N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 6, Number 444 (2020), 261 – 267 **https://doi.org/10.32014/2020.2518-170X.155**

UDC 691.16

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COMPARATIVE ANALYSIS OF LOW TEMPERATURE STRENGTH OF MODIFIED ASPHALT CONCRETES

Abstract. A comparative analysis has been performed in this work for low temperature strength of 31 types of the conventional (non-modified) and modified road asphalt concretes. The neat bitumens of the grades BND 70/100, BND 100/130 and BND 130/200 have been produced by the Pavlodar petrochemical plant from the crude oil of the Western Siberia (Russia) by the method of direct oxidation and they satisfy the requirements of the standard ST RK 1373-2013. The polymers Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS, SBS (L 30-01 A), KUMHO KTP and crumb rubber have been used for the modification of the bitumens. The modification of the bitumens has been performed in the laboratory of Kazakhstan Highway Research Institute. The modified bitumens satisfy the requirements of the standard ST RK 2534-2015. The conventional and modified asphalt concretes satisfy the requirements of the standards ST RK 1225-2019, ST RK 1223-2019, ST RK 2028-2010, ST RK 2373-2019 and GOST 31015-2002.

The strength of the asphalt concretes at uniaxial direct tension at a constant strain rate of 1 mm/min at the temperatures of -10 °C, -20 °C and -30 °C determined in the device TRAVIS under the standard EN 2697-46 has been accepted as a characteristic of their low temperature strength.

It is found out that various modifiers affect the asphalt concrete strength in different ways: a degree of impact depends both on a type of an asphalt concrete and a modifier, as well as on a negative temperature value. Some modifiers increase, and some of them decrease the strength of the asphalt concretes at low temperatures compared with the original asphalt concretes. Among the modifiers the polymer Elvaloy AM has been found to be the most efficient at low temperatures. The asphalt concretes of type B with the bitumens of grades BND БНД 100/130 and BND 130/200 at modification by the polymer Elvaloy AM had the biggest strength at all the considered low temperatures: at -10 ºC – 6.79 MPa and 6.43 MPa; at -20 ºC – 7.57 MPa and 7.87 MPa; at -30 ºC – 7.35 MPa and 8.86 MPa. The stone mastic asphalt concretes 15 and 20 with the polymers and without them at all the considered low temperatures practically had the strength not higher than the basic asphalt concretes of type B with neat (original) bitumens of grades BND 100/130 and BND 130/200.

Key words: bitumens, polymers, low temperatures, strength.

Introduction. An asphalt concrete as one of main road materials is widely used in the world. One of important characteristics of an asphalt concrete is its low temperature strength. In road practice and science, it is accepted that an asphalt concrete must have a low temperature strength not less than the required value defined in accordance with climatic conditions of a road location.

In present several (direct and indirect) methods for experimental evaluation of low temperature characteristics of road asphalt concretes are known [1]. In our opinion the direct methods provide a higher accuracy of the evaluations.

This paper is a continuation of the series of works of the authors devoted to the investigation and the comparative analysis of the characteristics of road bitumens and asphalt concretes [2-21]. In this paper a comparative analysis of low temperature strength of conventional and modified asphalt concretes is carried out.

Materials and methods. In present paper neat road bitumens of three grades (BND 70/100, BND 100/130, BND 130/200) were used for preparation of 31 kinds of conventional and modified asphalt

concretes. The conventional (non-modified) bitumens were produced by the Pavlodar petrochemical plant and were used for preparation of the conventional asphalt concretes. Polymer modified bitumens were used for preparation of the modified asphalt concretes. The neat and modified bitumens satisfy requirements of the Kazakhstan standards ST RK 1373-2013 and ST RK 2534-2015 respectively. The conventional and modified asphalt concretes satisfy requirements of the standards ST RK 1225-2019, ST RK 1223-2019, ST RK 2028-2010, ST RK 2373-2019 and GOST 31015-2002. Modification of the bitumens by polymers (Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS 198, SBS (L 30-01 A), KUMHO KTP) and a crumb rubber, preparation of the conventional and modified asphalt concretes has been performed in a laboratory of Kazakhstan Highway Research Institute. More detailed information about modification of the bitumens can be found in works [19, 22]. Information about types of the tested asphalt concretes, kinds and content of the modifiers is given in table.

Strength of the asphalt concretes at direct tension (constant deformation rate:1 mm/min) has been evaluated in the device TRAVIS at temperatures -10 ºC, -20 ºC and -30 ºC under the standard EN 12697-46.

Data about the tested asphalt concretes

№	Bitumen grade	Kind and type of asphalt concrete	Modifier, %	Short designation
1	BND 70/100	Type B	–	PNHZ_70-100_B
2	BND 100/130	Type B	–	PNHZ_100-130_B
3	BND 100/130	Type B	Elvaloy 4170-1.4	PNHZ_100-130_B+Elvaloy1
4	BND 100/130	Type B	Elvaloy AM-2.0	PNHZ_100-130_B +Elvaloy2
5	BND 100/130	Type B	Kraton-4.0	PNHZ_100-130_B +Kraton
6	BND 100/130	Type B	Calprene 501-4.0	PNHZ_100-130_B +Calprene
7	BND 100/130	Type B	Butonal NS 198-3.0	PNHZ_100-130_B +Butonal
8	BND 100/130	Type B	SBS (L 30-01 A)- 3.0	PNHZ_100-130_B +SBS
9	BND 100/130	Type B	KUMHO KTP-3.0	PNHZ_100-130_B +KUMHO3
10	BND 100/130	Type B	KUMHO KTP-6.0	PNHZ_100-130_B +KUMHO6
11	BND 100/130	Type B	Crumb rubber-15	PNHZ_100-130_B +PK15
12	BND 130/200	Type B	Elvaloy 4170-1.7	PNHZ_130-200_B +Elvaloy 1
13	BND 130/200	Type B	Elvaloy AM-2.2	PNHZ_130-200_B +Elvaloy 2
14	BND 130/200	Type B	Kraton-6.0	PNHZ_130-200_B +Kraton
15	BND 130/200	Type B	Calprene 501-6.0	PNHZ_130-200_B +Calprene
16	BND 130/200	Type B	Butonal NS 198-3.5	PNHZ_130-200_B +Butonal
17	BND 130/200	Type B	SBS (L 30-01 A)- 4.0	PNHZ_130-200_B +SBS
18	BND 100/130	Type A	–	PNHZ_100-130_A
19	BND 130/200	Type A	Elvaloy 4170-1.6	PNHZ_130-200_A +Elvaloy 1
20	BND 130/200	Type A	Elvaloy AM-2.2	PNHZ_ 130-200_A +Elvaloy 2
21	BND 130/200	Type A	Kraton-4.0	PNHZ_130-200_A+Kraton
22	BND 130/200	Type A	Calprene 501-5.0	PNHZ_130-200_A+Calprene
23	BND 130/200	Type A	Butonal NS 198-3.5	PNHZ_130-200_A +Butonal
24	BND 130/200	Type A	SBS (L 30-01 A)- 4.0	PNHZ_130-200_A +SBS
25	BND 100/130	SMA-15	–	PNHZ_100-130_SMA15
26	BND 100/130	SMA-20	–	PNHZ_100-130_SMA20
27	BND 130/200	SMA-20	Elvaloy 4170-1.7	PNHZ_130-200_SMA20+Elvaloy 1
28	BND 130/200	SMA-20	Calprene 501-5.0	PNHZ_130-200_SMA20+Calprene
29	BND 130/200	SMA-20	SBS (L 30-01 A)-5.0	PNHZ_130-200_SMA20+SBS
30	BND 130/200	SMA-20	Butonal NS 198-3.5	PNHZ_130-200_SMA20+Butonal
31	BND 130/200	SMA-20	Kraton-5.0	PNHZ_130-200_SMA20+Kraton

Results and discussion. Strength values of the considered asphalt concretes at tension at temperatures -10 ºC, -20 ºC and -30 ºC are shown in figures 1-3. The analysis of the obtained results shows that different modifiers affect the asphalt concretes strength in different ways: it is found out that the degree of impact depends both on an asphalt concrete type and a modifier, as well as on a negative temperature value.

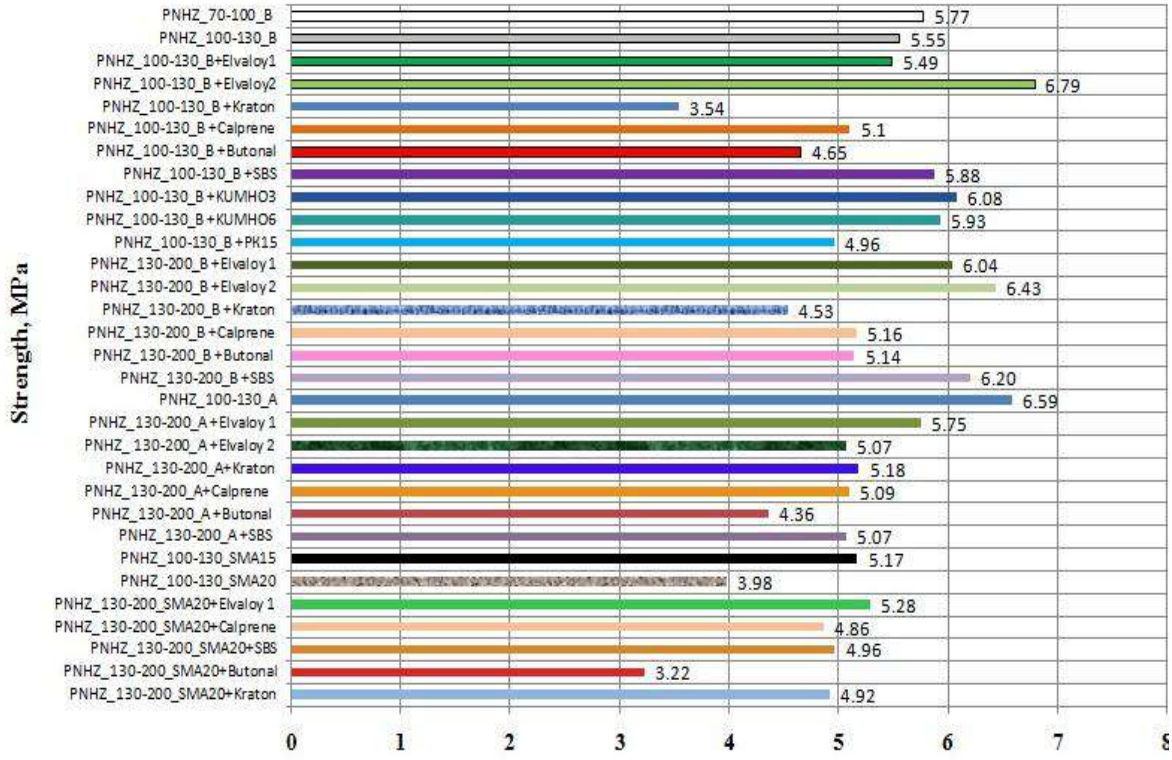

Figure 1 – Strength of the asphalt concretes at tension at temperature -10 ºC

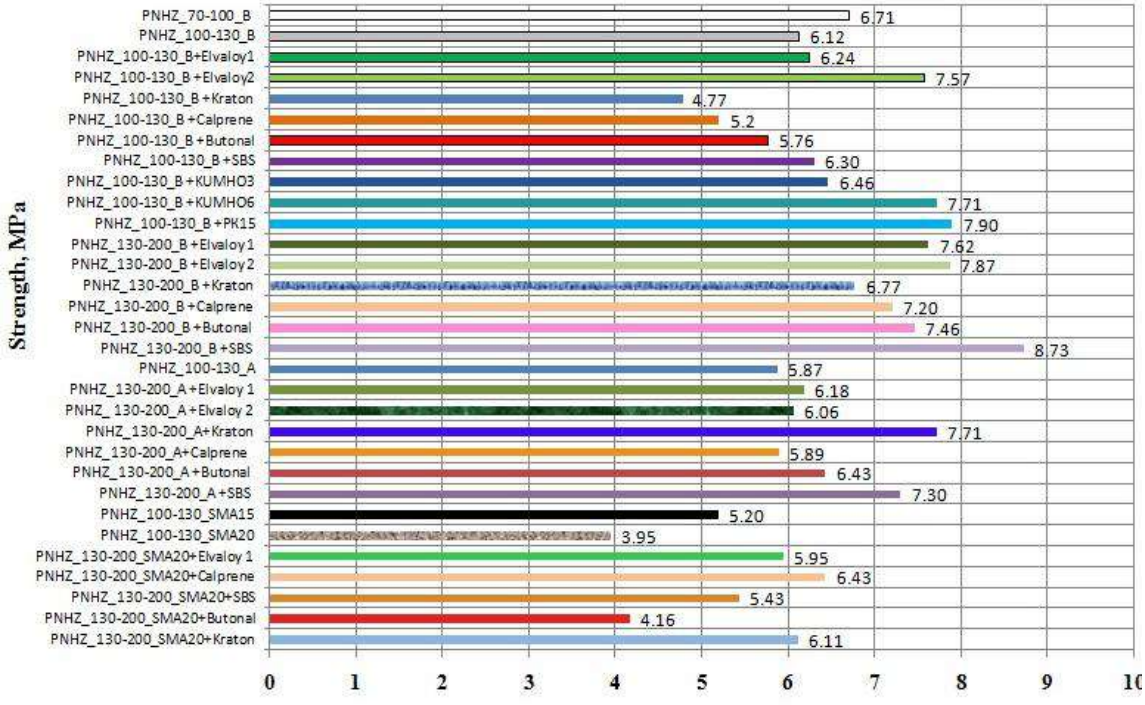

Figure 2 – Strength of the asphalt concretes at tension at temperature -20 ºC

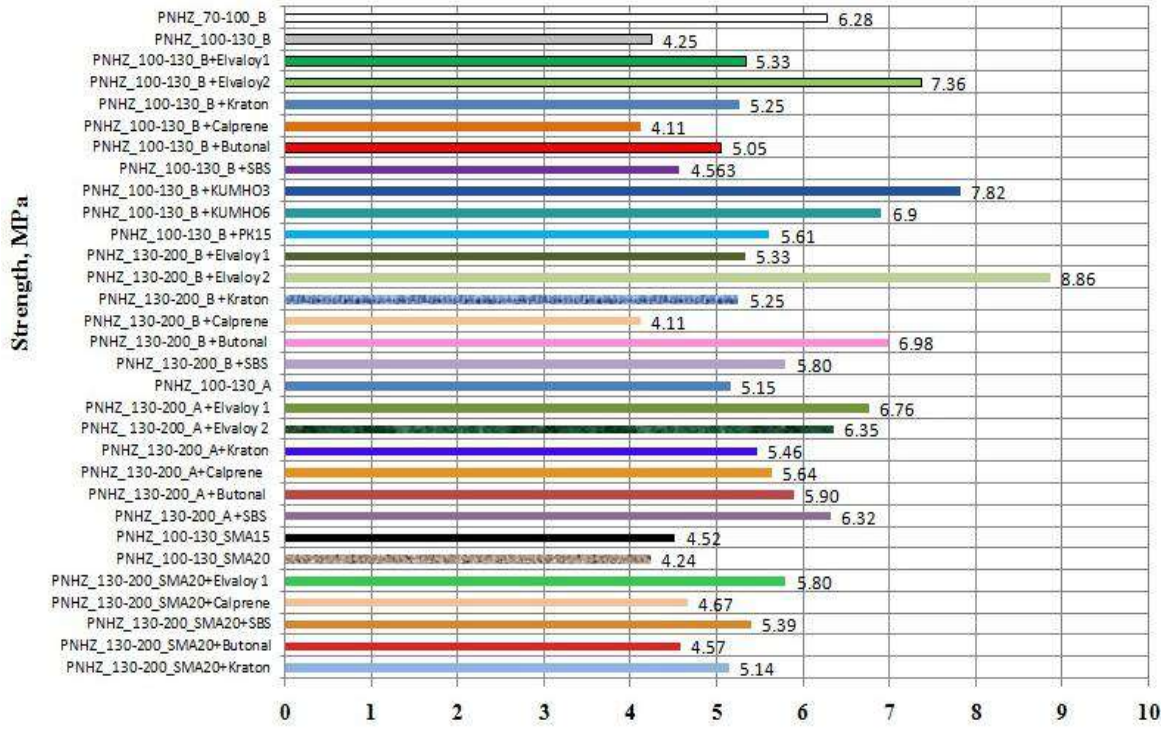

Figure 3 – Strength of the asphalt concretes at tension at temperature -30 ºC

The least strength at the temperature of -10 ºC has been shown by: asphalt concretes of type B with the bitumens of grades bND 100/130, BND 130/200 and the polymer Kraton; an asphalt concrete of type A with the bitumen of grade BND 130/200 and the polymer Butonal; the stone mastic asphalt concrete 20 with the bitumen of grade BND 100/130 and the stone mastic asphalt concrete 20 with the bitumen of grade BND 130/200 and the polymer Butonal. The biggest strength had: asphalt concretes of type B with the bitumens of grades BND 100/130 and BND 130/200 and the polymer Elvaloy AM; the asphalt concrete of type B with the bitumen of grade BND 130/200 and the polymer SBS; the asphalt concrete of type A with the bitumen of grade BND 100/130.

Many modified asphalt concretes had a high strength at the temperature of -20 ºC: the asphalt concretes of type B with the bitumen of grade BND 100/130 and the polymers Elvaloy AM, KUMHO (6 %) and crumb rubber (15 %); the asphalt concretes of type B with the bitumen of grade BND 130/200 and the polymers Elvaloy 4170, Elvaloy AM, Butonal, SBS; the asphalt concrete of type A with the bitumen of grade BND 130/200 and the polymer Kraton. The lowest strength has been shown by: the asphalt concrete of type B with the bitumen of grade BND 130/200 and the polymer Kraton; the stone mastic asphalt concrete 20 with the bitumen of grade BND 100/130; the stone mastic asphalt concrete 20 with the bitumen of grade BND 130/200 and the polymer Butonal.

At the temperature of -30 ºC most of the tested asphalt concretes have shown not very high strength (from 4.11 MPa to 5.8 MPa). The biggest strength had: the asphalt concretes of type B with the bitumens of grade BND 100/130, BND 130/200 and the polymer Elvaloy AM, the asphalt concrete of type B with the bitumen of grade BND 100/130 and the polymer KUMHO (3 %).

It should be noted that the stone mastic asphalt concretes 15 and 20 with the polymers and without them at all the considered low temperatures practically had the strength not higher than the basic asphalt concretes of type B with neat (original) bitumens of grades BND 100/130 and BND 130/200.

Conclusion. Based on the results of the comparative analysis for the low temperature strength of 31 types of conventional and modified asphalt concretes one can draw the following conclusions:

1. Various modifiers affect the asphalt concrete strength in different ways: a degree of impact depends both on a type of an asphalt concrete and a modifier, as well as on a negative temperature value.

2. Some modifiers increase, and some of them decrease the strength of the asphalt concretes at low temperatures compared with the original asphalt concretes.

3. The polymer Elvaloy AM has been found to be the most efficient at low temperatures. The asphalt concretes of type B with the bitumens of grades BND БНД 100/130 and BND 130/200 at modification by the polymer Elvaloy AM had the biggest strength at all the considered low temperatures: at -10 ºC – 6.79 MPa and 6.43 MPa; at -20 ºC – 7.57 MPa and 7.87 MPa; at -30 ºC – 7.35 MPa and 8.86 MPa.

4. The stone mastic asphalt concretes 15 and 20 with the polymers and without them at all the considered low temperatures practically had the strength not higher than the basic asphalt concretes of type B with neat (original) bitumens of grades BND 100/130 and BND 130/200.

Grant IRN AP 08857446 has been received from the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan in support of our research work. Agreement No. 230 dated 12 November, 2020.

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МОДИФИЦИРЛЕНГЕН АСФАЛЬТБЕТОННЫҢ ТӨМЕН ТЕМПЕРАТУРАЛЫҚ БЕРІКТІГІН САЛЫСТЫРМАЛЫ ТАЛДАУ

Аннотация. Жұмыста әдеттегі (модификацияланбаған) және модификацияланған жол асфальтбетондарының 31 түрінің төмен температуралық беріктігіне салыстырмалы талдау жасалды. МЖБ 70/100, МЖБ 100/130 және МЖБ 130/200 маркалы таза битумдарды Павлодар мұнай-химия зауыты Батыс Сібірдің (Ресей) шикі мұнайынан тікелей тотығу әдісімен өндірді және ҚР СТ 1373-2013 стандартының талаптарын қанағаттандырады. Битумды модификациялау үшін Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS, SBS (L 30-01 A), KUMHO KTP полимерлері және резеңке үгіндісі қолданылды. Битумдарды модификациялау Қазақстан жол ғылыми-зерттеу институтының зертханасында жүзеге асырылды. Модификацияланған битумдар ҚР СТ 2534-2015 стандартының және әдеттегі және түрлендірілген асфальтбетондар ҚР СТ 1225-2019, ҚР СТ 1223-2019, ҚР СТ 2028-2010, ҚР СТ 2373-2019 және МЕМСТ 31015-2002 стандарттарының талаптарын қанағаттандырады.

Асфальтбетондардың төмен температуралық беріктігінің сипаттамасы ретінде TRAVIS қондырғысында EN 2697-46 стандарты бойынша анықталған -10 °С, -20 °С және -30 °С температурада 1 мм/мин тұрақты деформация жылдамдығы барысында бір осьті тікелей созылу кезіндегі беріктігі қабылданды.

Түрлі модификатордың асфальтбетон беріктігіне әр қырынан әсер ететіні анықталды: әсер ету дәрежесі асфальтбетон мен модификатор түріне де, теріс температура мәніне де байланысты. Кейбір модификаторлар бастапқы асфальтбетондармен салыстырғанда төмен температурада асфальтбетонның беріктігін арттырады, ал кейбіреулері төмендетеді. Модификаторлардың ішінде Elvaloy AM полимері төмен температурада ең тиімді болды. Elvaloy AM полимерімен модификациялау кезінде МЖБ 100/130 және МЖБ 130/200 маркалы битумдары бар Б типті асфальтбетондар барлық қарастырылған төмен температурада ең жоғары беріктікке ие болды: -10 ºС кезінде – 6,79 МПа және 6,43 МПа; -20 ºС кезінде – 7,57 МПа және 7,87 МПа; -30 ºС кезінде – 7,35 МПА және 8,86 МПа. Полимерлі және полимерсіз 15 және 20 шағыл тасты-мастикалық асфальтбетондар барлық қарастырылған төмен температурада МЖБ 100/130 және МЖБ 130/200 маркаларының таза (бастапқы) битумдары бар Б типті базалық асфальтбетондарға қарағанда беріктігі жоғары емес.

Түйін сөздер: битумдар, полимерлер, төмен температура, беріктік.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ НИЗКОТЕМПЕРАТУРНОЙ ПРОЧНОСТИ МОДИФИЦИРОВАННЫХ АСФАЛЬТОБЕТОНОВ

Аннотация. В настоящей работе выполнен сравнительный анализ низкотемпературной прочности 31 вида обычных (немодифицированные) и модифицированных дорожных асфальтобетонов. Чистые битумы марок БНД 70/100, БНД 100/130 и БНД 130/200 были произведены Павлодарским нефтехимическим заводом из сырой нефти Западной Сибири (Россия) методом прямого окисления и удовлетворяют требованиям стандарта СТ РК 1373-2013. Для модифицирования битумов были использованы полимеры Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS, SBS (L 30-01 A), KUMHO KTP и резиновая крошка. Модификация битумов была осуществлена в лаборатории Казахстанского дорожного научно-исследовательского института. Модифицированные битумы удовлетворяют требованиям стандарта СТ РК 2534-2015. Обычные и модифицированные асфальтобетоны удовлетворяют требованиям стандартов СТ РК 1225-2019, СТ РК 1223-2019, СТ РК 2028-2010, СТ РК 2373-2019 и ГОСТ 31015-2020.

В качестве характеристики низкотемпературной прочности асфальтобетонов принята их прочность при одноосном прямом растяжении при постоянной скорости деформирования 1 мм/мин при температурах -10 °С, -20 °С и -30 °С, определенная в установке TRAVIS по стандарту EN 2697-46.

Установлено, что разные модификаторы по-разному влияют на прочность асфальтобетонов: степень влияния зависит как от вида асфальтобетона и модификатора, так и от значения отрицательной температуры. Некоторые модификаторы повышают, а некоторые понижают прочность асфальтобетонов при низких температурах по сравнению с исходными асфальтобетонами. Из модификаторов наиболее эффективным при низких температурах оказался полимер Elvaloy AM. Асфальтобетоны типа Б с битумами марок БНД 100/130 и БНД 130/200 при модификации полимером Elvaloy AM имели наибольшую прочность при всех рассмотренных низких температурах: при -10 ºС – 6,79 МПа и 6,43 МПа; при -20 ºС – 7,57 МПа и 7,87 МПа; при -30 ºС – 7,35 МПа и 8,86 МПа. Щебеночно-мастичные асфальтобетоны 15 и 20 с полимерами и без них при всех рассмотренных низких температурах практически имели прочность не выше, чем базовые асфальтобетоны типа Б с чистыми (исходными) битумами марок БНД 100/130 и БНД 130/200.

Ключевые слова: битумы, полимеры, низкие температуры, прочность.

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

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OF THE ACADEMY OF SCIENCES
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SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

6 (444)

NOVEMBER – DECEMBER 2020

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK