






Determination of the softening temperature of bitumen with different modifiers

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Abstract. Road construction is an important part of economic development, and the most pressing problem is improving the quality of road surfaces. Road pavements are a combination of mineral fillers and bitumen, in which bitumen is used as a durable waterproof binder. Bitumen modification can improve the quality of bitumen, by increasing the plasticity interval, increasing adhesion to metal and mineral materials, increasing resistance to aging, and expanding the operating temperature range. Softening point characterizes the thermal resistance of bitumen: the transition from the elastic-plastic state to a viscous-fluid state, in which the bitumen loses its adhesive properties. And this paper presented the investigation of the properties of bitumen by modifying it and determining the softening temperature on the device Ring and ball. The analysis of the obtained results of the use of various modifiers, their comparative characteristics, and the formulation of conclusions about the possibility of involving them in the production of bitumen to improve their quality.

Keywords: bitumen, modifier, property, softening temperature, investigation.

1. Introduction

1.1 Bitumen as a construction material

Currently, there is an increase in requirements for the operational and transportation characteristics of asphalt concrete pavements due to the annual increase in the number of vehicles in almost all regions of Kazakhstan, including heavy and extra heavy trucks, which reduces the service life of road asphalt concrete pavements [1-3]. Along with this, another cause of premature failure of road asphalt concrete pavement in the form of cracks, potholes, holes, ruts, etc. is a sharp drop in ambient temperature within a short period of time and severe weather conditions. At the same time, the service life of the pavement is affected by the quality of the bitumen used, which is one of the important components of the road surface in almost all categories of roads around the world [4-5].

Unlike natural bitumen, artificial bitumen is formed because of wastes of processed oil by releasing the following gases: butane, propane, ethylene. Bitumen has the following properties: density, flash point, viscosity, solubility, brittleness, plasticity, softening, adhesion, which affect the quality of bitumen [6].

However, to date, several the following problems are associated with bitumen in the road sector. One of them is the annual increase in the price of bitumen during the season of road construction and repair. Another problem is the low quality of proposed bitumen. Considering the above mentioned, one of the solutions of these problems is the modification of bitumen. First, it will solve the problem with bitumen storage, and secondly, it will reduce the amount of bitumen used in the construction and repair of roads of all categories, which will eventually lead to a reduction in demand for bitumen.

1.2 Application of various bitumen modifiers

The research team [7] presented the results of tests conducted on bitumen modification of "polyethylene terephthalate (PET) beverage bottles and used rubber tires, which are major municipal solid waste that can lead to various environmental problems if they are not properly recycled.

The main purpose of this work was to study the mechanisms of PET waste recycling with triethylenetetramine (TETA) and ethanolamine (EA), describing the properties of the above additives with bitumen modified with old rubber products. Based on the results of the tests, "two additives from PET waste, PET-TETA, PET-EA, and their molecular structures, thermal properties and synthesis mechanisms have been characterized. At the same time, it was found that PET wastes are amenable to chemical recycling in the form of functional additives that allow increasing the operation of bitumen using rubber as a modifier.

A study by D.S. Mabui [8] studied polyethylene terephthalate (PET) and budded modified asphalt (BMA), and to solve the problem of heavy precipitation and temporary flooding considered the use of porous asphalt concrete in the surface layer of the roadway. The advantage of porous asphalt is that voids are created in the mixture of coarse aggregate, sand and filler, which absorb excess storm water in bad weather and do not allow moisture to collect on the road surface.

Another interesting study material was budstone asphalt, which contains 30% bitumen and 70% minerals. At the same time in the mixture for the study modified budstone asphalt was used in the amount of 6.0% of the total weight of the aggregate. The work of L. Desideri et al. [9] studied the issue of combining bitumen with polyethylene and Fischer-Tropsch waxes. During the study bitumen PG64-10, polyethylene in granules and powder and two commercial Fischer-Tropsch waxes were used. The tests confirmed the fact that the mechanical response of bitumen is very dependent on the chain length of the wax.

Thus, the reaction of bitumen with long-chain wax is similar to the reaction of polymers not organically modified with binders in the entire range of temperatures considered, while the short-chain bitumen changes sharply at temperatures above 50°C in the form of melting and softening. At the same time, in view of the volatilizable of the components of the considered compositions and the resulting oxidation reaction in these mixtures because of high-temperature treatment, their mechanical properties change significantly. The patent "Asphalt-concrete mixture on nanomodified binder" [10] describes the composition of the asphalt-concrete mixture with the addition of rubber crumb of 0.25 mm in size as a bitumen modifier, which can improve the properties of asphalt-concrete on its basis.

However, each of the presented methods has its own characteristics and disadvantages, in this regard, the search for a solution of high-quality bitumen is open.

2. Methods

The purpose of this study was to determine the softening temperature of bitumen modified with various additives and to determine their influence on this indicator.

The tests were conducted according to the requirements of EN 1427:2015 [11].

As modifiers were used:

- 1) pellet modifiers;
- 2) crushed plastic weighing 1 g, 2 g, 4 g, 6 g;
- 3) polyethylene weighing 50 mg, 100 mg, 150 mg.

In each recipe used road bitumen brand 70/100 examined on the device to establish the softening temperature of bitumen in the "pure" form, and then with the use of additives. Prior to the study, polyethylene was separated into small pieces, a plastic disposable cup with a lid was used as plastic, which was previously crushed into smaller pieces to dissolve them better in the material used.

The Figure1 shows the preparation of the composition of bitumen using additives, presented data on the amount of material used in the tests conducted.

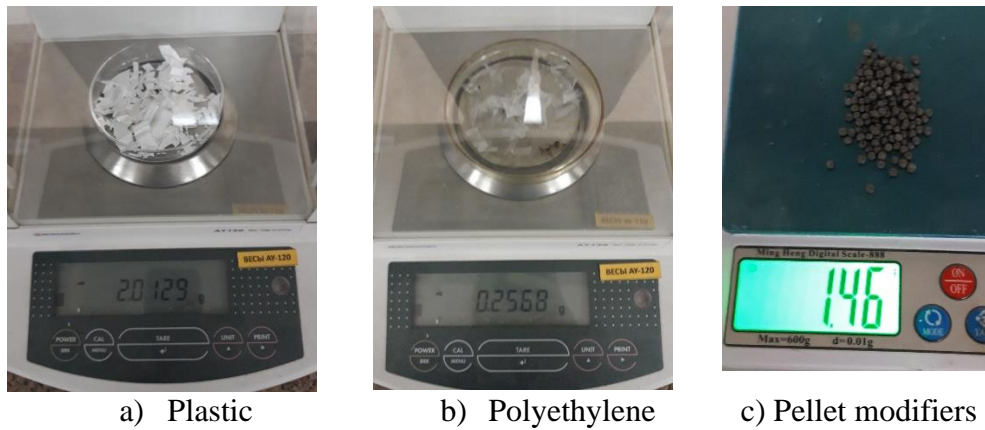


Figure 1 – Used additives

Since the introduction of pellets already has a strict proportion, this modifier was chosen in one recipe. And the quantitative composition of the modifiers as plastic and polyethylene were tested in different ratios. Figure 2 shows samples of bitumen heated to a viscous state on the slab and mixed with additives.



Figure 2 – Mixing bitumen with plastic and polyethylene samples

The molds were pre-lubricated with an ointment in the form of a mixture of glycerin and talc in a ratio of 1:2 to effectively remove the residual bitumen after the test. Figure 3 shows images of the ring molds before the bitumen was poured with the additives used and after.

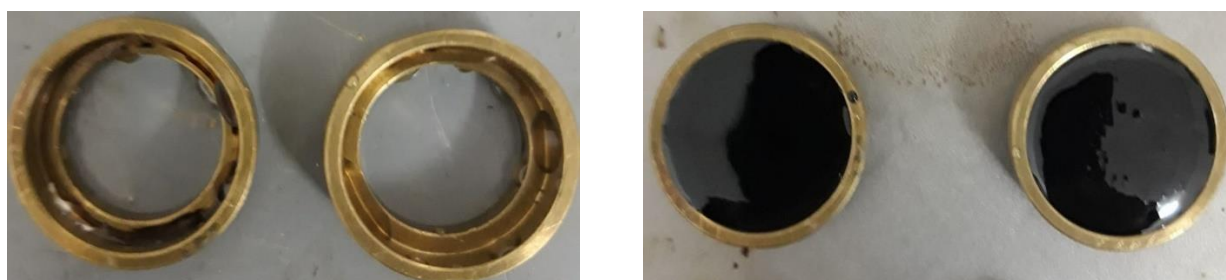
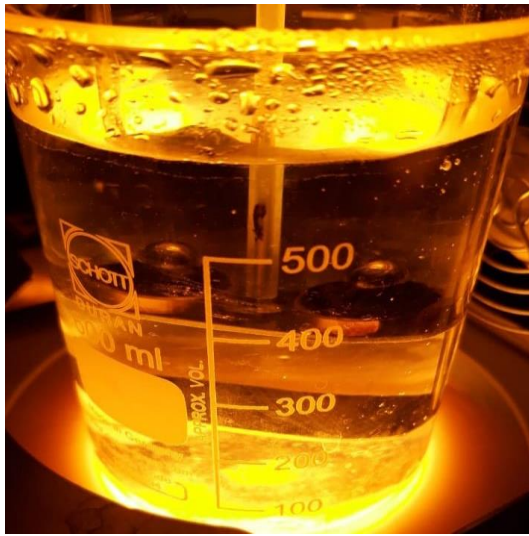


Figure 3 – Shapes for the "Ring and Ball" device

Properties of polymer bitumen depends on the peculiarities of the properties of the original bitumen, the compatibility of the injected polymer with bitumen, compliance with the technology of polymer bitumen preparation, considering the characteristics of the properties of polymer plasticizers [12].

The balls placed in the center of special round forms are pressed through the bitumen due to the increase in water temperature in the device (Figure 4) as well as due to the gradual softening of bitumen [8].



a) Start of the test

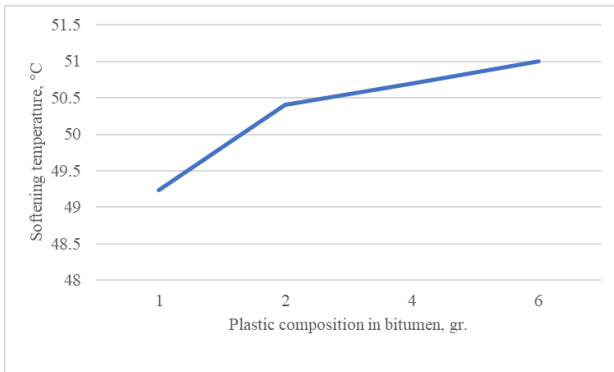


b) Completion of the test

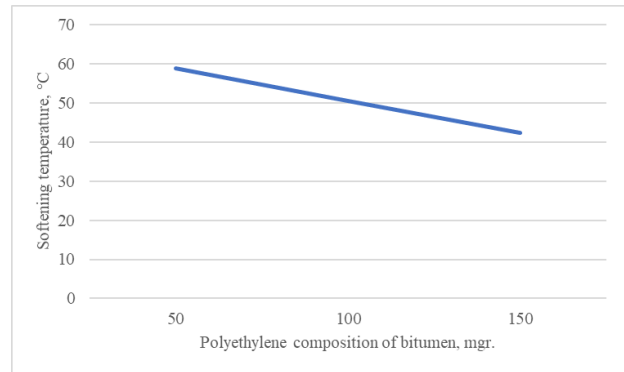
Figure 4 – Conducting a test on the "Ring and Ball" device

3. Results and Discussion

When introducing different ratios of modifiers to bitumen from the mass of the bitumen, the results of the study of the kinetics of change in the softening temperature are shown in Figure 5. Thus, the main results obtained are presented in Table 1, with the modifier of plastic and podiatylene selected as the best composition.



a) Plastic



a) Polyethylene

Figure 5 – Softening temperature depending on the amount of modifier

Table 1 – Softening temperature regarding modification composition

Composition	Softening temperature, °C
Bitumen 70/100	52
Bitumen with granule modification	52.03
Bitumen with polyethylene	58.87
Bitumen with plastic	51.0

Analysis of the results compared with the properties of the original bitumen (Table 1) shows that the introduction of 50 mgr polyethylene into bitumen creates a spatial structure, resulting in an increase in the softening temperature (Figure 6).

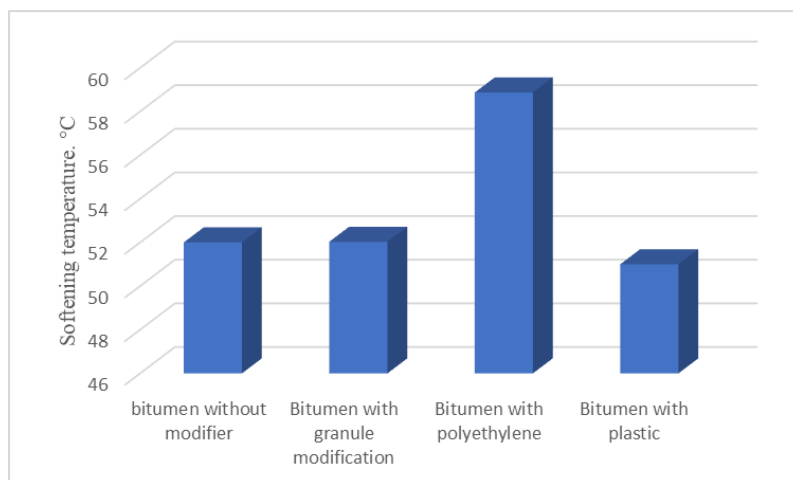


Figure 6 – Comparison analysis

The effect of adding polyethylene occurs at its lower ratio to bitumen, which is the optimal modification between considered modifiers.

4. Conclusions

Due to modern technologies, it is possible to improve the composition of asphalt concrete mixture in the following ways: by improving the production technology of bitumen and asphalt concrete mixture; by using modifying additives both in bitumen itself and in asphalt concrete mixture. As the analysis showed, the method of bitumen improvement by polymeric additives is more promising. Using it, it is possible to improve the quality of bitumen performance properties or to obtain a topical material with improved physical, mechanical and chemical properties.

The choice of materials presented in the study is since they are readily available, easy to use, and their volume is growing every year. The use of waste materials in the form of polyethylene and plastic is also an effective direction in obtaining polymer bitumen binders for asphalt concrete, as their combination with bitumen does not cause difficulties.

Based on the conducted study conclusions were obtained: the properties of polymer-bitumen binder depend on the properties of the initial bitumen, polymer properties and its compatibility with bitumen, the quality characteristics of the plasticizer; the required amount of polymer to obtain the polymer-bitumen binder to ensure reliable operation of waterproofing will depend on the structure of the initial bitumen.

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