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EFFECT OF MODIFIED BITUMEN ON PHYSICO-MECHANICAL PROPERTIES OF ASPHALT CONCRETE

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Abstract. The investigation results of type B fine asphalt concrete and its form modified by rapeseed oil epoxide are represented. The efficiency of ERO addition and its positive effect on the physico-mechanical properties of asphalt concrete has been established.

Keywords: asphalt concrete, modifier, epoxide, bitumen, strength, water resistance.

1. Introduction

Taking into account the increase of traffic in Ukraine, as well as poor condition of the roads, it is necessary to raise the requirements for asphalt concrete (AC) and its components. Road bitumen is one of the main components of AC. Bitumen produced at the Ukrainian plants does not meet the modern requirements. Low quality bitumen causes the occurrence of pot-holes, cracks, fracturing pattern, *etc*. on the coating surface. The occurred destructions significantly affect vehicle driving, causing emergency and dangerous situations. Moreover, they are the reason of frequent repair works on roads, which further reduces the safety and creates inconvenience for the passage of vehicles [1].

Since the quality of asphalt concretes depends on the quality of bitumen, which is the basis for AC production, it is necessary to pay attention to the properties of asphalt concrete based on modified bitumen. Polymers and latexes of different types, synthetic waxes (low-molecular modifiers), natural asphalt, fiberglass and others are among the additives that improve the quality of asphalt and may be introduced into the bitumen composition or fed directly to the asphalt mixer. Thus, the guarantee of AC quality is one of the priorities in the road industry [2].

However, despite the relative simplicity of AC application, the behavior of modified asphalt layers has not been sufficiently investigated. Regardless of the fact that they are widely used in Ukraine, their application is based on some physical and mechanical properties that do not allow to verify the feasibility of their use [2].

According to the literature data analysis, the modification of bitumen by polymers has been studied quite thoroughly. The use of epoxy compounds is the most promising direction. Previously we determined that bitumen modification by epoxy rapeseed oil (ERO) improves bitumen qualitative characteristics, such as penetration, softening temperature, ductility, adhesion, *etc*. [3]. EPO is produced *via* rapeseed oil epoxidation.

Therefore, the aim of this work was to study the effect of bitumen modified by ERO on the physico-mechanical properties of asphalt concrete.

2. Experimental

Pure road bitumen BND 90/130 and bitumen modified by ERO in the amount of 3 wt % were used as initial materials at 463 K for 300 min. Such a choice should demonstrate a clear difference between non-modified and modified bitumen and ERO effect on the improvement of AC characteristics. The ERO effect on bitumen properties is represented in Table 1.

The mineral part of AC mixture corresponds to the B25 grading. In accordance with [4] it is hot, fine-grain, dense mixture of B type with continuous grading, I type, based on BND 90/130.

To study the efficiency of ERO addition we selected two AC mixtures similar by grain size (Fig. 1) with the maximum size of aggregates 20 mm according to [4].

Table 1

Physico-mechanical properties of bitumen modified by ERO

Index	BND 90/130	BND 90/130 + 3 wt % ERO
Softening temperature by "ring and ball" method, K	318	322
Penetration at 298 K, $m \cdot 10^{-4}$ (0.1 mm)	95	85
Ductility at 298 K, $m \cdot 10^{-2}$ (cm)	133	132
Adherence with glass, adhesion, %	95	92

Table 2

Physico-mechanical properties of fine asphalt concrete

Index	For asphalt concrete based on:		
	BND 90/130 in accordance with standard	BND 90/130	BND 90/130 modified by ERO
Bitumen content, %	–	6.2	6.2
Water saturation, vol %	up to 2.5	0.49	0.51
Average density, g/cm^3	–	2.4	2.4
Ultimate strength, MPa, at			
293 K	not less than 2.9	5.2	8.1
323 K	not less than 1.4	1.8	3.8
Water resistance factor	not less than 0.91	0.91	0.97

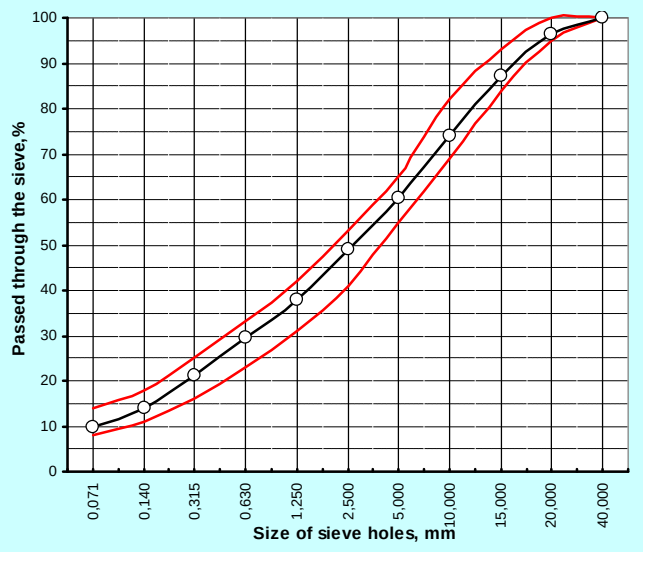

Fig. 1. Grain size composition of the mineral part of dense fine asphalt concrete of B25 type with continuous grading

Fig. 2. Photograph of the samples

Physico-chemical properties of AC mixture were determined using cylindric samples (D = 71.4 mm, h = 71.4 ± 1.5 mm) obtained under the laboratory conditions by means of mixtures compaction in the standard form (Fig. 2).

After samples formation on the basis of standard and modified bitumen we determined their physico-mechanical characteristics in order to study the change in properties of AC modified by ERO. All investigations were carried out according to the standards.

The results demonstrate that ERO is suitable for use as bitumen modifier. It improves the AC properties and meets the demands for petroleum viscous modified bitumen BMP-90/130-49 [5]. The introduction of 3 % modifier into bitumen increases the AC strength by half at 293 K and doubles it – at 323 K compared with the

non-modified AC (Table 2). This fact indicates that they are characterized by higher thermal stability and coatings on their basis will have higher track stability under working conditions. The AC water resistance factor is equal to 0.97.

The bitumen modification by ERO is technologically simple process and needs the same equipment and technology necessary while using other modifiers (Elvaloi, Kraton D, *etc*.), i.e.:

1. Bitumen heating to 453–463 K.

2. Gradual and regular introduction of 2–5 % of ERO under constant stirring of the binding agent.

3. After the additive introduction, the intensive mixing of bitumen with ERO for a definite time.

It is known from the literature that there are a lot of additives for bitumen modification. Generally they are good modifiers and characterized by high physico-mechanical properties but their cost is also high. The most popular are additives of SBS type: Kraton D (Kraton Polimers company) and Calprene (Dynasol company). The synthetic latexes of Butonal NS type (BASF company) and thermopolymers of Elvaloy type (DuPont company) are widely used in Ukraine.

All the mentioned additives reduce bitumen sensibility to the temperature change, increase cohesion strength and thermal stability of the binding agent, strengthen their elasticity and improve their behavior at low temperatures. The result is the increase of AC ultimate strength, resistance to crack formation and shear strength.

The high cost of modifiers is the main reason restraining the amount of used asphalt concrete based on modified bitumen. The introduction of modifier into bitumen increases the binding agent cost 1.5–2.5 times. The use of cheaper polymers does not reduce the cost because in such a case their greater amount is needed (5–7 %). Moreover, cheap additives do not guarantee such necessary properties as elasticity, high thermal stability, increasing plasticity, and stress-strain behavior at low temperatures, *etc*. [6].

Taking into account all the mentioned above we compared the properties of AC modified by ERO and asphalt concretes modified by other modern additives (Table 3).

On the basis of the obtained results we may assert that ERO:

- allows to improve the qualitative characteristics of road bitumen (penetration, softening temperature, ductility, and adhesion; see Table 1);
- is relatively simple in use;
- allows to improve the AC properties (durability and water resistance);
- meets all demands and standards and may be used as a modifier for road bitumen;
- can compete with modern foreign analogues.

Table 3

Physico-mechanical properties of asphalt concrete modified by different additives

Index	Additive			
	ERO	Polydom	Kraton D 1101	Elvaloy
Additive content in bitumen, %	3	3	3	3
Bitumen content in AC, %	6.2	6.2	6.3	6.3
Water saturation, vol %	0.51	1.1	1.17	0.97
Average density, g/cm^3	2.40	2.42	2.49	2.48
Ultimate strength, MPa, at				
293 K	8.1	5.8	4	4.45
323 K	3.8	2.8	1.32	1.41
Water resistance factor	0.97	1.0	–	–

4. Conclusions

The experimental results show high efficiency of ERO additive and its essential effect on the ultimate strength and durability of road coatings on the basis of modified AC. The comparison of different asphalt concretes with various additives indicates high efficiency of the bitumen modified by ERO.

Such bitumen meets all standards [5] and its characteristics (especially strength and water resistance) are better as compared to the non-modified ones.

References

[1] Besarab O., Prokopenko Yu., Khrystych M. and Mozgovyi V.: Bezpeka Dorogn. Rukhu Ukrainy, 1999, **5**, 15.

[2] Zhdanyuk V., Kostin D. and Volovyk O.: Naukovo-Vyrovbychyi Zh., 2011, **223**, 38.
[3] Grynchuk Yu. and Nykypanchuk M.: Visnyk Nats. Univ. Lviv. Polytechn., 2011, **700**, 474.
[4] Sumishi Asphaltbetonni i Asphaltobeton Dorogniy i Aerodromnyi. Technichni Umovy: DSTU B V.2.7-119-2011. Kyiv 2012.
[5] Budivelni Materialy. Bitumy Dorogni Modifikovani Polimeramy. Technichni Umovy: DSTU B V.2.7-135:2007.
[6] http://www.mnt.ee/bra/conference27/papers/27BRC_AA_Kishchinsky.pdf
[7] Rudenskyi A. and Nikonova O.: Mosty i Dorogi, 2011, **26**, 287.

ВПЛИВ МОДИФІКОВАНИХ БІТУМІВ НА ФІЗИКО-МЕХАНІЧНІ ВЛАСТИВОСТІ АСФАЛЬТОБЕТОНУ

Анотація. *Наведені результати досліджень властивостей дрібнозернистого асфальтобетону типу Б та його модифікованої епоксидом ріпакової олії (ЕРО) форми. Встановлено ефективність дії добавки ЕРО та її позитивний вплив на фізико-механічні властивості асфальтобетону.*

Ключові слова: *асфальтобетон, модифікатори, епоксид, бітум, міцність, водостійкість.*