UDC 625.8
DOI 10.36622/VSTU.2023.2.58.008

Yu. I. Kalgin [1], A. Alshahwan [2], N. I. Panevin [3]

STRUCTURAL AND MECHANICAL PROPERTIES OF MODIFIED HOT AND WARM MIX ASPHALT CONCRETE*

Voronezh State Technical University [1, 2, 3]
Russia, Voronezh

[1] *D. Sc. in Engineering, Prof. of the Dept. of Construction and Operation of Highways, e-mail: kalgin36@yandex.ru*
[2] *PhD student of the Dept. of Design of Construction and Operation of Highways, e-mail: alaaalaash@yahoo.com*
[3] *PhD in Engineering, Assoc. Prof. of the Dept. of Construction and Operation of Highways, e-mail: panevinn@mail.ru*

Statement of the problem. The problem of improving the structural and mechanical properties of hot and warm mix asphalt concrete based on mineral materials, produced by Ltd. «PavlovskNerud», Voronezh region, is considered, using the method of polymer-dispersed reinforcement. The effect of the modifier RTEP-M on the resistance of rutting for hot and warm mix asphalt concrete has been studied.
Results. By studying hot and warm mixes asphalt with RTEP-M modifier in the amount of 0.3 and 0.6 % by weight in the mineral part, respectively, and the control composition, a significant improvement in structural and mechanical properties was achieved. It is shown that it is possible to increase the resistance of rutting for hot and warm asphalt concrete prepared on local road construction materials by increasing its viscous-elastic properties by using the method of dispersed reinforcement using the Russian additive RTEP-M.
Conclusions. The efficiency of using the method of polymer-dispersed reinforcement to improve the structural and mechanical properties of hot and warm asphalt concrete based on local mineral materials has been proven. It is shown that the addition of the RTEP-M modifier to the mineral part of hot and warm asphalt concrete mix in the amount of 0.3 and 0.6 % by weight, respectively, improves the rutting resistance of the road surface. It has been proved that by applying the method of polymer-dispersed reinforcement, it is possible to optimize the properties of warm asphalt concrete for its use in hot climatic conditions for the introduction of warm technologies instead of hot ones in the construction and repair of road surfaces.

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

Introduction. Hot asphalt mixes are the most widely used type of asphalt concrete for paving, but they have a considerable number of disadvantages [1—20]. Among such is a large amount of consumed energy resources, high temperatures during the preparation and use of this type of asphalt concrete mixes, which is accompanied by greenhouse gas emissions, and dangerous working conditions for employees of asphalt concrete plants. These and other factors call for the expansion of the use of alternative technologies for the production of asphalt concrete mixes for road pavement [1, 2, 11]. The use of warm asphalt mixes, which have structural and mechanical properties that are not inferior to hot ones, is an effective way to substitute hot technologies.

Warm asphalt mixes are prepared at a temperature of 20—40 °C lower than that for the production of hot mixes, which is achieved through the use of methods to reduce the viscosity of the road bitu-

* Acknowledgements. The experimental studies have been carried out using the facilities of the Collective Research Center named after Professor Yu.M. Borisov, Voronezh State Technical University, which is partly supported by the Ministry of Science and Education of the Russian Federation, Contract No 075-15-2021-662.

men used. A negative factor in utilizing these methods is commonly the insufficient strength of asphalt concrete and the resistance to rutting of the road surface at high summer temperatures [2, 11]. An effective method for improving the resistance to rutting of the road surface and the structural and mechanical properties of asphalt concrete is polymer-dispersed reinforcement using RTEP as a modifier [2, 3, 5, 7, 9—11]. The RTEP-M polymer modifier is a well-known Russian additive to the mineral part of asphalt concrete, which contains recycled polyethylene, bitumen, mineral stabilizers and other available materials. RTEP-M is a modifier designed to produce polymer-dispersed-reinforced asphalt concrete for road construction (hereinafter — PDA-asphalt concrete, PDA-asphalt concrete mix). PDA-asphalt concrete has an increased resistance to compression and bending, as well as improved viscoelastic properties, which in combination result in a considerable increase in resistance to rutting.

1. Conducting an experiment to improve the resistance to rutting and structural and mechanical properties of hot and warm asphalt concrete prepared on mineral materials of JSC PavlovskNerud, Voronezh region. For the study, the A16VN asphalt concrete mix was adopted according to GOST R 58406.2-2020. The mineral part of this mixture was represented by mineral materials produced by OJSC PavlovskNerud: crushed granite M 1000 fractions 11.2—16 mm, 8—11.2 mm, 4—8 mm; sand from granite crushing screenings 0—4 mm. Limestone, non-activated mineral powder MP-1 was used. The mineral part of the asphalt concrete mixture is presented in Table 1.

Table 1

Grain composition of the mineral part of the asphalt concrete mix A16B$_H$

Content, % (bitumen over 100 %)	Grain composition (passed through a sieve with a hole, mm), % of the mass											
	16	11.2	8	5.6	4	2	1	0.5	0.25	0.125	0.063	Under 0.063
Name of the material												
Granite crushed stone fractioned 11.2—16 mm Ltd. Pavlovsk Nerud												
18	17.44	1.08	0.08	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.00
Granite crushed stone fractioned 8—11,2 mm Ltd. Pavlovsk Nerud												
24	24.00	20.19	1.74	0.15	0.11	0.10	0.10	0.10	0.09	0.09	0.07	0.00
Granite crushed stone fractioned 4—8 mm Ltd. Pavlovsk Nerud												
15	15.00	15.00	14.26	7.67	2.03	0.56	0.32	0.27	0.15	0.15	0.09	0.00
Sand from crushing waste fractioned 0—4 mm Ltd. Pavlovsk Nerud												
38	38.00	38.00	37.86	35.19	33.49	22.08	14.84	10.47	7.25	5.02	3.06	0.00
Mineral powder MP-1												
5	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.99	4.82	4.50	3.83	0.00
Maximum density line												
–	85.95	73.20	62.92	53.59	46.06	33.72	24.68	18.07	13.23	9.68	7.11	
Total												
100	99.44	79.27	58.93	48.04	40.66	27.77	20.28	15.84	12.34	9.78	7.06	0.00
Requirements GOST R 58406.2-2020 for A16Vn												
Min	90	70			37	25				7	5	
Max	100	85			58	40				20	10	

The control composition of the A16VN hot asphalt concrete mix on BND 70/100 bitumen was preliminarily prepared and tested. The main physical indicators of the control composition according to GOST R 58406.2-2020 are presented in Table. 2, performance indicators are in Table 3.

Table2

Physical indicators of asphalt concrete mixtures A16VN

Name of the index	Requirements GOST R 58406.2-2020 for A16B_H	Actual value of the indicator for the mix, modifier content in the mix		
		Hot one without a modifier	Hot one, 0.3 % RTAP-M by the mass	Warm one, 0.6 % RTAP-M by the mass
Volumetric density, g/cm^3	Not standard	2.38	2.37	2.36
Maximum density,g/cm^3	Not standard	2.49	2.47	2.47
Content of air vacuums, %	2.5—4.5	4.06	4.1	4.5
Vacuums in the mineral filler, %	No less than 12	15.86	–	–
Vacuums filled with the bitumen filler, %	67—80	75.41	–	–

Table 3

Performance indicators of asphalt concrete mixes A16VN

Name of the index	Requirements GOST P 58406.2-2020 for A16V_N	Actual value of the indicator for the mix, content modifier in the mineral part of the mixture, % by the mass		
		Hot one without a modifier	Hot one, 0.3 RTAP-M	Warm one, 0.6 RTAP-M
Average rut depth mm	Not over 4.5	5.81	3.41	3.52

It was found that the control composition A16BH does not meet the regulatory requirements in terms of the average rut depth, which is indicative of an insufficient resistance of the hot asphalt concrete of the control composition to rutting. This is a consequence of the insufficient level of structural and mechanical properties of hot asphalt concrete. The mineral part of the control composition of asphalt concrete A16VN corresponds to GOST R 58406.2-2020. It is thus possible to increase the resistance to rutting only by improving the viscoelastic properties by using the method of dispersed reinforcement. Hence two types of PDA-asphalt-concrete mix were prepared and tested: A16VN hot mix based on BND 70/100 bitumen with RTEP-M content in the mineral part in the amount of 0.3 % by weight; warm mixture A16BH on bitumen BND 70/100, diluted with diesel fuel to a conditional viscosity of 250 × 0.1 mm using the specified modifier 0.6 % by the mass. The amount of the RTEP-M modifier in the mineral part of the PDA mix was taken from the results of the analysis of the technical literature and the practice of using the method of dispersed reinforcement of asphalt concrete [3, 5, 7, 9—11]. The main physical parameters of the studied PDA-asphalt-concrete mixes A16VN according to GOST R 58406.2-2020 are presented in Table 2, performance indicators are in Table 3.

2. Proposals for improving the resistance to rutting and structural and mechanical properties of asphalt concrete prepared on domestic mineral materials and road bitumen grades BND. It is known [4, 6, 8] that the resistance to rutting of hot asphalt concrete is affected by a number of structure-forming factors, which, first of all, include the macrostructure of asphalt concrete, where, by increasing the content of crushed stone in the mineral part, it is possible to inexpensively and effectively improve mechanical parameters, and on the second in terms of the microstructure of the material, where the properties of the organic binder play a major role. Thus, the use of a more viscous grade of oil road bitumen also improves the structural and mechanical properties and resistance to rutting of hot asphalt concrete.

According to GOST R 58406.2-2020, the indicators of operational properties determine the quality and resistance to deformations of asphalt concrete in the road surface. The experiment showed significant difficulties in achieving the required indicators of operational properties of the control composition of hot asphalt concrete, which meets the regulatory requirements for the content of a mixture of mineral components in the mineral part using domestic viscous road bitumen grades BND. Thus, the above known structure-forming factors are not sufficiently effective to obtain the required resistance index of hot asphalt concrete to rutting.

Achieving the required values of resistance to rutting in accordance with GOST R 58406.2-2020 is possible by using polymer-bitumen binders instead of domestic petroleum bitumen grades BND (which will require more than 100 % rise in price of the organic binder used) or by using an inexpensive and effective method of polymer-dispersed reinforcement. According to the results of the experiment, a significant increase in resistance to rutting by dispersed reinforcement is achieved not only for hot, but also for warm asphalt concrete on a low-viscosity binder obtained by diluting BND 70/100 bitumen with diesel fuel to a conditional viscosity of 250 × 0.1 mm.

The use of the method of polymer-dispersed reinforcement expands the possibility of using a more efficient warm technology for the preparation of asphalt concrete mixes for the construction of road surfaces, including those in regions with a hot climate.

Conclusions

1. It has been established that hot and warm PDA-asphalt-concrete mixes A16VN based on mineral materials produced by OJSC PavlovskNerud, Voronezh region are characterized by increased resistance to rutting.
2. The use of the method of polymer-dispersed reinforcement of asphalt concrete based on the Russian modifier RTEP-M makes it possible to broadly use domestic mineral materials and viscous road bitumen grades BND for the preparation of hot asphalt concrete mixes that meet regulatory requirements, and pavement with an increased service life.
3. The experiment showed that it is possible to effectively optimize the structural and mechanical properties of warm asphalt concrete for its use, including in hot climatic conditions, instead of hot technologies in the construction and repair of road surfaces.

References

1. Alshakhvan A., Kalgin Yu. I. Aktual'nost' primeneniya teplykh asfal'tobetonnykh smesei dlya dorozhnogo stroitel'stva v usloviyakh siriiskoi arabskoi respubliki [The relevance of the use of warm asphalt concrete mixtures for road construction in the conditions of the Syrian Arab Republic]. *Vestnik BGTU im. V. G. Shukhova*, 2020, no. 2, pp. 26—33.
2. Alshakhvan A., Kalgin Yu. I. Uluchshenie strukturno-mekhanicheskikh svoistv teplogo asfal'tobetona metodom po-limerno-dispersnogo armirovaniya [Improvement of structural and mechanical properties of warm asphalt concrete by the method of polymer-dispersed reinforcement]. *Nauchnyi zhurnal stroitel'stva i arkhitektury*, 2021, no. 1 (61), pp. 33—61.
3. Iliopolov S. K., Mardirosova I. V. Vliyanie modifikatora RTEP i dobavki «VIATOP 66» na svoistva ShchMA [The influence of the RTEP modifier and the additive "VIATOP 66" on the properties of SHMA]. *Nauka i tekhnika v dorozhnoi otrasli*, 2010, no. 2, pp. 38—40.
4. Kalgin Yu. I., Strokin A. S., Tyukov E. B. *Perspektivnye tekhnologii stroitel'stva i remonta dorozhnykh pokrytii s prime-neniem modifitsirovannykh bitumov* [Promising technologies for the construction and repair of road surfaces with the use of modified bitumen]. Voronezh, Voronezhskaya oblastnaya tipografiya, 2014. 224 p.
5. Kalgin Yu. I. *Dorozhnye bitumomineral'nye materialy na osnove modifitsirovannykh bitumov* [Road bitumen-mineral materials based on modified bitumen]. Voronezh, Izd-vo Voronezh. gos. un-ta, 2006. 272 p.
6. Korolev I. V. *Dorozhnyi teplyi asfal'tobeton* [Road warm asphalt concrete]. Kiev, Vishcha shkola publ., 1975. 156 p.
7. Mardirosova I. V., Balabanov O. A., Chan N. Kh. Modifikatsiya asfal'tovyazhushchego kompleksnoi dobavkoi iz rezinovogo termo-elastoplasta (RTEP) i izvesti-pushonki [Modification of asphalt binder with a complex additive made of rubber thermo-elastoplast (RTEP) and lime-pushonki]. *Dorogi i Mosty*, 2010, no. 1, pp. 215—221.
8. Rudenskii A. V., Kalgin Yu. I. *Dorozhnye asfal'tobetonnye pokrytiya na modifitsirovannykh bitumakh* [Road asphalt concrete coatings on modified bitumen]. Voronezh, VGASU publ., 2009. 143 p.
9. Saraev D. S. Issledovanie protsessov stareniya asfal'tovyazhushchego, modifitsirovannogo rezino-vym termoelastoplastom (RTEP) i rezinovoi kroshkoi [Investigation of the aging processes of asphalt binder modified with rubber thermoplastic elastomer (RTEP) and rubber crumb]. *Izvestiya Rostovskogo gosudarstvennogo stroitel'nogo universiteta*, 2013, no. 17, p. 152.
10. Solomentsev A. B. Svoistva asfal'tovyazhushchego c dobavkami VIATOP 66 i RTEP [Properties of asphalt binder with VIATOP 66 and RTEP additives]. *Nauka i tekhnika v dorozhnoi otrasli*, 2009, no. 4, pp. 20—21.
11. Alshahwan A., Kalgin Yu. I. Improving the structural and mechanical properties of warm asphalt concrete by the method of polymer-disperse reinforcement. Russian Journal of Building Construction and Architecture, 2021, no. 2 (50), pp. 53—61.
12. Almeida-Costa A., Benta A. Economic and environmental impact study of warm mix asphalt compared to hot mix asphalt. *J. Cleaner Prod.*, 2016, no. 112, pp. 2308—2317.
13. Blankendaal T., Schuur P., Voordijk H. Reducing the environmental impact of concrete and asphalt: a scenario approach. *Cleaner Prod*., 2013, no. 66, pp. 27—36.
14. Capitão S. D., Picado-Santos L. G., Martinho F. Pavement engineering materials: Review on the use of warm-mix asphalt. *Constr. Build. Mater*., 2012, no. 36, pp. 1016—1024.
15. Jamshidi A., Hamza M. O., You Z. Performance of Warm Mix Asphalt containing Sasobit: State-of-the-art. *Construction and Building Materials*, 2013, no. 38, pp. 530—553.
16. Omari I., Aggarwal V., Hesp S. Investigation of two Warm Mix Asphalt additives. *International Journal of Pavement Research and Technology*, 2016, no. 9, pp. 83—88.
17. Silva H. M. R. D., Oliveira J. R. M., Peralta J., Zoorob S. E. Optimization of warm mix asphalts using different blends of binders and synthetic paraffin wax contents. Construction and Building Materials, 2010, no. 24, pp. 1621—1631.
18. Vidal R., Moliner E., Martínez G., Rubio M. C. Life cycle assessment of hot mix asphalt and zeolite-based warm mix asphalt with reclaimed asphalt pavement. *Conserv. Recycl*, 2013, no. 74, pp. 101—114.
19. Zaumanis M. *Warm Mix Asphalt Investigation: Thesis*. Riga Technical University, 2010, p. 185.
20. Zhao G., Guo P. Workability of Sasobit Warm Mixture Asphalt. *2012 International Conference on Future Energy, Environment, and Materials*, 2012, no. 16, pp. 1230—1236.