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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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MAIN STANDARD INDICATORS OF POLYMER ASPHALT CONCRETES

Abstract. The main indicators of 29 types of asphalt and polymer asphalt concretes prepared with the use of neat bitumens of 2 grades and 7 types of polymer bitumens have been determined and comparatively analyzed in the work. The bitumens of grades BND 100/130 and BND 130/200 produced by the Pavlodar petrochemical plant have been selected for preparation of the asphalt concretes, polymer bitumens and polymer asphalt concretes. 7 types of the polymers (Elvaloy 4170, Elvaloy AM, Kraton D 1192A, Calprene 501, SBS L 30-01 A, KUMHO KTR, Butonal NS 198) have been selected for the modification of the bitumens. Short procedure has been represented for the preparation of the polymer bitumens. 29 types of the asphalt and the polymer asphalt concretes have been prepared with the use of the above bitumens and polymer bitumens (asphalt concrete of type A - 7, asphalt concrete of type B - 15, stone mastic asphalt concrete SMA-15 - 1, stone mastic asphalt concrete SMA-20 - 6).

The following main indicators of quality have been determined for the asphalt concretes and polymer asphalt concretes by testing in relevant laboratory devices: 1) rut depth at the temperature of 60 °C after 10 000 passages of the wheel (ST RK EN 12697-22-2012); 2) tensile strength at the temperature of -30 °C (pr. EN 12697-46-2012); 3) compression strength at the temperature of 50 °C (ST RK 1218-2003); 4) water saturation (ST RK 1218-2003).

It is found out that the modification of the bitumens with the polymers increases essentially the main standard indicators of the asphalt concretes: rutting resistance, strength at high temperatures and low temperatures, resistance to the cyclic freezing and thawing (frost resistance). The reactive polymers Elvaloy 4170 and Elvaloy AM are the most efficient among the used ones.

Key words: Bitumens, polymers, asphalt concretes, polymer asphalt concretes, standard indicators.

1. Introduction. At present in Kazakhstan, as well as in many countries of the world, quality of road bitumens and asphalt concretes is evaluated separately in accordance with the requirements of the current standard and technical base [1, 2]. Meanwhile, it is important to bear in mind that an asphalt concrete rather than a bitumen is a final material used in a road structure. The bitumen is one of the components of the asphalt concrete. However, preliminary evaluation of quality of the bitumen and other used materials facilitated essentially the design of the optimal composition of the asphalt concrete – a final product.

It follows from the above that the problem of efficiency for the use of bitumens and polymers should be finally solved only after determination and analysis of the indicators of quality for the relevant asphalt concretes and polymer asphalt concretes.

This work determines and analyzes comparatively the main standard indicators of 29 types of the asphalt concretes and polymer asphalt concretes prepared with the use of neat bitumens of 2 grades and 7 types of polymer bitumens.

2. Materials

2.1. Bitumens. The bitumens of grades BND 100/130 and BND 130/200 produced by the Pavlodar petrochemical plant have been selected for preparation of asphalt concretes, polymer bitumens and polymer asphalt concretes. The indicators of quality for these bitumens satisfy the requirements of the standard ST RK 1373-2013 [1].

2.2. Polymers. 7 types of polymer compositions belonging to two different groups have been selected for modification of bitumens (table 1).

Table 1 – Polymer compositions

Description	Group	Producer	Country
Elvaloy 4170 Elvaloy AM	Elastomeric copolymer	Dow Corporate	USA
Kraton D 1192A	Linear block copolymer	USA Headquarters	USA
Calprene 501	Linear block copolymer	Dynasol Group	USA
SBS L 30-01 A	Linear block copolymer	SIBUR	Russia
KUMHO KTR	Linear block copolymer	Kumho Petrochemical Co. LTD	South Korea
Butonal NS 198	Cation water dispersion copolymer	BASF Trading Company GmbH	Germany

2.3. Polymer bitumen preparation. Preparation of polymer bitumens with the use of the neat bitumens produced by the plants has been performed in the laboratory of Kazakhstan Highway Research Institute (KazdorNII). Mixer of model IKAEUROSTAR 20 DIGITAL has been used for this purpose the paddle of which is rotating with the constant rate of 2000 rotations per minute.

The preparation of the polymer bitumens has been performed in the following technological order:

1) neat bitumen was heated up to the temperature of 175-180 °C in the mixer;

2) an amount of polymer selected before was added gradually and regularly into a heated neat bitumen;

3) the mixture of bitumen and polymer has been mixed in a continuous manner and regularly for 2 hours.

As for the polymers Elvaloy 4170 and Elvaloy AM, the obtained homogeneous mix of the bitumen and the polymer for the following 12 hours has been at the constant temperature of 175-180 °C for complete carrying-out of chemical reactions between components of the bitumen and the polymers of grade Elvaloy.

The indicators of quality for the prepared polymer bitumens satisfy the requirements of the standard ST RK 2534-2014 [4].

2.4. Polymer asphalt concretes. 29 types of the asphalt concrete and polymer asphalt concrete (asphalt concrete of type A – 7, asphalt concrete of type B – 15, stone mastic asphalt concrete SMA-15 – 1, stone mastic asphalt concrete SMA-20 - 6) have been prepared with the use of the above bitumens and polymer bitumens. The data regarding the prepared and tested asphalt concretes and polymer asphalt concretes are represented in table 2.

The indicators of quality for the prepared asphalt concretes and polymer asphalt concretes satisfy the requirements of the standards ST RK 1225-2019 [2], ST RK 1223-2019 [4], GOST 31015-2002 [5] and ST RK 2373-2019 [6].

Table 2 – Data regarding the prepared and tested asphalt concretes and polymer asphalt concretes

No	Type of asphalt concrete	Bitumen grade	Description of modifier	Amount of modifier, %	Contracted notation
1	Asphalt concrete fine-grained type B	BND 100/130	–	–	PNHZ_100-130_B
2		BND 100/130	Elvaloy 4170	1.4	PNHZ_100-130_B+Elvaloy1
3		BND 100/130	Elvaloy AM	2.0	PNHZ_100-130_B +Elvaloy2
4		BND 100/130	Kraton	4.0	PNHZ_100-130_B +Kraton
5		BND 100/130	Calprene 501	4.0	PNHZ_100-130_B +Calprene
6		BND 100/130	Butonal NS 198	3.0	PNHZ_100-130_B +Butonal
7		BND 100/130	SBSL 30-01 A	3.0	PNHZ_100-130_B +SBS
8		BND 100/130	KUMHO KTP	3.0	PNHZ_100-130_B +KUMHO1
9		BND 100/130	KUMHO KTP	6.0	PNHZ_100-130_B +KUMHO2
10		BND 130/200	Elvaloy 4170	1.8	PNHZ_130-200_B +Elvaloy1
11		BND 130/200	Elvaloy AM	2.2	PNHZ_130-200_B +Elvaloy2
12		BND 130/200	Kraton	6.0	PNHZ_130-200_B +Kraton
13		BND 130/200	Calprene 501	6.0	PNHZ_130-200_B +Calprene
14		BND 130/200	Butonal NS 198	3.5	PNHZ_130-200_B +Butonal
15		BND 130/200	SBSL 30-01 A	5.0	PNHZ_130-200_B +SBS
16	Asphalt concrete fine-grained type A	BND 100/130	–	–	PNHZ_100-130_A
17		BND 130/200	Elvaloy 4170	1.6	PNHZ_130-200_A +Elvaloy1
18		BND 130/200	Elvaloy AM	2.2	PNHZ_ 130-200_A +Elvaloy2
19		BND 130/200	Kraton	4.0	PNHZ_130-200_A+Kraton
20		BND 130/200	Calprene 501	5.0	PNHZ_130-200_A+Calprene
21		BND 130/200	Butonal NS 198	3.5	PNHZ_130-200_A +Butonal
22		BND 130/200	SBSL 30-01 A	4.0	PNHZ_130-200_A +SBS
23	Asphalt concrete stone mastic SMA-15	BND 100/130	–	–	PNHZ_100-130_SMA15
24	Asphalt concrete stone mastic SMA-20	BND 100/130	–	–	PNHZ_100-130_SMA20
25		BND 130/200	Elvaloy 4170	1.7	PNHZ_130-200_SMA20+Elvaloy1
26		BND 130/200	Calprene 501	5.0	PNHZ_130-200_SMA20+Calprene
27		BND 130/200	SBSL 30-01 A	5.0	PNHZ_130-200_SMA20+SBS
28		BND 130/200	Butonal NS 198	3.5	PNHZ_130-200_SMA20+Butonal
29		BND 130/200	Kraton	5.0	PNHZ_130-200_SMA20+Kraton

3.Methods

3.1. Rut depth at the temperature of 60 °C after 10 000 wheel passages. It is determined under the standard ST RK EN 12697-22-2012 [7] in the device ‘Hamburg wheel”. It characterizes the resistance of asphalt concretes to the rutting in a hot season of the year at the frequent repeated passages of heavy trucks. The less the rut size is the more resistant this type of the asphalt concrete is considered to be. Comparison of the rut sizes obtained for a number of the asphalt concretes gives an opportunity to determine the most resistant ones to the rutting among them.

3.2. Tensile strength at the temperature of -30 °C. This indicator is determined under the standard pr. EN 12697-46-2012 [8] and it characterizes the strength of asphalt concretes at low temperatures. In other words, this indicator gives an opportunity to perform the comparative evaluation for the resistance to the low temperature cracking in asphalt concrete pavements in cold regions.

3.3. Compression strength at the temperature of 50 °C. This indicator is determined under the standard ST RK 1218-2003 [9] and it characterizes the strength of asphalt concretes at high temperatures.

3.4. Water saturation. It is determined under the standard ST RK 1218-2003 [9]. It is considered that the asphalt concretes with the lower value of water saturation are more resistant to the cyclic freezing and thawing.

4. Results and discussion

4.1. Rut depth at the temperature of 60 °C after 10 000 wheel passages. It is clearly seen from Figure 1 that, as a rule, non-modified (neat) bitumens are the weakest resistant to rutting. Modification of bitumens decreases essentially the size of the rut. Big (by several times) increase of the rutting resistance for the asphalt concretes occurs in cases of bitumen modifications with the polymers Elvaloy 4170 and Elvaloy AM. For example, the decrease of the rut size for the asphalt concretes with the polymers Elvaloy 4170 and Elvaloy AM for the asphalt concretes of types A and B was by 3-5 and 2-3 times respectively.

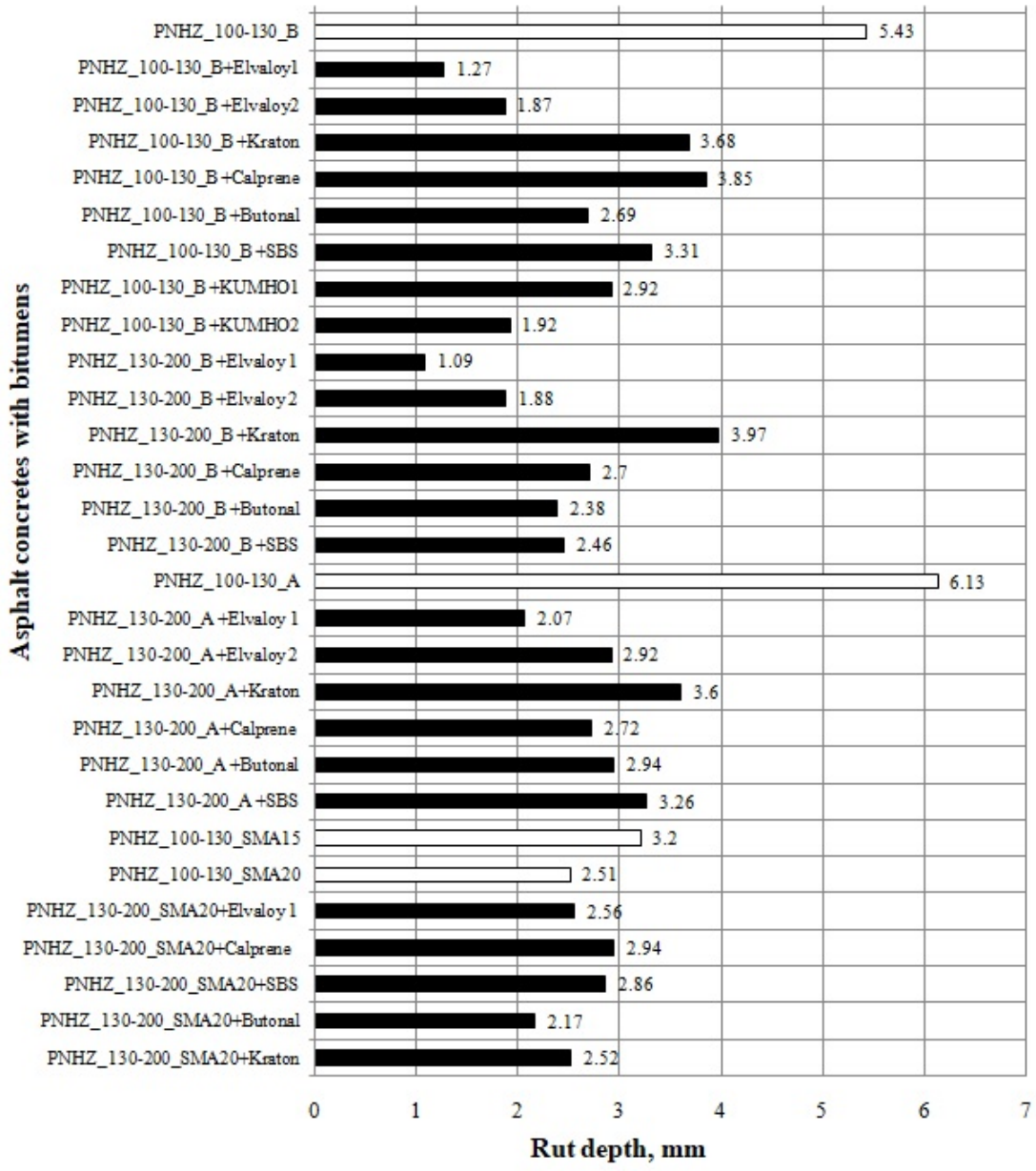

Figure 1 – Rut depth on the asphalt concrete samples at 60 °C after 10 000 wheel passages

4.2. Tensile strength at the temperature of -30 °C. As it is seen from figure 2, the modification of the bitumens with the polymers increases its low temperature strength. Meanwhile, the asphalt concretes with the polymers Elvaloy 4170, Elvaloy AM and KUMHO (3%) have the largest effect. For example, the strength of the asphalt concrete of type B with the bitumen of grade BND 130/200 and the polymer Elvaloy AM has been increased by 2.09 times compared with the conventional asphalt concrete of type B with the bitumen of grade BND 100/130. And the strength increase of the asphalt concrete of type B with the bitumen of grade BND 100/130 with this polymer has been 1.73 times. The addition of the polymer KUMHO (3%) into the bitumen of grade BND 100/130 specified the increase of the low temperature strength for the asphalt concrete of type B by 1.84 times.

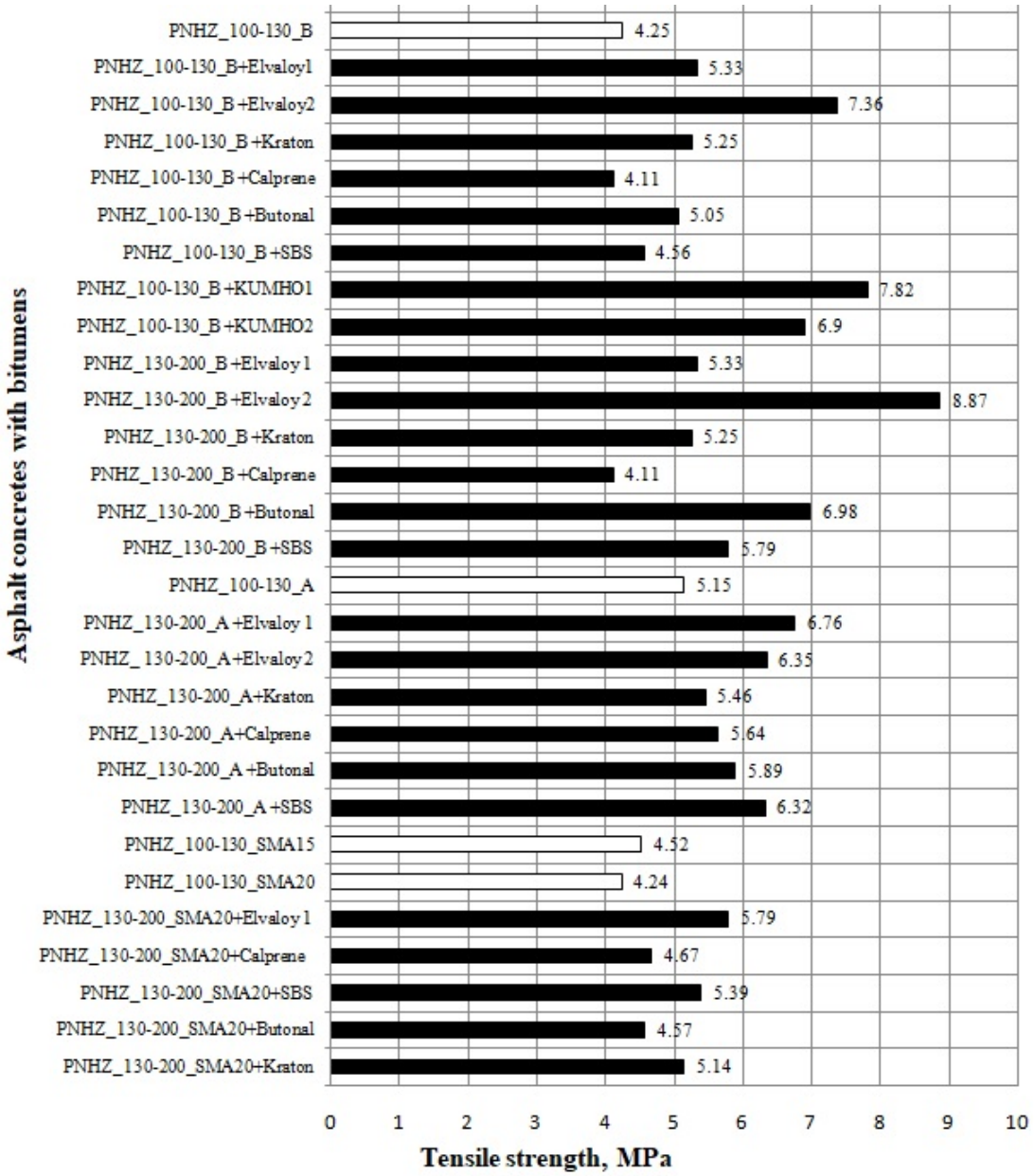

Figure 2 – Tensile strength of the asphalt concretes at the temperature of -30 °C

4.3. Compression strength at the temperature of 50 °C. It is found out that the modification of the bitumens with the polymers increases essentially the high temperature (at +50°C) compression strength of the asphalt concretes as well (figure 3). The polymers Elvaloy 4170, Elvaloy AM, Calprene 501 and

KUMHO (6 %) have proved to be the most efficient for the asphalt concretes of type B, and Elvaloy 4170 and Elvaloy AM proved to be the most efficient for the asphalt concretes of type A. The strength increases for the asphalt concretes of types A and B, the stone mastic asphalt concretes were 47.5- 96.7 %, 44.9-88.4 % and 60.6-97.2 % respectively.

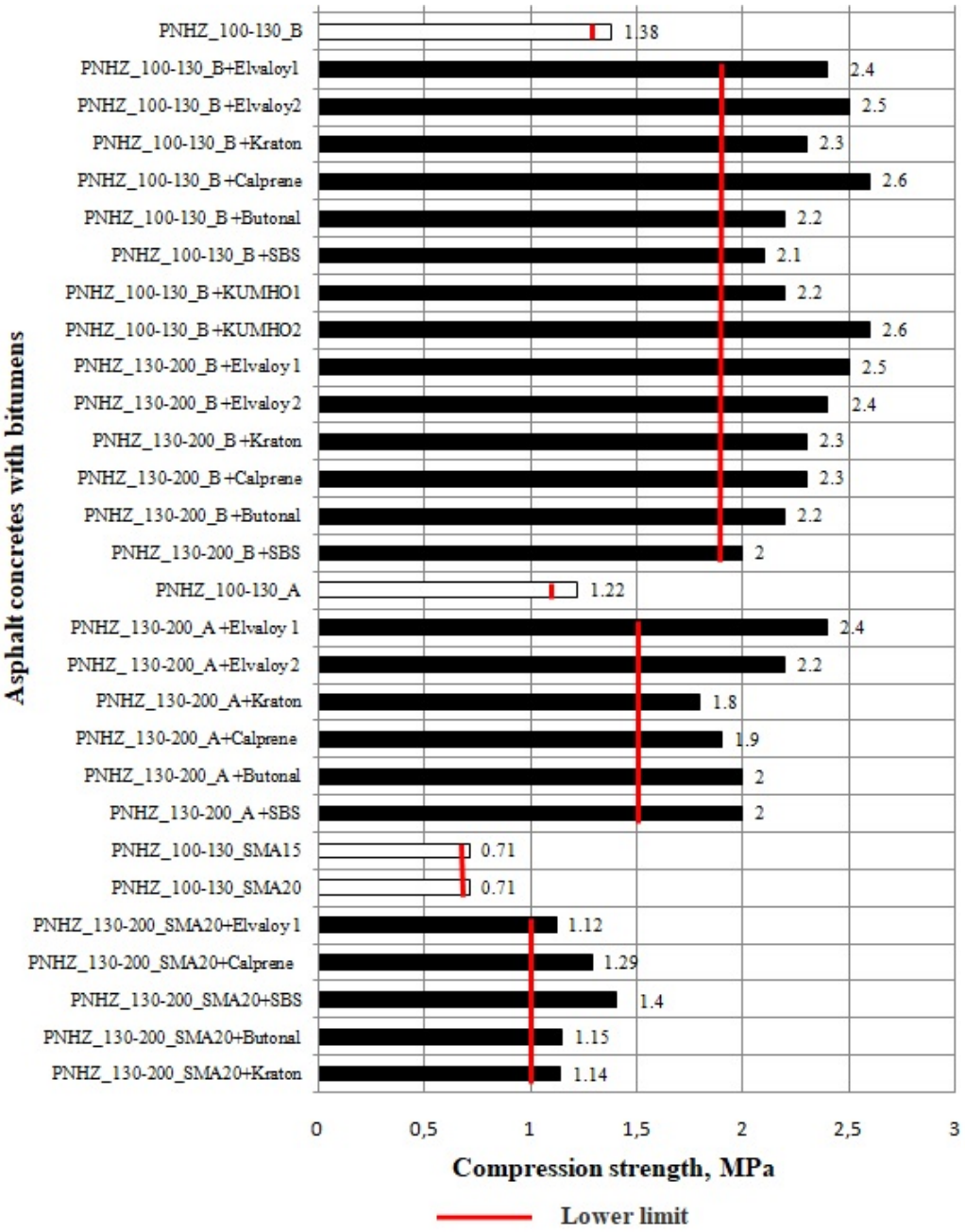

Figure 3 – Compression strength of the asphalt concretes at the temperature of 50 °C

4.4. Water saturation. Test results have shown (figure 4) water saturation of the asphalt concretes is essentially improved practically in all the considered cases for the modification of the bitumens. Meanwhile, as it is seen, some differences occur depending on the type of the asphalt concrete. For example, the water saturation decreases for the asphalt concretes of types B and A, stone mastic asphalt concrete SMA-20 were 1.3-2.3; 1.14-1.32 and 1.39-2.13 times.

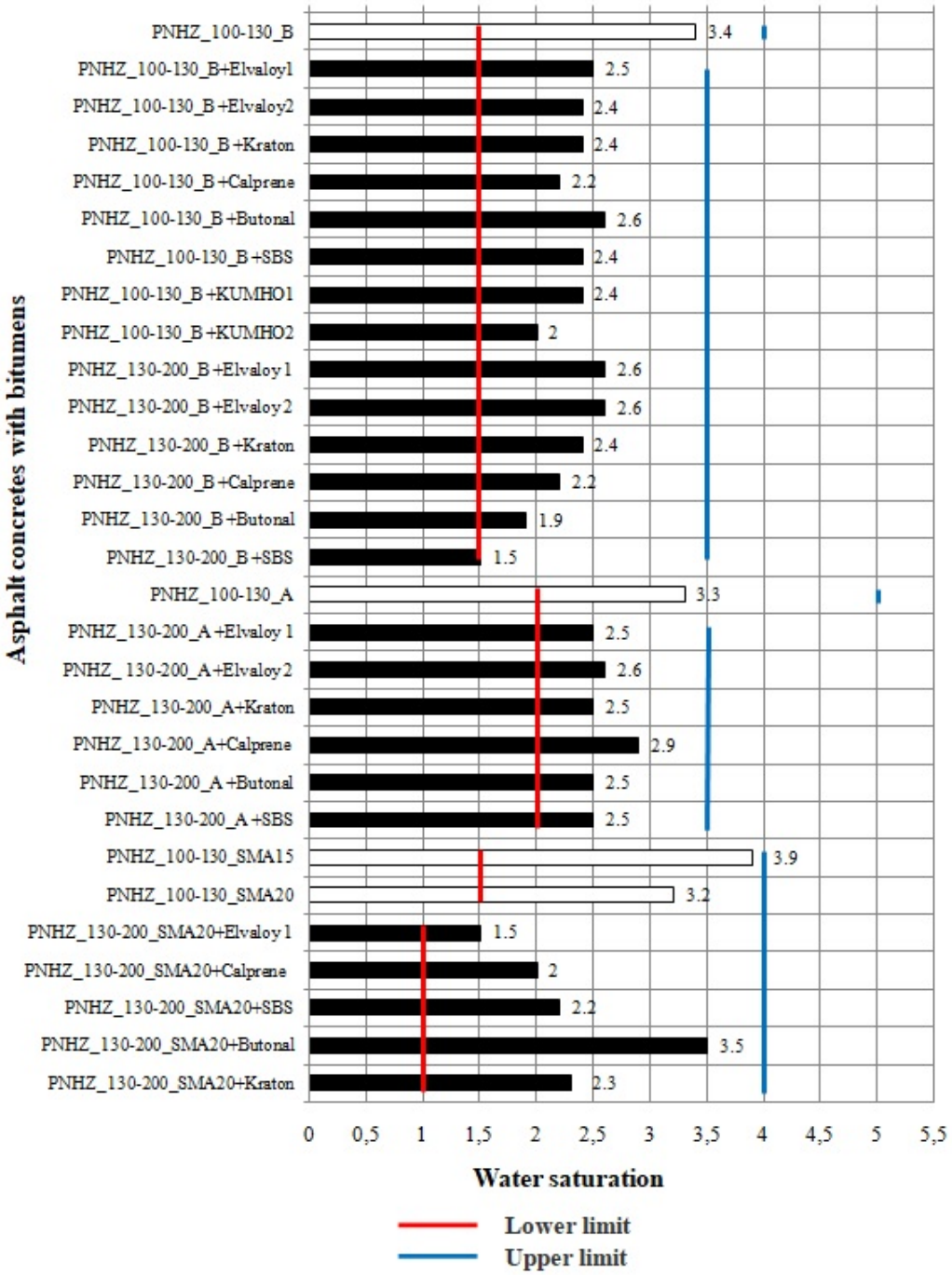

Figure 4 – Water saturation of the asphalt concretes

Conclusion. Based on the results of the comparative analysis for the main standard indicators of the tested asphalt concretes and polymer asphalt concretes one can draw the following conclusions:

1. The modification of the bitumens with the polymers increases essentially the main standard indicators of the asphalt concretes: rutting resistance, strength at high and low temperatures, resistance to cyclic freezing and thawing (frost resistance).

2. The reactive polymers Elvaloy 4170 and Elvaloy AM are the most efficient among the used ones.

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ПОЛИМЕРАСФАЛЬТОБЕТОНДАРДЫҢ НЕГІЗГІ СТАНДАРТТЫҚ КӨРСЕТКІШТЕРІ

Аннотация. Бұл жұмыста 2 маркалы таза битум және полимербитумдардың 7 түрін қолдана отырып дайындалған асфальтбетондар мен полимерасфальтобетондардың 29 түрінің негізгі стандарттық көрсеткіштері анықталды және салыстырмалы түрде талданды. Асфальтбетондар, полимербитумдар және полимерасфальтбетондарды дайындау үшін Павлодар мұнай-химия зауытында (ПМХЗ) өндірілген МЖБ 100/130 және МЖБ 130/200 маркалы битумдар таңдалды. Таңдалған битумдардың сапа көрсеткіштері ҚР СТ 1373-2013 стандартының талаптарын қанағаттандырады. Битумды модификациялау үшін полимерлердің 7 түрі таңдалды (Elvaloy 4170, Elvaloy AM, Kraton D 1192A, Calprene 501, SBS L 30-01 A, KUMHO KTR, Butonal NS 198). Зертханалық жағдайда полимербитумдарды дайындаудың қысқаша әдістемесі келтірілген. Аталған битумдар мен полимербитумдарды қолдану арқылы асфальтбетон мен полимерасфальтобетонның 29 түрі (А типті асфальтбетон - 7, Б типті асфальтбетон - 15, шағыл тасты мастикалық асфальтбетон ШМА-15 - 1, шағыл тасты мастикалық асфальтбетон ШМА-20 - 6) дайындалды. Асфальтбетондар мен полимерасфальтобетондар сапасының көрсеткіштері ҚР СТ 1225-2019, ҚР СТ 1223-2019, МЕМСТ 31015-2002, ҚР СТ 2373-2019 стандарттарының талаптарын қанағаттандырады.

Тиісті зертханалық қондырғыларда сынау арқылы асфальтбетондар мен полимерасфальтобетондар сапасының мынадай негізгі көрсеткіштері анықталды: 1) 60 °С температурада доңғалақтың 10 000 рет жүріп өтуінен кейін пайда болған сораптың тереңдігі (ҚР СТ EN 12697-22-2012); 2) -30 °С температурада созылудағы беріктік (pr. EN 12697-46-2012); 3) 50 °С температурада сығудағы беріктік (ҚР СТ 1218-2003); 4) сумен қанығу (ҚР СТ 1218-2003).

Битумдарды полимерлермен модификациялау асфальтбетондардың негізгі стандарттық көрсеткіштерін едәуір арттыратыны анықталды: сораптарға төзімділік, жоғары және төмен температуралардағы беріктік, циклдік тоңу және еруге төзімділік (аязға төзімділік). Пайдаланылғандардың ішінде ең тиімдісі - Elvaloy 4170 және Elvaloy AM реактивтік полимерлері.

Түйін сөздер: Битумдар, полимерлер, асфальтобетондар, полимерасфальтобетондар, стандарттық көрсеткіштер.

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ОСНОВНЫЕ СТАНДАРТНЫЕ ПОКАЗАТЕЛИ ПОЛИМЕРАСФАЛЬТОБЕТОНОВ

Аннотация. В настоящей работе определены и сравнительно проанализированы основные стандартные показатели 29-и видов асфальтобетонов и полимерасфальтобетонов, приготовленных с применением чистых битумов 2-х марок и 7-и видов полимербитумов. Для приготовления асфальтобетонов, полимербитумов и полимерасфальтобетонов были выбраны битумы марок БНД 100/130 и БНД 130/200, произведенные Павлодарским нефтехимическим заводом (ПНХЗ). Показатели качества выбранных битумов удовлетворяют требованиям стандарта СТ РК 1373-2013. Для модифицирования битумов были выбраны 7 видов полимеров (Elvaloy 4170, Elvaloy AM, Kraton D 1192A, Calprene 501, SBS L 30-01 A, KUMHO KTR, Butonal NS 198). Изложена краткая методика приготовления полимербитумов в лабораторных условиях. С применением указанных битумов и полимербитумов было приготовлено 29 видов асфальтобетона и полимерасфальтобетона (асфальтобетон типа А – 7, асфальтобетон типа Б – 15, щебеночно-мастичный асфальтобетон ЩМА-15 – 1, щебеночно-мастичный асфальтобетон ЩМА-20 – 6). Показатели качества асфальтобетонов и полимерасфальтобетонов удовлетворяют требованиям стандартов СТ РК СТ РК 1225-2019, СТ РК 1223-2019, ГОСТ 31015-2002, СТ РК 2373-2019.

Путем испытания в соответствующих лабораторных установках были определены следующие основные показатели качества асфальтобетонов и полимерасфальтобетонов: 1) глубина колеи при температуре 60 °С после 10 000 проходов колеса (СТ РК EN 12697-22-2012); 2) прочность при растяжении при температуре -30 °С (pr. EN 12697-46-2012); 3) прочность при сжатии при температуре 50 °С (СТ РК 1218-2003); 4) водонасыщение (СТ РК 1218-2003).

Установлено, что модификация битумов полимерами существенно повышает основные стандартные показатели асфальтобетонов: колееустойчивость, прочность при высоких и низких температурах, устойчивость к циклическим замораживаниям и оттаиваниям (морозостойкость). Среди использованных наиболее эффективными являются реактивные полимеры Elvaloy 4170 и Elvaloy AM.

Ключевые слова: битумы, полимеры, асфальтобетоны, полимерасфальтобетоны, стандартные показатели.

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