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IMPROVING THE STRUCTURAL AND MECHANICAL PROPERTIES OF WARM ASPHALT CONCRETE BY THE METHOD OF POLYMER-DISPERSE REINFORCEMENT

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Statement of the problem. The problem of improving the structural and mechanical properties of warm asphalt concrete using the method of polymer-dispersed reinforcement is considered. The effect of the dosage of the RTEP-M modifier in the mineral part of the mixture on the structural and mechanical properties of warm mix asphalt (WMA) was studied.

Results. By preparing a warm mix asphalt with mixing and molding samples at a temperature of 110—120 °C with the RTEP-M modifier at a ratio of 0.5; 1.0; 1.5 and 1.75 % of the mineral part and control mixtures, the effect of the modifier dosage on the structural and mechanical properties of WMA was studied. By testing the samples, the compressive strength of warm asphalt concrete at temperatures of 0.20 and 50 °C was determined, as well as the indicators of average density, water saturation and water resistance.

Conclusions. The effectiveness of the application of the method of polymer-dispersed reinforcement to improve the structural and mechanical properties of warm concrete asphalt has been proven. It is shown that the addition of the RTEP-M modifier to the mineral part of the warm mix asphalt improves the strength characteristics of the asphalt concrete. It has been established that by applying the method of polymer-dispersed reinforcement, it is possible to optimize the properties of warm asphalt concrete for its use in cold or hot climatic conditions within the limits of indicators permissible according to the requirements of regulatory documents.

Keywords: warm mix asphalt, warm asphalt concrete, modifier, polymer-dispersed reinforcement, RTEP-M, structural and mechanical properties.

Introduction. For a long time, hot asphalt concrete mixtures (HAS) was the only type of asphalt concrete utilized for laying layers of asphalt concrete pavements, as in most countries HAS were chosen for constructing road networks of various categories and types [2, 10].

Relatively high temperatures during the production and use of this type of asphalt mixtures, a large amount of consumed fuel, greenhouse gas emissions, challenging operating conditions for employees [1, 4] and other factors called for an alternative technology for producing asphalt concrete mixtures. Therefore the recent years have seen an increase in the number of scientific studies, laboratory and field experiments in developing technologies for preparing warm asphalt mixes with properties not lower than those of hot asphalt mixes, in order for them to be used as an alternative in the construction of pavement layers.

Warm asphalt mixes are a type of asphalt mixes manufactured at temperatures lower than those of traditional hot asphalt mixes, by about 20—40 °C [9, 15, 16]. This is achieved by using various technologies for lowering the viscosity of bitumen, contributing to the lower temperatures required for the preparation and placement of asphalt mixes. A decrease in temperature causes a reduction in the amount of fuel required for heating materials at all stages of production, a decrease in emissions of harmful gases, an improvement in operating conditions and an extension of the road construction season. According to studies, compared to hot asphalt mixes, warm asphalt mixes reduce greenhouse gas emissions and energy consumption by about 33 % (Fig. 1) and 18 %, respectively [14, 19, 21].

Fig. 1. The difference in emissions of harmful substances into the atmosphere between hot and warm mixes: on the left is a hot mix, on the right is a warm mix [9]

Despite its multiple advantages, a number of flaws emerged in the technology of warm asphalt concrete mixtures during the period of its operation, the most critical one being the low

water resistance (particularly while using water-based technologies) and the low values of mechanical properties of asphalt concrete, particularly while used in hot climates [2, 7]. The development of a technology for preparing TAS using simple production technologies and available local additives that improve the physical and mechanical properties of TAS will expand the application field of warm asphalt concrete.

Polymer-dispersed reinforcement [3, 5, 8] is known to be an effective method for improving the structural and mechanical properties of hot asphalt concrete. In these studies, the specified method was utilized with the use of RTEP-M as a modifier.

RTEP-M is a polymer dispersion-reinforcing modifier, which is a rubber thermoplastic elastomer that acts as a stabilizer and dispersion-reinforcing additive in asphalt concrete. RTEP-M is one of the well-known Russian additives containing recycled polyethylene, bitumen, stabilizers and other available materials.

Introducing RTEP-M into the mineral part of the warm asphalt concrete mix, we investigated the effect of the additive on the mechanical properties of asphalt concrete at high, low and natural temperatures, as well as its effect on the physical and chemical properties whose indicators were the average density, water saturation and water resistance of asphalt concrete.

1. Selection of the components of warm asphalt concrete mix and consideration of the properties of the used materials. The examined asphalt concrete mix is an asphalt concrete mix of type B, grade II.

For selecting the components of warm asphalt concrete mix in compliance with the requirements of GOST 9128-2009 «Asphalt Concrete Road, Airfield and Asphalt Concrete Mixes. Technical Conditions» with continuous grain composition, crushed stone of 5—20 mm fraction, sand from crushing screenings of 0—5 mm fraction and activated mineral powder were employed (grain compositions of materials for the mineral part of TAS are shown in Table 1).

Table 1

Grain compositions of mineral materials

Name	Size of the grains, mm, finer, % of the mass									
	20	15	10	5	2.5	1.25	0.63	0.315	0.16	0.071
Crushed stone	95.6	71.9	26.2	1.2	0.15	0.0	0.0	0.0	0.0	0.0
Sand from crushing screenings	100	100	99.9	94.1	62.6	50.4	35.0	24.8	16.45	8.65
Mineral powder	100	100	100	100	100	100	100	100	96.0	87.0

The grain composition of the mineral part is selected in compliance with the requirements of GOST 9128-2009. A mixture was selected which consisted of 41 % crushed stone, 53 % sand from crushing screenings and 6 % mineral powder [5]. Fig. 2 shows a particle size distribution curve for the mineral part of a warm asphalt mix.

Fig. 2. Grain size curves: *max*, *min* and actual grain size distribution, mm

The organic binder was BND 70/100 grade petroleum bitumen produced by Ltd. RNPk. This bitumen was liquefied using diesel fuel to obtain road bitumen BND 200/300 to be employed for preparing the TAS. The optimal content of bitumen (5 % over the mineral part) was identified in terms of physical and mechanical properties: average density, compressive strength, water saturation and water resistance [6, 11].

Table 2

Physical and Mechanical Properties of RTEP-M according to the STO 39952490-001-2020

Index	Value, standard	Testing method
Physical appearance	Freeform granules without any inclusions; foaming is allowed	10.2 (STO 39952490-001-2020)
Colour	Brown, black	10.2 (STO 39952490-001-2020)
Softening temperature, °C, no less than	140	GOST 33142
Average granule size by the largest dimension, mm	2—6	10.4 (STO 39952490-001-2020)
Bulk density, g/cm ³	0.35—0.70	GOST P 55419

All of the components of the warm asphalt concrete mix complied with the requirements of the current regulatory and technical documentation.

Rubber thermoplastic elastomer RTEP-M complied with the requirements of STO 39952490-001-2020 "Rubber Thermoplastic Elastomer RTEP-M. Technical Conditions". Its physical and mechanical properties are presented in Table 2.

The effect of the RTEP-M modifier on the structural and mechanical properties of asphalt concrete mixtures was evaluated by means of the ratio of the additive to the mineral part: 0.5; 1.0; 1.5 and 1.75.

2. Research methodology and testing results. The preparation of samples of warm asphalt concrete mixes, the testing and processing of the results were performed in the same fashion as for the hot asphalt concrete mixes, with the only difference being the temperatures of mixing and forming samples taken within 110—120 °C.

The TAS samples were prepared by heating mineral materials (crushed stone and sand from crushing screenings) of a specific mass to a temperature of 130 °C [17, 18]. Then mineral powder in a cold state was added and the mix was well mixed, after which road bitumen BND 200/300 was added at a temperature of 105—115 °C with all of the components mixed until well covered with bitumen [17].

For forming the samples, the temperature of the asphalt concrete mix was in the range of 110—120 °C [20, 22], the warm mix in the required amount was placed in preheated molds (while making the samples, the molds and inserts were heated to 90—100 °C), and then the mixture was compacted under load in compliance with GOST 12801-98 "Materials Based on Organic Binders for Road and Airfield Construction. Testing Methods", after which the samples were removed from the molds and kept in air to be tested on the next day.

The specified sample preparation scheme was also implemented while using the RTEP-M modifier in TAS, which was introduced in a cold state by adding a mineral powder with thorough mixing of the mixture components and observing the steps discussed earlier [3, 8, 12, 13].

The sample testing procedure was performed in compliance with the requirements of GOST 12801-98. In order to determine the values of the indicators in each case, the arithmetic mean of the three test samples was taken.

The results of evaluating changes in the parameters of the mechanical properties of warm asphalt concrete while using the RTEP-M modifier in the mineral part of the mixture are shown in Fig. 3. According to these graphs (Fig. 3), as the percentage of RTEP-M additive increases, so does the value of the compressive strength of warm asphalt concrete in the entire range of

the temperatures. The value of the increase in the compressive strength index is most significant at 20 °C, while at the temperatures of 0 °C and 50 °C there is a slight increase. It should be noted that the value of the tensile strength in compression of warm asphalt concrete complies with the regulatory requirements for hot asphalt concrete of type B according to GOST 9128-2009 for the entire range of operating temperatures.

Fig. 3. Influence of the content of the modifier RTEP-M on the mechanical properties of warm asphalt concrete

Indicators (water saturation, water resistance and average density of warm asphalt concrete) while using the content of the RTEP-M modifier in the mineral part of the mixture are shown in Fig. 4. The graphs indicate that the average density of warm asphalt concrete drops with an increase in the content of the RTEP-M modifier in the mineral part, particularly in the amount of 1 % or more. Water saturation with an additive content of 0.5—1 % drops slightly, and

then increases considerably with an increase in the dosage of RTEP-M to 1.5 %. The coefficient of water resistance increases as does the content of the modifier, which is particularly noticeable when its amount is 1% or more. It should be noted that the values of the indicators of these properties remain within the permissible limits according to the regulatory requirements for hot asphalt concrete of type B in compliance with GOST 9128-2009.

According to the results, the optimal content of RTEP-M in TAS is 1.5 % of the mass of mineral materials, as with such an amount of modifier, all of the indicators are in the range of good or the best values.

Fig. 4. Influence of the content of the modifier RTEP-M on water saturation, water resistance and average density of warm asphalt concrete

Conclusions

1. The preparation of the modified warm asphalt concrete mix with the improved mechanical and physical properties in compliance with the regulatory requirements is possible by means of using low viscosity road bitumen BND 200/300 obtained as a result of liquefaction of BND 70/100 bitumen in comparison with the hot production technology.

2. It has been established that the addition of the thermoplastic elastoplast rubber modifier RTEP-M improves the mechanical properties of warm asphalt concrete when added in the amount of 1.5% of the mass of mineral materials, as a result of which the compressive strength increases by 29 % at 20 °C, 13 % and 17 % at 0 °C and 50 °C, respectively.
3. The results confirmed that the average density of warm asphalt concrete mixes drops with an increase in the content of the RTEP-M modifier in the mineral part, particularly at the dosage of 1% or more of the mass of mineral materials. The water saturation of warm asphalt concrete increases with an increase in the content of RTEP-M, but the value of the indicator remains within the permissible limits according to the regulatory requirements for hot asphalt concrete in compliance with GOST 9128-2009. The water resistance of warm asphalt concrete does not change significantly with the addition of a modifier up to 1 % by weight, remaining within the permissible limits according to regulatory requirements, and increases with the introduction of a modifier in the amount of 1.5 % or more of the mineral part.

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