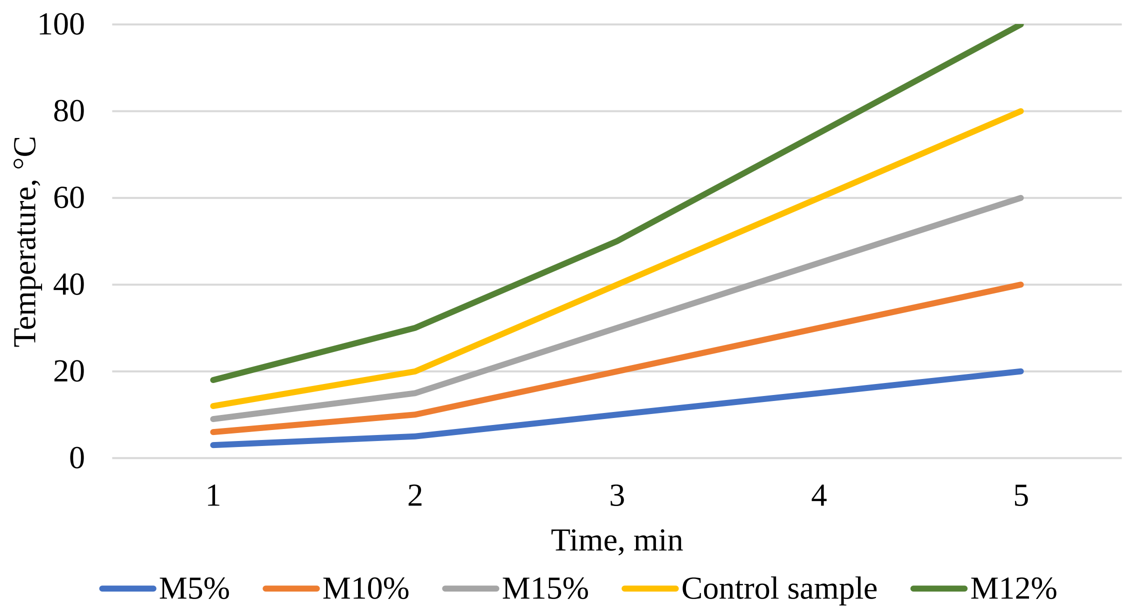

Figure 9 – Indicators of the softening temperature of samples by the ring and ball method

Taking into account the test results obtained, bitumen samples with a modifier content of 12% and 15% correspond to the standard indicators [15].

4. Conclusions

The obtained test results of bitumen samples with different percentages of a modifier based on rubber crumbs indicate the effectiveness of the additive on the physical and mechanical properties of the bitumen binder. The problem of recycling worn-out car tires is of great ecological importance all over the world. The accumulation of worn tires pollutes the environment, and their uncontrolled burning has an irreversible impact on the environment. According to many scientific studies, the use of rubber crumbs in the production of asphalt concrete solves the issues of noise reduction, and also increases the strength properties, water resistance, deformative stability of asphalt concrete pavement at high and low operating temperatures. The conducted research on the use of rubber crumbs as a modifier of bitumen binder has shown the effectiveness of its use.

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