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COMPARATIVE ANALYSIS OF STANDARD INDICATORS FOR NANOCARBON ASPHALT CONCRETE AND OTHER ASPHALT CONCRETES

Abstract. A comparative analysis of the standard indicators for a nanoasphalt concrete of the type B prepared with the use of a nanocarbon powder and the asphalt concretes of the type B and stone mastic asphalt concretes (SMA20) with modifiers and without them has been performed in the work. The bitumens of the grades BND 70/100, BND 100/130 and BND 130/200 have been used for preparing of the asphalt concretes. The bitumens of the grades BND 70/100 and BND 100/130 have been produced by the Pavlodar petrochemical plant, and the bitumen of the grade BND 130/200 has been manufactured by compounding of the bitumen of the grade BND 100/130 and the petroleum tar of the same plant in Kazakhstan Highway Research Institute. A nanopowder (150-200 nm) has been manufactured from a coal rock of the deposit "Saryadyr" of the "Corpoation "ON-Olzha" LLP (Akmola region) by three-stage size reduction sequentially in a mechanical dispergator (up to 2-3 mm), an aerodynamic mill (up to 20 mcm) and a reactor with a rotating electromagnetic field (150-200 nm).

To compare the standard indicators of 13 types of asphalt concretes have been prepared. The standard indicators of the asphalt concretes have been determined in a laboratory under the standard ST RK 1218-2003. The comparative analysis has been performed under the following 6 main standard indicators: a compression strength at the temperature of 50 °C;a compression strength at the temperature of 20 °C;a compression strength at the temperature of 0 °C;the shear resistance (atfriction at the temperature of50 °C);the crack resistance at the temperature of0 °C; the water saturation.

It is found out that thenanoasphalt concrete under the considered standard indicators can substitute practically all the main types of the asphalt concretes used in a road construction in many countries of the world and in Kazakhstan. It has essentially high resistance to the shear, low temperature and fatigue failures, cyclic freezing and thawing.

Keywords:bitumens, carbon nanopowder, polymers, crumb rubber, asphalt concretes, stone mastic asphalt concretes, standard indicators.

1. Introduction. An asphalt concrete is one of the main road materials in the world. It is used, as a rule, for construction of the upper road surfacing layers – a pavement of highways. Therefore, it is exactly the pavement from the asphalt concrete which sustains the strongest weather-climatic and mechanical impacts during its full service life. The road asphalt concrete should have a complex of the required properties to become sufficiently resistant to the above impacts. As the multiyear experience shows the composition, the technology of preparing and construction of the asphalt concretes are constantly improved to have all the required properties. At present all over the world it is considered that it is possible to achieve the considerable increase of the operational characteristics of the road asphalt concretes by the modification of the bitumens with different polymers.

The works [1-4] show the possibility of the essential increase for the low temperature characteristics of the road bitumens by their modification with a nanocarbon powder. Based on the electromagnetic theory [5,6] and the quantum physics [7] a physic-chemical phenomenon has been explained for a group

chemical composition variation of the bitumen which stipulated the essential variation of the low temperature characteristics of the bitumen. The work [8] demonstrates the increased characteristics of ananoasphaltconcrete of the type B prepared with the use of the bitumen with the nanocarbon powder we obtained before.This article is a continuation of our above works, and it gives the results of the comparative analysis for the standard indicators of the nanoasphalt concrete of the type B and 12 other main types of asphalt concrete: 2 asphalt concretes of the type B, 5 asphalt concretes of the type B with the polymers and a crumb rubber, 5 types of stone mastic asphalt concretes (SMA 20) with polymers and without them.

2. Materials and methods.

2.1. Bitumens. In this work the road bitumens of three grades (BND 70/100, BND 100/130 and BND 130/200) satisfying the requirements of the standard ST RK 1373-2013 have been used for preparing of the asphalt concretes of 13 different types including thenanoasphalt concrete of the type B. In this work the polymers Elvaloy 4170, Calprene 501, Butonal NS 198, SBS L30-01 A and a crumb rubber have been used as the modifiers. The bitumens modified with the polymers satisfy the requirements of the standard ST RK 2534-2014. The detailed information about preparing of the bitumens modified with the polymers one can obtain in the work [9].

The nanopowder (150-200 nm) has been manufactured from a coal rock of the deposit "Saryadyr" ("Corpoation "ON-Olzha" LLP, Akmola region). First for the purpose of provision a homogeneous distribution of the nanopowder particles in the bitumen the nanocarbon powder has been dispersed in a kerosene under the impact of an ultrasound with the frequency of 20 kHz for 5 minutes at a room temperature. Then the dispersed solution (kerosene+nanopowder) has been added to the bitumen at the temperature of 160 °Cand constant mixing for 30 minutes.

2.2. Asphalt concretes. For the purpose of the determination of the standard indicators the next 13 types of asphalt concretes have been prepared and tested: a nanoasphalt concrete of the type B, 2 asphalt concretes of the type B, 5 asphalt concretes of the type B with polymers and a crumb rubber, 5 type of the stone mastic asphalt concretes (SMA 20) with the polymers and without them. The data about the prepared and tested asphalt concretes are given in the Table 1. The asphalt concrete mixes have been prepared in accordance with the requirements of the following relevant standards:

Data about the tested types of asphalt concretes

Serial number	Type of asphalt concrete	Grade of bitumen	Modifier	Content of modifier, %	Contracted notation
1	Dense fine-grained, type B	BND 70/100	–	–	B-70-100
2	Dense fine-grained, type B	BND 70/100	nanocarbon	2.0	B-70-100+nano
3	Dense fine-grained, type B	BND 100/130	–	–	B-100-130
4	Dense fine-grained, type B	BND 100/130	polymer Elvaloy 4170	1.4	B-100-130+Elvaloy
5	Dense fine-grained, type B	BND 100/130	polymer Calprene 501	4.0	B-100-130+Calprene
6	Dense fine-grained, type B	BND 100/130	polymer Butonal NS 198	3.0	B-100-130+Butonal
7	Dense fine-grained, type B	BND 100/130	Crumb rubber	10	B-100-130+CR10
8	Dense fine-grained, type B	BND 100/130	Crumb rubber	15	B-100-130+CR15
9	Stone mastic asphalt concrete-20	BND 100/130	–	–	SMA-100-130
10	Stone mastic asphalt concrete-20	BND 130/200	polymer Elvaloy 4170	1.7	SMA-130-200+Elvaloy
11	Stone mastic asphalt concrete-20	BND 130/200	polymer Calprene 501	6.0	SMA-130-200+Calprene
12	Stone mastic asphalt concrete-20	BND 130/200	polymer Butonal NS 198	3.5	SMA-130-200+Butonal
13	Stone mastic asphalt concrete-20	BND 130/200	polymer SBSL30-01 A	5.0	SMA-130-200+SBS

The asphalt concretes and thenanoasphalt concrete of the type B–ST RK 1225-2019; the polymer asphalt concretes of the type B – ST RK 1223-2019; the asphalt concretes of the type B with the crumb rubber – ST RK 2028-2010; the stone mastic asphalt concrete (SMA 20) – under GOST 31015-2002; the stone mastic asphalt concretes (SMA 20) with the polymers – ST RK 2373-2019.

3. Results and discussion

3.1. Compression strength at the temperature of 50 °C. It is found out in our work [8] that the strength of the asphalt concrete of the type B with nanocarbon bitumen (content of the carbon nanopowder is 2%) at compression at the temperature of 50 °C is higher for 29% than the strength of the conventional asphalt concrete of the type B. Now we can see (figure 1) that the strength of the nanoasphalt concrete of the type B at 50 °C is higher than the average strength of the stone mastic asphalt concretes nearly for 60% and not lower than the minimum allowed strength of the polymer asphalt concretes of the type B.

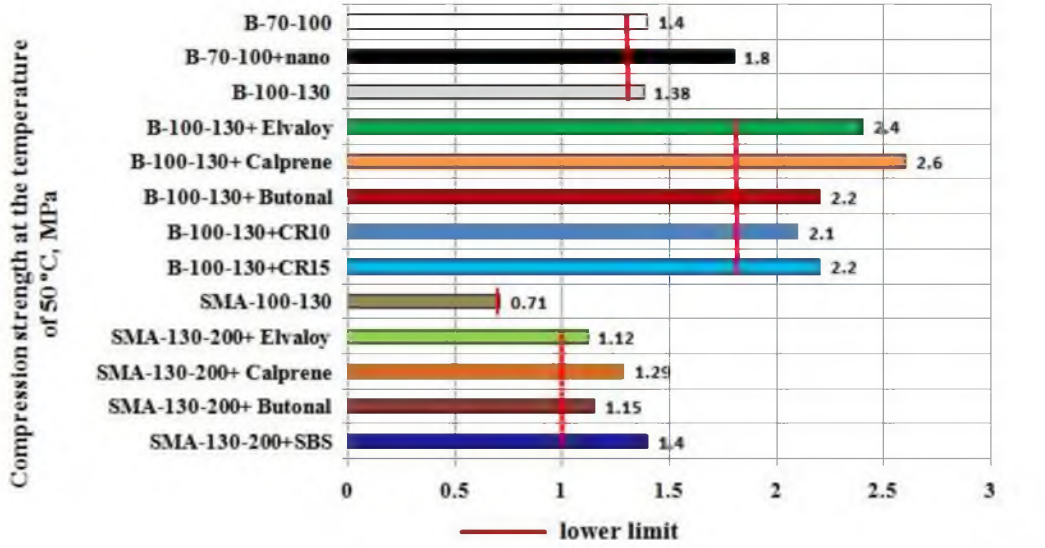

Figure 1 – Compression strength of the asphalt concretes at the temperature of 50°C

3.2. Compression strength at the temperature of 20°C. It is clearly seen (figure 2) that the values of this indicator for the compared asphalt concretes are varied within narrow limits (3.2-4.1 MPa), i.e. they havethe similar values. Meanwhile, thenanoasphalt concrete of the type B has the strength (3.5 MPa) essentially higher than the minimum allowed values for all the compared asphalt concretes. The minimum allowed value of the compression strength at the temperature of 20°C for the asphalt concretes of the type B and the stone mastic asphalt concrete without a polymer is equal to 2.5 MPa, and it is equal to 2.8 MPa for the stone mastic asphalt concretes with the polymers. For example, the nanoasphalt concrete has the strength at the temperature of 20°C higher than the minimum allowed value for the asphalt concretes of type B without polymers and for the stone mastic polymer asphalt concretes for 40% and 25% respectively.

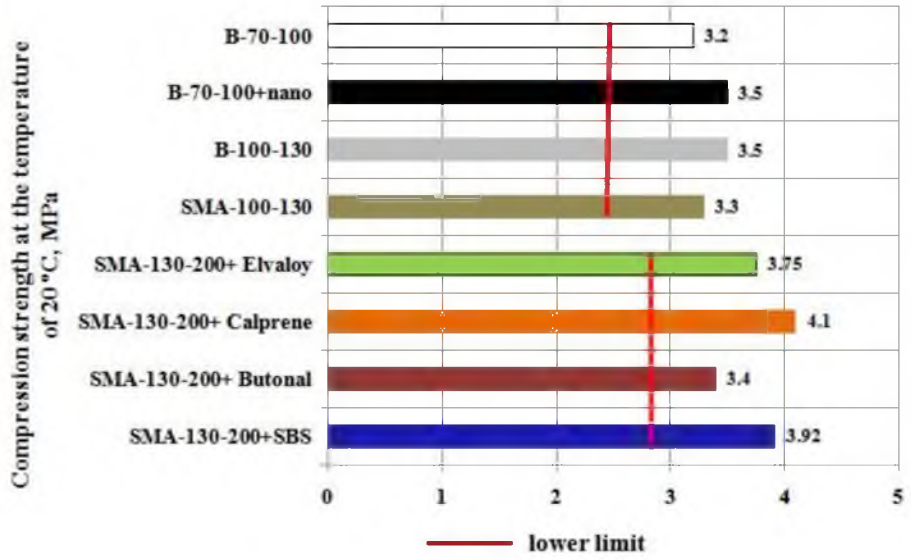

Figure 2 – Compression strength of the asphalt concretes at the temperature of 20°C

3.3. Compression strength at the temperature of 0 °C. It is found out in our work [8] that the strength at 0°Cfor the nanoasphalt concrete of the type B is nearly 2 times (44%) lower than for the conventional asphalt concrete of the type B. Now we can see (figure 3) that the nanoasphalt concrete reigns supreme under this indicator – its strength at 0°C is nearly 2 times (more exactly 1.91 times) lower than the average strength of other compared asphalt concretes.

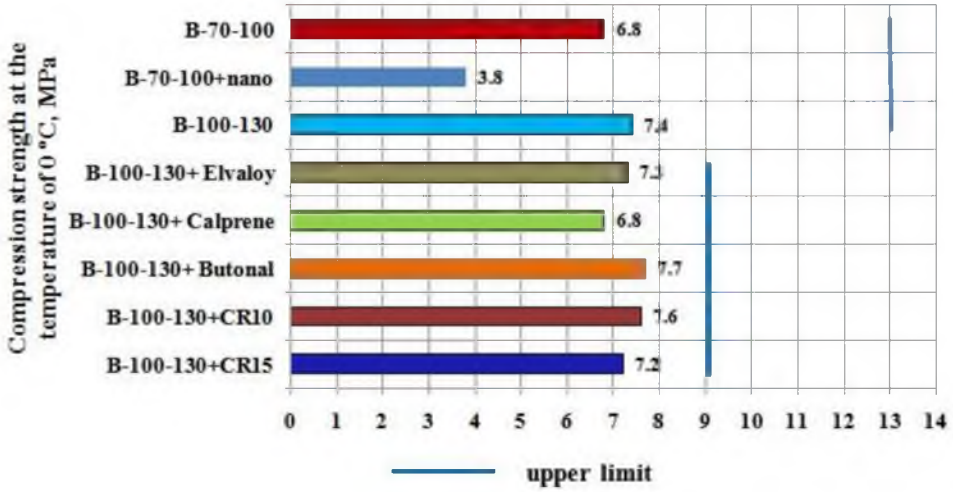

Figure 3 – Compression strength of the asphalt concretes at the temperature of 0°C

3.4. Shear resistance. It is found out in our work [8] that the nanoasphalt concrete of the type B has the shear resistance for 43% higher than for the conventional asphalt concrete of the type B. And now it is clearly seen (figure 4) that under this indicator the nanoasphalt concrete is one of the best among the compared ones: its shear resistance is more for 48%, 25% and 2.04 times compared with the conventional asphalt concretes of the type B, the asphalt concretes of the type B with the polymers and the stone mastic asphalt concretes with the polymers and without them.

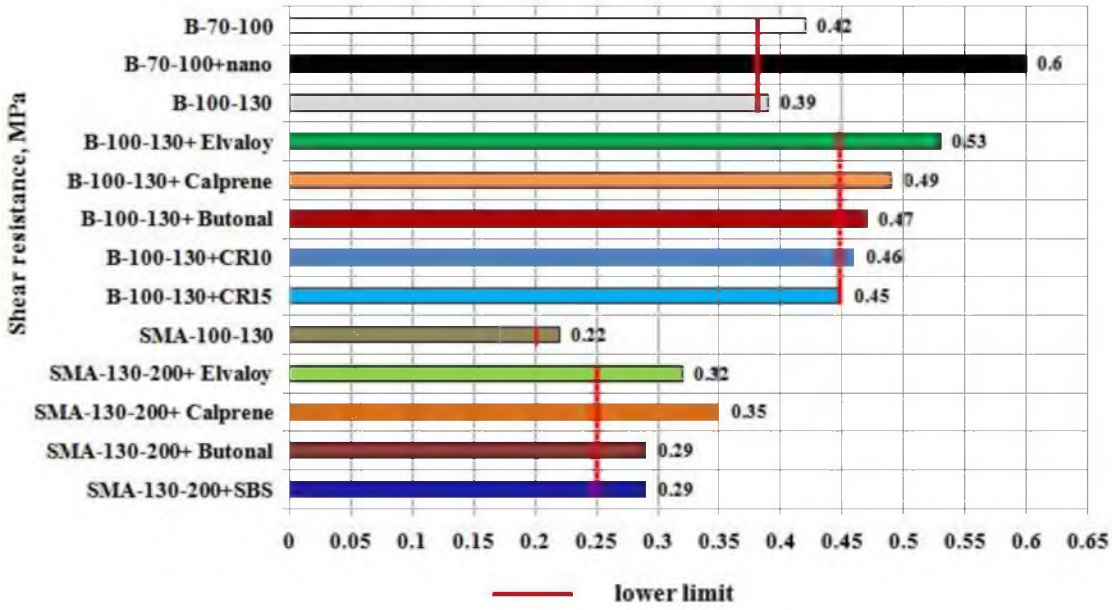

Figure 4 – Shear resistance of the asphalt concretes (at friction at the temperature of 50°C)

3.5. Crack resistance at the temperature of 0°C. It is seen from the figure 5 that the nanoasphalt concrete of the type B has the crack resistance considerably lower than the maximum allowed values for all the considered types of the asphalt concretes. This fact indicates that the nanoasphalt concrete according to the considered standard indicator can substitute practically all the main types of the asphalt concretes used in a road construction in many countries of the world including Kazakhstan.

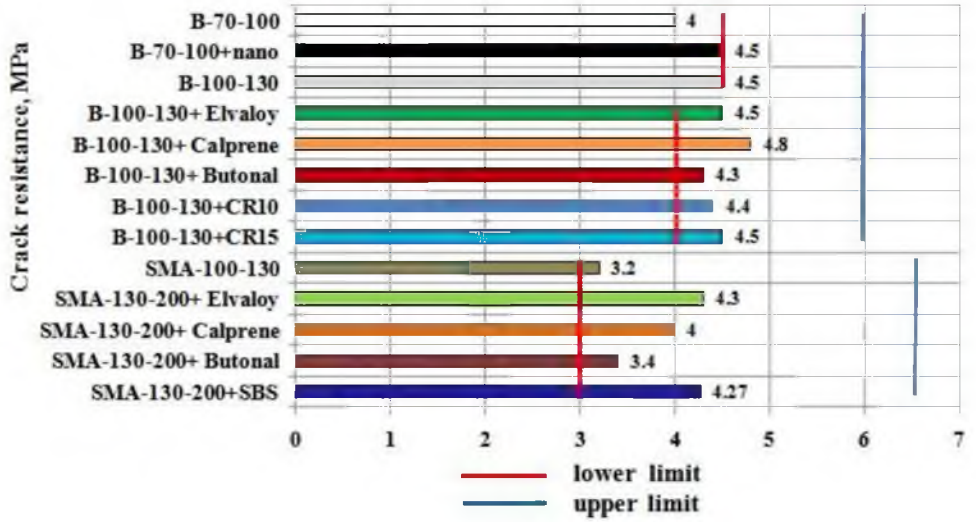

Figure 5. Crack resistance of the asphalt concretes at the temperature of 0°C

3.6. Water saturation. It has been found out in our work [8] that the water saturation for the nanoasphalt concrete of the type B is for18% less than for the conventional asphalt concrete of the type B. And now it is seen (figure 6) that except for the asphalt concrete of the type B with the polymerCalprene the nanoasphalt concrete of the type Bis among those types of the asphalt concrete which have the least values of the water saturation (2.5-2.8%). It is also should be mentioned that the water saturation of the nanoasphalt concrete is lower than the maximum allowed values for all the considered types of the asphalt concrete.

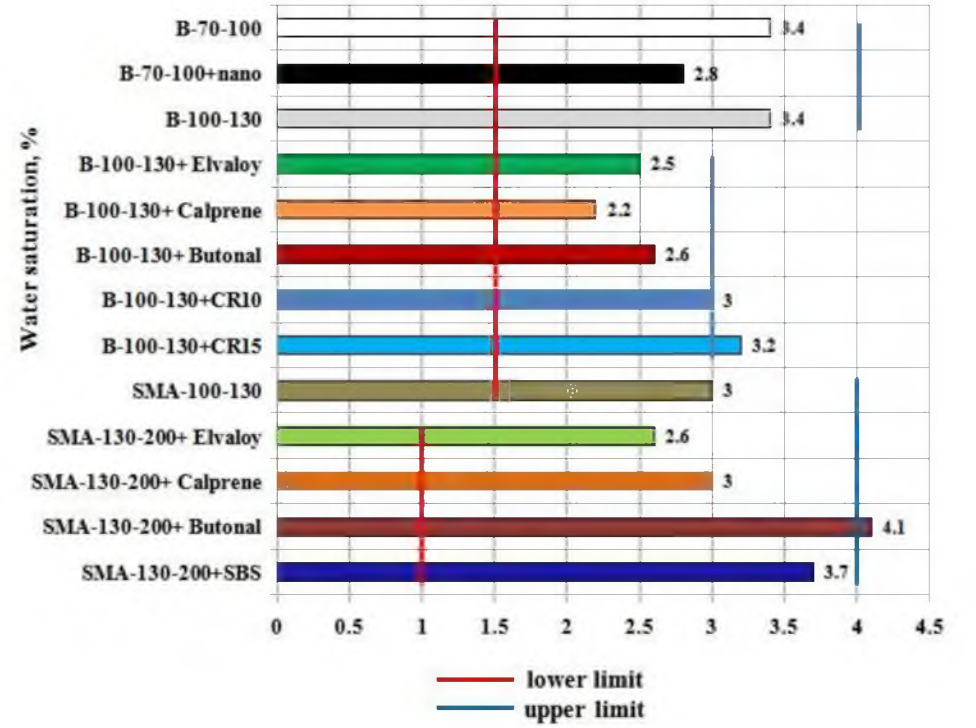

Figure 6 – Water saturation of the asphalt concretes

Conclusion. 1. The nanoasphalt concrete according to the considered standard indicators can substitute practically all the main types of the asphalt concretes used in a road construction in many countries of the world and in Kazakhstan.

2. The nanoasphalt concrete has the compression strength at the temperature of 0º Con average nearly 2 times higher than other types of the asphalt concretes, i.e. it has essentially high low temperature and fatigue strengths.

3. The nanoasphalt concrete proved to be the most shear resistant among the considered types of the asphalt concretes: its shear resistance is more for 25-204 % than for other asphalt concretes.

4. The nanoasphalt concrete is among the group of the asphalt concretes with the least water saturation values, i.e. after appropriate additional tests it may prove to be one of the most frost resistant types of the asphalt concretes.

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НАНОКӨМІРТЕК АСФАЛЬТБЕТОН МЕН БАСҚА АСФАЛЬТБЕТОНДАРДЫҢ СТАНДАРТТЫҚ КӨРСЕТКІШТЕРІН САЛЫСТЫРМАЛЫ ТАЛДАУ

Аннотация. Жұмыста нанокөміртек ұнтағы негізінде дайындалған Б типті наноасфальтбетон, модификатормен және онсыз Б типті асфальтбетон және шағыл тас-мастикалық асфальтбетондардың стандарттық көрсеткіштерін салыстырмалы талдау жасалған. Асфальтбетондарды дайындауға МЖБ 70/100, МЖБ 100/130 және МЖБ 130/200 маркалы битумдар пайдаланылды. МЖБ 70/100 және МЖБ 100/130 маркалы битумдар Павлодар мұнай-химия зауытында, ал МЖБ 130/200 маркалы битумы Қазақстан жол ғылыми-зерттеу институтында МЖБ 100/130 маркалы битум мен сол зауыттың гудронын араластыру негізінде алынды. Наноұнтақ (150-200 нм) «ОН-Олжа» ЖШС-нің (Ақмола облысы) «Сарадыр» кенорнының көмір жынысын механикалық дисперғаторда (2-3 мм-ге дейін), аэродинамикалық диірменде (20 мкм-ге дейін) және айналмалы электр-мағниттік өрісті реакторда үшсатылы тізбектей ұнтақтау жолымен алынды.

Стандарттық көрсеткіштерін салыстыру үшін асфальтбетонның 13 түрі дайындалып, сынақтан өткізілді. Зертханада ҚР СТ 1218-2003 стандарты бойынша асфальтбетондардың стандарттық көрсеткіштері анықталды. Салыстырмалы талдау келесі 6 негізгі стандарттық көрсеткіштер бойынша жасалды: 50°С температурадағы сығу беріктігі; 20°С температурадағы сығу беріктігі; 0°С температурадағы сығу беріктігі; ығысуға тұрақтылық (50°С температурадағы ілігісу бойынша); 0°С температурадағы жарылуға тұрақтылық; суға қанығу.

Қарастырылған стандарттық көрсеткіштер бойынша наноасфальтбетонның әлемнің көптеген елдерінде және Қазақстанда жол құрылысында қолданылатын асфальтбетондардың барлық негізгі түрлерін алмастыра алатындығы анықталды. Оның ығысуға, төменгі температуралық және шаршау бұзылысына, циклдік тоңу мен еруге тұрақтылығы айтарлықтай жоғары.

Түйін сөздер: битумдар, көміртек наноұнтағы, полимерлер, резеңке ұнтағы, асфальтбетондар, шағыл тас-мастикалық асфальтбетондар, стандарттық көрсеткіштер.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ СТАНДАРТНЫХ ПОКАЗАТЕЛЕЙ НАНОУГЛЕРОДНОГО АСФАЛЬТОБЕТОНА И ДРУГИХ АСФАЛЬТОБЕТОНОВ

Аннотация. В настоящей работе выполнен сравнительный анализ стандартных показателей наноасфальтобетона типа Б, приґотовленноґо с использованием наноуґлероднoґо порошка и асфальтобетонов типа Б и щебеночно-мастичных асфальтобетонов (ЩМАС-20) с модификаторами и без них. Для приґотовления асфальтобетонов использовались битумы марок БНД 70/100, БНД 100/130 и БНД 130/200. Битумы марок БНД 70/100 и БНД 100/130 были произведены Павлодарским нефтехимическим заводов, а битум марки БНД 130/200 был получен путем компаундирования битума марки БНД 100/130 и гудрона из тоґо же завода в Казахстанском дорожном научно-исследовательском институте. Нанопорошок (150-200 нм) получен из

угольной породы месторождения «Сарыадыр» ТОО «Корпорация «ОН-Олжа» (Акмолинская область) путем трехстадийного измельчения последовательно в механическом диспергаторе (до 2-3 мм), аэродинамической мельнице (до 20 мкм) и реакторе с вращающимся электромагнитным полем (150-200 нм).

Для сравнения стандартных показателей были приготовлены и испытаны 13 видов асфальтобетонов. В лаборатории по стандарту СТ РК 1218-2003 были определены стандартные показатели асфальтобетонов. Сравнительный анализ был выполнен по следующим 6 основным стандартным показателям: прочность при сжатии при температуре 50 °С; прочность при сжатии при температуре 20 °С; прочность при сжатии при температуре 0 °С; сдвигоустойчивость (по сцеплению при температуре 50 °С); трещиностойкость при температуре 0 °С; водонасыщение.

Установлено, что наноасфальтобетон по рассмотренным стандартным показателям может заменить практически все основные виды асфальтобетонов, применяемых в дорожном строительстве во многих странах мира и в Казахстане. Он имеет существенно высокую устойчивость к сдвигу, низкотемпературному и усталостному разрушению, циклическому замораживанию и оттаиванию.

Ключевые слова: битумы, углеродный нанопорошок, полимеры, резиновая крошка, асфальтобетоны, щебеночно-мастичные асфальтобетоны, стандартные показатели.

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