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ASPHALT CONCRETE WITH NANOCARBON BITUMEN

Abstract. This paper shows the possibility for producing a road asphalt concrete with the improved characteristics with the use of the bitumen with nanocarbon powder we manufactured before compared with the conventionally used asphalt concrete. The paper determines and compares the standard indicators of two types for road asphalt concrete: 1) a hot fine-grained asphalt concrete of Type B, prepared with the use of bitumen with nanocarbon powder; 2) a conventional hot fine-grained asphalt concrete of type B prepared with the use of a neat bitumen of grade BND 70/100. The neat bitumen was produced by the Pavlodar petrochemical plant, a nanopowder (150-200 nm) was manufactured from the coal rock of "Saryadyr" deposit ("Corporation "ON'Olzha" LLP, Akmola region) by three-stage grinding in a mechanical dispergator (up to 2-3 mm), an aerodynamic mill (up to 20 mcm) and a reactor with rotating electromagnetic field (150-200 nm). Modifying of the neat bitumen with nanocarbon powder in the amount of 0.5 % and 2 % has been performed in Kazakhstan Highway Research Institute by continuous mixing of the neat bitumen and the nanocarbon powder for 30 minutes at the temperature of 160 °C.

The asphalt concretes were prepared under standard ST RK 1225-2013, their volumetric characteristics and standard indicators were determined under standard ST RK 1218-2003. To prepare the asphalt concretes a crushed stone was used from the Novo-Alekseyevsk quarry (Almaty region), a sand from the plant "Asphalt concrete-1" (Almaty city) and an activated mineral powder from "Zhartas" LLP (Kordai village, Zhambyl region). It is established that the use of the nanocarbon bitumen improves essentially the standard indicators of the road asphalt concrete. For example, with the content of the nanopowder in bitumen of 2 % the water saturation is decreased for 18 %, shear resistance is increased for 43 %, the strength at the temperature of 20 °C in dry and water-saturated conditions is increased for 9 % and 17 % respectively, the strength at the temperature of 50 °C is increased for 29 %, the strength at the temperature of 0 °C is decreased for 44 % (nearly 2 times).

Key words: bitumen, nanopowder from coal, bitumen with nanocarbon powder, asphalt concrete with nanocarbon bitumen, standard indicators.

1. Introduction. In Kazakhstan, as well as in other countries, it is accepted to evaluate standard indicators of bitumens and asphalt concretes with their use separately. Meanwhile, for optimum mix design it is accepted to use only those bitumens which satisfy the requirements of the current standard. At present in Kazakhstan the standard requirements to road bitumens and asphalt concretes are specified in standards ST RK 1373-2013 [1] and ST RK 1225-2013 [2] respectively.

In our works [3-6] the possibility has been shown for improvement of characteristics for road bitumens by modification with a nanocarbon powder, and their standard and non-standard characteristics have been investigated. This paper is the continuation of our above works, and it shows the possibility for producing of a road asphalt concrete with the improved characteristics at the use of the bitumen with nanocarbon powder we manufactured before.

2. Materials and methods.

2.1. Bitumens and nanopowder. To prepare a conventional road asphalt concrete of type B satisfying the requirements of the standard ST RK 1225-2013 [2] the road bitumen of grade BND 70/100 has been accepted, which satisfies the requirements of the standard ST RK 1373-2013 [1]. The bitumen has been produced by the Pavlodar petrochemical plant from a crude oil of the Western Siberia (Russia) by direct oxidation.

A nanopowder (150-200 nm) was manufactured from the coal rock of "Saryadyr" deposit ("Corporation "ON'Olzha" LLP, Akmola region) by three-stage grinding. A mechanical dispergator (up to 2-3 mm), an aerodynamic mill (up to 20 mcm) and a reactor with rotating electromagnetic field (150-200 nm) were used on grinding stages respectively.

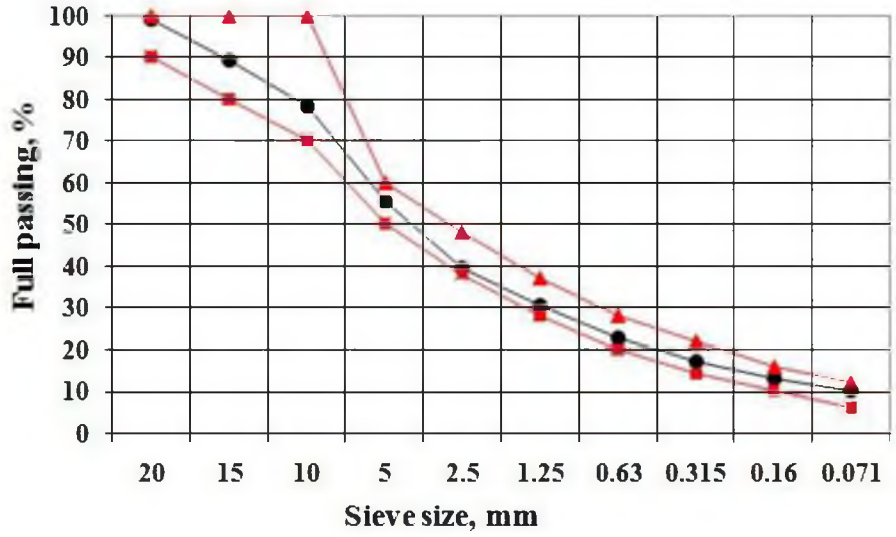
The nanocarbon bitumen with the content of the carbon nanopowder in the amount of 0.5 % and 2.0 % by weight of the neat bitumen was prepared by constant mixing of the neat bitumen and the nanopowder at the temperature of 160 °C for 30 minutes.

The detailed information about the neat bitumen, the nanopowder and the nanocarbon bitumen and their standard and non-standard characteristics is included in our previous works [3-6].

2.2. Asphalt concretes. Conventionally used in the road construction the hot fine-grained asphalt concrete of type B with the use of the neat bitumen of grade BND 70/100 and the similar hot fine-grained asphalt concrete of type B with the use of the nanocarbon bitumen have been prepared under standard ST RK 1225-2003 [2]. To prepare the asphalt concretes a crushed stone (20%) was used from the Novo-Alekseyevsk quarry (Almaty region), a sand of fraction 0-5 mm (49%) from the plant "Asphalt concrete-1" (Almaty city) and an activated mineral powder (7%) from "Zhartas" LLP (Kordai village, Zhambyl region). The content of the neat bitumen and the nanocarbon bitumen in the asphalt concretes was 4.8 % by weight of the dry mineral materials.

The granulometric curve of the mineral part of the asphalt concretes is shown in figure. The standard indicators of the crushed stone, the sand and the mineral powder determined under the standards ST RK 1213-2003 [7], ST RK 1217-2003 [8] and ST RK 1221-2003 [9] respectively are given in tables 1-3.

Volumetric characteristics determined under standard ST RK 1218-2003 [10] are given in table 4. As it is seen, the average and the real densities of the conventional and the nanobitumen asphalt concretes are practically similar. Residual air voids is decreased with the increase of the amount of the nanopowder: with the content of nanopowder 2.0 % by decreasing of residual air voids of the asphalt concrete it reaches 15%. It is possible to improve the standard indicators of the asphalt concrete by decreasing of residual air voids.



Granulometric curve of the mineral part of the asphalt concretes

Table 1 – Standard indicators of the crushed stone

Description of indicator	Norm	Actual results	
		Fraction 10-20 mm	Fraction 5-10 mm
Content of grains of thin flake and needle-shaped form, % Class	up to 15 incl. 1	6.8 1	12.9 1
Strength according to crushability - weight loss, % - grade	up to 10 incl. 1000	6.4 1000	8.9 1000
Wearing quality, - weight loss, % - grade	up to 25 incl. W1	14.1 W1	17.3 W1
Content of grains of soft rocks, %,	not more than 10	5.0	6.1
Frost resistance (saturation in solution of sodium sulphate): - number of cycles - weight loss, % - grade	 10 not more than 5 F100	 10 2.7 F100	 10 3.3 F100
Content of dust and clay particles, %	not more than 1.0	0.11	0.2
Content of clay in lumps, %	not more than 0.25	0	0
Content of granulated grains, %	not less than 80	90.0	87.5

Table 2 – Standard indicators of the sand

Description of indicator	Norm	Actual results
Size modulus	above 2.5 up to 3.0 large	2.6 large
General sieve residual with mesh No. 063	above 45 up to 65 large	54.1 large
Content of grains with size, II class: - above 10 mm - above 5 mm - less than 0.16 mm	 5 15 15	 3.0 10.6 12.0
Content of dust and clay particles, %	not more than 10	6.4
Content of clay in lumps, %	not more than 0.25	0
Content of clay particles by swelling method, %,	not more than 0.5	0.21

Table 3 – Standard indicators of the mineral powder

Description of indicator	Norm	Actual results
Grain size, % under mass: - less than 1.25 mm - less than 0.315 mm - less than 0.071 mm	 not less than 100 not less than 90 not less than 80	 100 98.5 80.1
Air voids, %	not more than 28	21
Swelling of specimens from the mix of filler with bitumen, %	not more than 1,5	0.5
Bitumen content value, g,	not more than 50	38.0
Water content, %	not more than 0.5	0.16

Table 4 – Volumetric characteristics of the asphalt concretes with the neat bitumen and the nanocarbon bitumen

Amount of nanopowder, %	Average density, g/cm^3	Real density, g/cm^3	Residual air voids, %
0	2.39	2.49	4.0
0.5	2.39	2.48	3.6
2.0	2.40	2.49	3.4

3. Results and discussion. The standard indicators of the asphalt concretes with the neat bitumen and the nanocarbon bitumen determined under the standard ST RK 1218-2003 [10] are represented in eable 5. As it is seen, the use of the nanocarbon bitumen improves all the considered standard indicators of the asphalt concrete. With the content of the nanopowder in bitumen 2 % water saturation is decreased for 18 %, shear resistance is increased for 43 %, strength at the temperature of 20 °C in dry and water-saturated conditions is increased for 9 % and 17 % respectively, strength at the temperature of 50 °C is increased for 29 %, strength at the temperature of 0 °C is decreased for 44 % (nearly 2 times).

Table 5 – Standard indicators of the asphalt concretes with the neat bitumen and the nanocarbon bitumen

Indicator	Amount of nanopowder, %			Norm
	0	0.5	2.0	
Water saturation, %	3.4	3.1	2.8	1.5-4.0
Compression strength (MPa) at the temperature (°C):				
-20 °C	3.2	3.3	3.5	not less 2.5
- 20 °C (in water-saturated condition)	3.0	2.9	3.5	–
- 50 °C	1.4	1.6	1.8	not less than 1.3
- 0 °C	6.8	4.5	3.8	not more than 13.0
Shear resistance	0.42	0.44	0.60	not less than 0.38

The considerable increase in the strength at the temperature of 50 °C (29 %) and shear resistance (43 %) shows the increased shear resistance of the asphalt concrete with the nanocarbon bitumen compared with the conventional asphalt concrete. The essential decrease of the strength at the temperature of 0 °C (44 %) informs about the increased resistance of this asphalt concrete to the fatigue and low temperature cracking. Water saturation decrease characterizes its comparatively better frost resistance.

Conclusion. 1. A new road asphalt concrete has been manufactured with the improved standard indicators. It was prepared with the use of a nanocarbon bitumen.

2. With the content of the nanopowder in the bitumen 2 % water saturation is decreased for 18 %, shear resistance is increased for 43 %, the strength at the temperature of 20 °C in dry and water-saturated conditions is increased for 9 % and 17 % respectively, the strength at the temperature of 50 °C is increased for 29 %, the strength at the temperature of 0 °C is decreased for 44 % (nearly 2 times).

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НАНОКӨМІРТЕК БИТУМДЫ АСФАЛЬТБЕТОН

Аннотация. Мақалада дәстүрлі асфальтбетонмен салыстырғанда бұрын өзіміз қол жеткізген нанокарбон ұнтағы бар битумды қолдана отырып, жақсартылған сипаттамалары бар жол асфальтбетонын алу мүмкіндігі көрсетілген. Онда жол асфальтбетонның екі түрінің стандарт көрсеткіштері анықталып, салыстырылған: 1) нанокөміртек ұнтақты битумды пайдаланып дайындалған ыстық майда түйіршікті Б типтік асфальтбетон; 2) МЖБ 70/100 маркалы таза битумды пайдаланып дайындалған ыстық майда түйіршікті Б типтік асфальтбетон. Таза битум Павлодар мұнай-химия зауытында, наноұнтақ (150-200 нм) «Сарыадыр» кен орнының («ОН-Олжа» корпорациясы» ЖШС, Ақмола облысы) көмір жынысынан механикалық диспергаторда (2-3 мм-ге дейін), аэродинамикалық диірменде (90 мкм дейін) және айналма электр-магниттік өрісті реакторда (150-200 нм дейін) үш сатылы ұнтақтау арқылы алынды. Таза битумды 0,5 % және 2 % наноұнтақпен модификациялау Қазақстан жол ғылыми-зерттеу институтында 160 °C

температурада 30 минут бойы таза битум мен нанокөміртек ұнтақты үздіксіз араластыру негізінде жүзеге асырылды.

Асфальтбетондар ҚР СТ 1225-2003 стандарты бойынша дайындалды, олардың көлем сипаттамалары мен стандарт көрсеткіштері ҚР СТ 1218-2003 стандарты бойынша анықталды. Асфальтбетондарды даярлауға Ново-Алексеевск (Алматы облысы) карьерінің шағыл тасы, «Асфальтбетон-1» ЖШС (Алматы облысы) зауытының құмы және «Жартас» ЖШС-нің (Қордай ауылы, Жамбыл облысы) активтендірілген минералдық ұнтағы пайдаланылды. Нанокөміртек ұнтақты битумды пайдалану жол асфальтбетонының стандарт көрсеткіштерін едәуір жақсартатындығы анықталды. Атап айтқанда, битумдағы көмір наноұнтағының мөлшері 2 % болганда асфальтбетонның сумен қанығуы 18 %-га азаяды, ығысуга тұрақтылығы 43 %-га артады, 20 °С температурадага құргақ және суга қаныққан күйдегі беріктігі тиісінше 9 % және 17 %-га өседі, 50 °С температурадагы беріктігі 29 %-га артады, 0 °С температурадагы беріктігі 44 % (2 есеге жуық) кемиді.

Түйін сөздер: битум, көмірден алынган наноұнтақ, нанокөміртекті ұнтағы бар битум, нанокөміртекті битумы бар асфальтбетон, стандартты көрсеткіштер.

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АСФАЛЬТОБЕТОН С НАНОУГЛЕРОДНЫМ БИТУМОМ

Аннотация. В настоящей статье показана возможность получения дорожного асфальтобетона с улучшенными характеристиками с использованием ранее полученного нами битума с наноуглеродным порошком по сравнению с традиционно применяемым асфальтобетоном. В ней определены и сравнены стандартные показатели двух видов дорожного асфальтобетона: 1) горячего мелкозернистого асфальтобетона типа Б, приготовленного с использованием битума с наноуглеродным порошком; 2) традиционного горячего мелкозернистого асфальтобетона типа Б, приготовленного с использованием чистого битума марки БНД 70/100. Чистый битум произведен Павлодарским нефтехимическим заводом, нанопорошок (150-200 нм) получен из угольной породы месторождения «Сарыадыр» (ТОО «Корпорация «ОН-Олжа», Акмолинская область) путем трехстадийного измельчения в механическом диспергаторе (до 2-3 мм), аэродинамической мельнице (до 20 мкм) и реакторе с вращающимся электромагнитным полем (150-200 нм). Модифицирование чистого битума наноуглеродным порошком в количестве 0,5 % и 2 % осуществлено в Казахстанском дорожном научно-исследовательском институте путем непрерывного перемешивания чистого битума и наноуглеродного порошка в течение 30 минут при температуре 160 °С.

Асфальтобетоны были приготовлены по стандарту СТ РК 1225-2013, их объемные характеристики и стандартные показатели были определены по стандарту СТ РК 1218-2003. Для приготовления асфальтобетонов были использованы щебень из Ново-Алексеевского карьера (Алматинская область), песок – из завода «Асфальтобетон-1» (г. Алматы) и активированный минеральный порошок – из ТОО «Жартас» (п. Кордай, Жамбылская область). Установлено, что использование наноуглеродного битума существенно улучшает стандартные показатели дорожного асфальтобетона. Так, при содержании нанопорошка в битуме 2% водонасыщение уменьшается на 18 %, сдвигоустойчивость увеличивается на 43 %, прочность при температуре – 20 °С в сухом и водонасыщенном состояниях повышается соответственно на 9 % и 17 %, прочность при температуре 50 °С повышается на 29 %, прочность при температуре 0 °С уменьшается на 44 % (почти в 2 раза).

Ключевые слова: битум, нанопорошок из угля, битум с наноуглеродным порошком, асфальтобетон с наноуглеродным битумом, стандартные показатели.

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