EFFECTIVENESS OF CAST POLYMER-SULFUR ASPHALT CONCRETE TECHNOLOGY FOR OPERATIONAL CONDITIONS WITH HIGH TEMPERATURES

Sadikov Ibragim Salikhovich
Doctor of Technical Sciences, Professor

Tilakov Sukhrob Mukhammadiyevich
Basic Doctoral Student
Tashkent State Transport University, Uzbekistan
Corresponding authors: tftutfsuxrob0089@mail.ru

Abstract
The article analyzes existing technologies of cast asphalt concrete and cast sulfur asphalt concrete. A new composition of the cast polymer-sulfur asphalt concrete mixture has been developed, and the improved performance indicators of the cast polymer-sulfur asphalt concrete coating, manufactured according to the new composition, in particular, crack resistance and high-temperature resistance, have been experimentally scientifically substantiated.

Keywords: cast polymer asphalt concrete, cast asphalt concrete, optimal composition, granulometric composition, sand, gravel, mineral powder, bitumen, temperature, sulfur, modified sulfur, sulfur bitumen, asphalt concrete compressive strength limit, asphalt concrete water saturation, asphalt concrete water resistance.

Introduction

Our republic belongs to the countries with a hot climate. The summer is dry and hot, in the plains the average temperature in July reaches +26...+30 °C, and in the south - +31...+32 °C. The highest temperature reaches +44 °C in Tashkent and +50 °C in Termez. Asphalt concrete pavements under the influence of high temperatures up to +70 °C lose their strength, resulting in the formation of plastic deformations. To solve the aforementioned problems, it is necessary to introduce asphalt concrete technology that is resistant to hot climatic conditions on our country's roads. One such technology is the cast polymer sulfur asphalt concrete technology. To implement the technology of cast polymer-sulfur asphalt concrete on roads, it is necessary to increase the thermal stability of the binder in the mixture, only then will the physical and mechanical properties of the coating be resistant to high-temperature operating conditions. Increasing the thermal stability of asphalt concrete coatings is one of the pressing issues today. Increasing the thermal stability of asphalt concrete coatings is one of the pressing issues today.

LITERATURE REVIEW

A number of scientific studies on cast asphalt concrete technology have been conducted worldwide. Among them, we will present the following:

The technology of cast asphalt concrete was first used in Babylon and Egypt in 1532. In 1832-1835, it was employed in the construction of sidewalks and bridges in Paris, and in 1836-1838, the cast asphalt concrete technology was introduced in London and Philadelphia. This technology was first implemented in 1865 in the Russian city of Saint Petersburg, and in 1870-1873, it was introduced in Moscow, Kiev, Kharkov, Odessa, and Riga.

The patent RU 2452748 C1 for the production of sulfur asphalt concrete primarily refers to the technology for producing modified sulfur asphalt concrete. The technology involves mixing heated bitumen, sulfur, and an activating additive-modifier during heating. Amines in the amount of 0.3-3.0% by mass are used to activate the reaction mixture. The reaction is carried out at a temperature of 130-150°C for 2-3 hours. The mass ratio of sulfur to bitumen is 20-70:30-80 [2].

The drawback of this technology lies in the low temperature during the modification process of sulfur-containing bitumen. The softening temperature of sulfur-modified bitumen at 130-150 °C does not meet the requirements of ГОСТ 22245, resulting in the asphalt concrete pavement's inability to withstand high temperatures during its service period. Consequently, this reduces the operational lifespan of automobile roads.

RU 2554585 C2 patentda esa oltingugurtni modifikasiya qilib oltingugurtli beton, oltingugurtli asfaltobeton tayyorlash texnologiyasi hamda uni yoʻl qurilishiga tadbiq etish keltirib oʻtilgan. Reaktorda oltingugurtga ammoniy tuzi yoki kaliy qoʻshib, oltingugurtdagi modifikatorning ulushi 0.001-0.005 % ni tashkil etib, 120-135 ^{0}C haroratda 5-10 daqiqa, keyin esa unga 5-etilen, 2-norbornen massa ulushi 0,08-0,1 % qoʻshilib 20-50 daqiqa qizdirib aralashtirilgandan soʻng modifikasiyalangan oltingugurt tayyorlangani keltirib oʻtilgan. Modifikasiya qilish jarayoni 3-5 soatni tashkil etadi [3].

The drawback of this invention lies in the complexity of the modification process.

In patent RU 2585618 C1, for the preparation of sulfur-modified bitumen, it is first necessary to obtain modified sulfur. To do this, technical sulfur is melted with sulfuric acid, heated and stirred at a temperature of 180-200°C for 10-15 minutes. Then, the modified sulfur is added to the heated bitumen and stirred at a temperature of 180-200°C for 60 minutes, as indicated in [4].

The aforementioned technology has several drawbacks. First, it is difficult to prepare a modified sulfur bitumen using this technology. Secondly, due to the slow process of modification, sulfur has the ability to sublimate at a temperature of 190-200°C. Furthermore, at temperatures above 180°C, a large amount of hydrogen sulfide gas is released from sulfur, which negatively affects human health during the modification process.

In the dissertation by Vladimir Viktorovich Pronin titled "Литой асфальтобетон повышенной сдвигоустойчивости для покрытий автомобильных дорог" scientific research was conducted on two different compositions of modified bitumen polymer BND 40/60. In the first composition, 2.5% of technical carbon was added to the mixture by total mass, which increased the physical and mechanical properties of the coating. In the second composition, the physical and mechanical properties of the coating were enhanced by adding 2.5% of chemical water

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treatment sludge by total mass to the mixture. The cast asphalt concrete technology in this dissertation is significantly more expensive than conventional asphalt concrete technology, but the economic indicator of the work is shown for the period of road operation. Specifically, during one repair cycle of the cast asphalt concrete surface, conventional asphalt concrete required repairs twice [5].

Due to the fact that Russia is not located in the hot climate zone, scientific research on improving the coating's resistance to high temperatures has not been conducted in this dissertation.

The aforementioned scientific works have been analyzed and their shortcomings have been identified. To eliminate these shortcomings, experiments were planned to increase the stability of cast polymer-sulfur asphalt concrete coatings to high temperatures.

MATERIALS AND METHODS

A special device was first prepared to modify bitumen with sulfur.

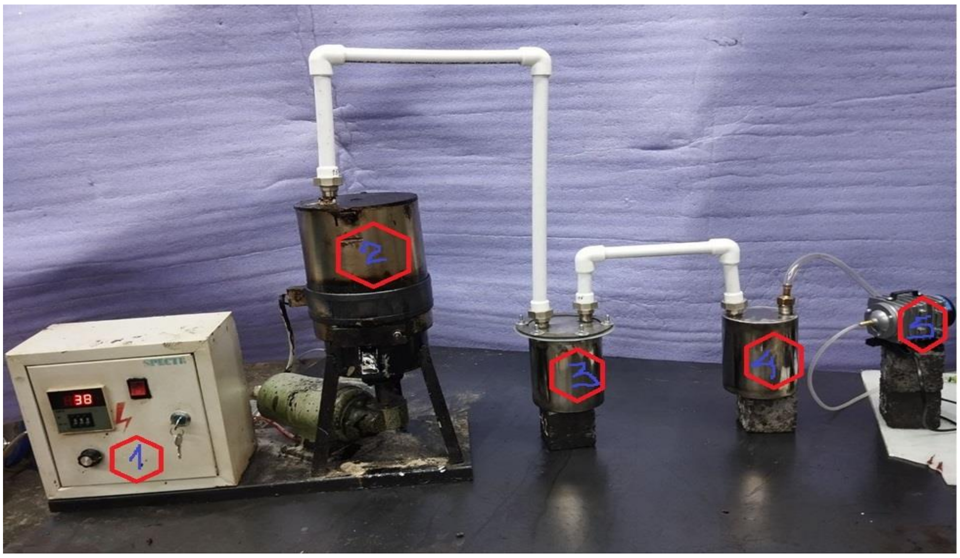

Figure 1. Modification reactor.

1. Control box and its components. 2. Main reactor vessel and its parts: 3. Receiver for toxic gases released during modification process 1 – container and its parts; 4. Receiver for toxic gases released during modification process 2 - container and its parts; 5. Vacuum pump and its parts.

This laboratory setup has the following technological advantages:

✓ the liquid temperature in the reactor is controlled up to 400°C,

✓ the drum rotation speed inside the reactor is controlled within the range of 0-500 rpm.

When conducting experiments using this device, the accuracy of the experiment increases.

Using the technology, we developed, we conducted laboratory tests in the following order:

Experiment 1. To prepare a modified sulfur-containing bitumen with a bitumen-to-sulfur ratio of 90:10, sulfur and 0.5% of the M4 modifier were added to the reactor, heated and stirred for 110 minutes, then dehydrated BND 60/90 bitumen was added to the modified sulfur in the reactor and stirred while heating for 70 minutes. In our experiment, the reactor temperature was 135°C.

Experiment 2. To prepare a modified sulfur-containing bitumen with a bitumen-to-sulfur ratio of 80:20, sulfur and 1% of the M4 modifier were added to the reactor, then heated and stirred for 110 minutes. After that, dehydrated BND 60/90 bitumen was added to the reactor with modified sulfur and heating and stirring continued for 70 minutes. In this experiment, the reactor temperature was 135°C.

Experiment 3. To prepare a modified sulfur-containing bitumen with a bitumen-sulfur ratio of 70:30, sulfur and 1.5% M4 modifier were added to the reactor, then heated and stirred for 110 minutes. After that, dehydrated BND 60/90 bitumen was added to the modified sulfur reactor and continued to heat and stir for 70 minutes. In this experiment, the reactor temperature was 135°C.

Experiment 4. To prepare a modified sulfur-containing bitumen with a bitumen-sulfur ratio of 60:40, sulfur and 2% M4 modifier were added to the reactor, then heated and stirred for 110 minutes. After that, dehydrated BND 60/90 bitumen was added to the modified sulfur reactor and continued to heat and stir for 70 minutes. In this experiment, the reactor temperature was 135°C.

Experiment 5. To prepare a modified sulfur-containing bitumen with a bitumen-sulfur ratio of 50:50 in the reactor, sulfur and 2.5% M4 modifier were added, then stirred for 110 minutes upon heating. After that, dehydrated BND 60/90 bitumen was added to the modified sulfur reactor and stirred for 70 minutes. In this experiment, the reactor temperature was 135°C.

Experiment 6. To prepare a modified sulfur-containing bitumen with a bitumen-sulfur ratio of 90:10, sulfur and 0.5% M4 modifier were added to the reactor, then stirred for 100 minutes upon heating. After that, dehydrated BND 60/90 bitumen was added to the reactor with modified sulfur and stirred for 60 minutes. In this experiment, the reactor temperature was 175°C.

Experiment 7. To prepare a modified sulfur-containing bitumen with a bitumen-sulfur ratio of 80:20 in the reactor, sulfur and 1% of the M4 modifier were added, then stirred for 100 minutes. After that, dehydrated BND 60/90 bitumen was added to the reactor with modified sulfur and stirred for 60 minutes. In this experiment, the reactor temperature was 175°C.

Experiment 8. To prepare a modified sulfur bitumen with a bitumen-sulfur ratio of 70:30, sulfur and 1.5% M4 modifier were added to the reactor, heated and stirred for 100 minutes, then dehydrated BND 60/90 bitumen was added to the reactor with modified sulfur and stirred for 60 minutes. In this experiment, the reactor temperature was 175°C.

Experiment 9. To prepare a modified sulfur bitumen with a bitumen-sulfur ratio of 60:40, sulfur and 2% M4 modifier were added to the reactor, heated and stirred for 100 minutes, then dehydrated BND 60/90 bitumen was added to the reactor with modified sulfur and stirred for 60 minutes. In this experiment, the reactor temperature was 175°C.

Experiment 10. To prepare a modified sulfur bitumen with a bitumen-sulfur ratio of 50:50 in the reactor, sulfur and 2.5% M4 modifier were added, heated and stirred for 100 minutes, then dehydrated BND 60/90 bitumen was added to the reactor with modified sulfur and stirred for 60 minutes. In this experiment, the reactor temperature was 175°C.

RESULTS AND THEIR DISCUSSION

Results and their discussion. The physical and mechanical properties of the finished modified binder were determined according to ГОСТ 22245[7] according to the requirements of ГОСТ 11501 [8], ГОСТ 11506 [9], ГОСТ 11505 [10] (Table 1).

Table 1. **Physical and mechanical properties of modified polymer-sulfur bitumen**

№	Bitumen and sulfur content, %	Modifier M4, %	Reactor drum rotation rate (min/ab)	Reactor temperature (^{0}C)	Modification time, (min)	Needle penetration depth, (0,1 мм) 25^{0}C ГОСТ 11503	Softening temperature, (^{0}C) ГОСТ 11506	Elongation, (sм) ГОСТ 11505
1	100	-	-	-	-	68	46	67
2	90:10	0,5	200	135	180	66	48	35
3	80:20	1	200	135	180	63	52	30
4	70:30	1,5	200	135	180	64	54	29
5	60:40	2	200	135	180	58	55	28
6	50:50	2,5	200	135	180	57	54	27
7	90:10	0,5	200	175	160	63	51	39
8	80:20	1	200	175	160	58	54	32
9	70:30	1,5	200	175	160	55	63	31
10	60:40	2	200	175	160	52	70	30
11	50:50	2,5	200	175	160	50	65	28

To address the aforementioned shortcomings in scientific research on cast asphalt concrete technology, we abandoned the traditional cast asphalt concrete approach and developed an improved technology for cast polymer-sulfur asphalt concrete [10].

The advantages of cast polymer-sulfur asphalt concrete over conventional cast asphalt concrete are as follows:

- ✓ Low temperature required for mixture preparation;
- ✓ High thermal resistance of the coating;
- ✓ Bitumen efficiency;
- ✓ Short curing time of the coating;
- ✓ High economic efficiency.

The amount of toxic gases released into the environment decreases [11].

During the experiments, using the technological parameter of the 10th line, we first modified the sulfur, and when determining the degree of polymerization of the modified sulfur, it was found to be 42%. A high degree of modified sulfur polymerization positively affects the physical and mechanical properties of the binder.

The physical and mechanical properties and granular composition of granite stone materials from the Aktash stone crushing plant in the Samarkand region of the Republic of Uzbekistan

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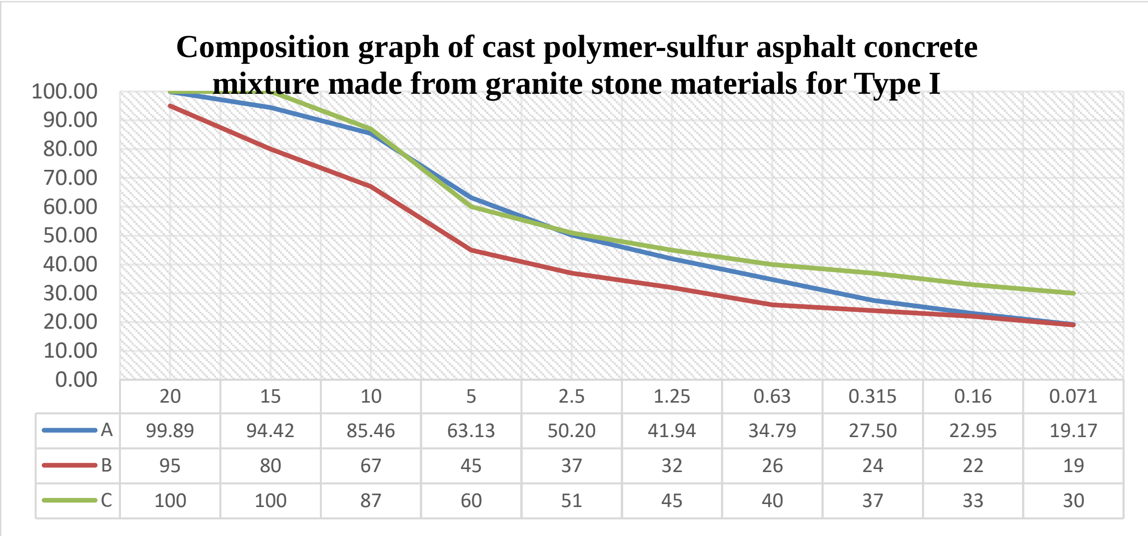
have been developed, and a new composition for the production of cast polymer-sulfur asphalt concrete mixtures of types I, II, and III has been developed.



Graph 1.

Based on the aforementioned granular composition, a type I cast polymer-sulfur asphalt concrete mixture made of granite stone materials was prepared using 7 different compositions with a binder content ranging from the lower to the upper limit of 0.2%, and cast asphalt concrete samples were prepared from it.

Based on the above-mentioned compositions, 7,7%, 7,9%, 8,1%, 8,3%, 8,5%, 8,7%, 8,9% modified sulfur bitumen was added to the inert materials (modified sulfur content in the binder was 40%), and a cast asphalt concrete mixture was prepared from which samples were made [12]. The physical and mechanical properties of the samples were determined and compared with the requirements of the regulatory document (Table 2).

Table 2 **The physical and mechanical properties of I-type polymer sulfur asphalt concrete cast from granite stone materials**

№	Binder content, %	Water saturation, %	Water resistance, %	Compressive strength, 20 ^{0}C, MPa	Compressive strength, 50 ^{0}C, MPa	Compressive strength, 60 ^{0}C, MPa	Compressive strength, 70 ^{0}C, MPa	Compressive strength, 0 ^{0}C, MPa	Resistance to cracking, MPa	Easy spreading of the mixture ,mm
1	7,7	0,52	0,81	2,62	1,35	1,14	0,89	7,1	10,5	21
2	7,9	0,42	0,83	2,69	1,38	1,12	0,91	7,3	11,2	24
3	8,1	0,15	1,03	2,68	1,39	1,18	0,93	7,2	11,4	27
4	8,3	0,04	0,95	2,63	1,23	1,11	1,01	7,7	11,96	32
5	8,5	0,13	0,84	2,81	1,16	0,98	0,85	6,8	13,8	34
6	8,7	0,09	0,9	2,55	1,04	0,89	0,78	6,24	12,16	33
7	8,9	0,14	0,87	2,48	0,97	0,85	0,75	6,12	11,42	34

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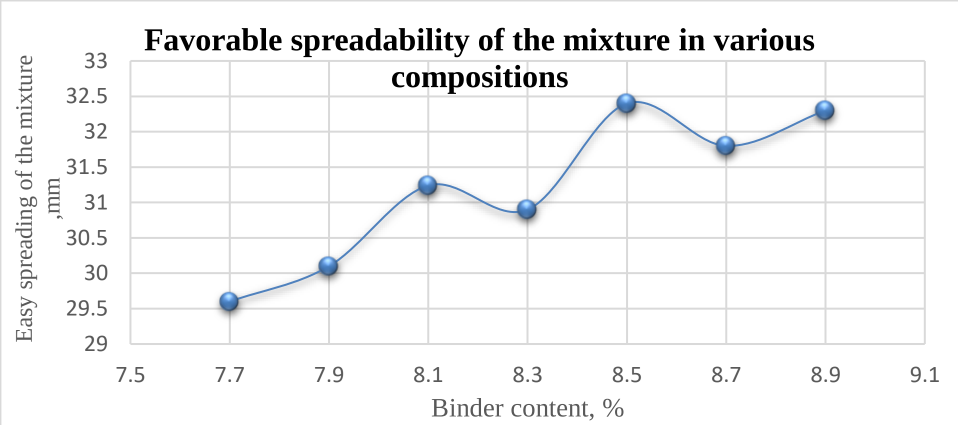
DISCUSSION

High physical and mechanical properties of cast asphalt concrete samples (polymer content in the binder 40 %) were achieved with a binder content of 8,3 %.

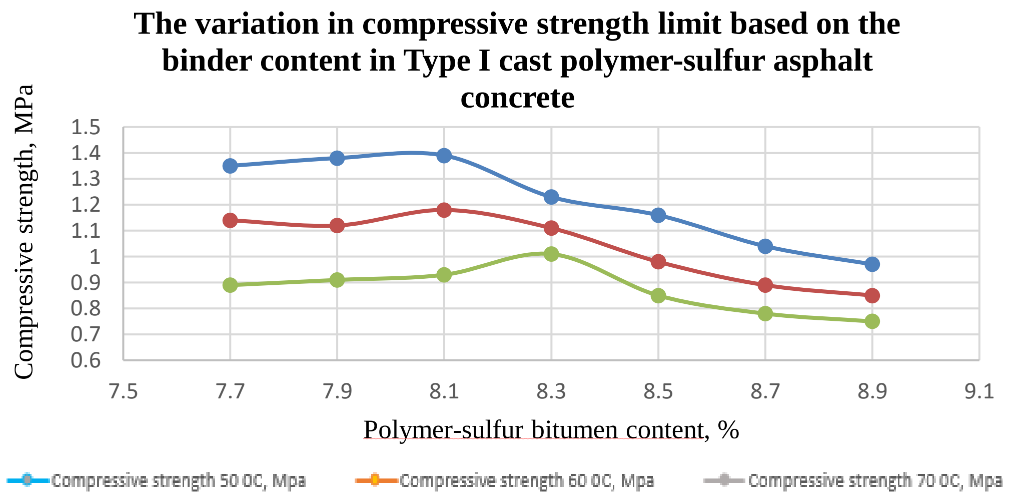
The optimal spread ability index of the mixture is one of the main indicators of cast polymer-sulfur asphalt concrete. Therefore, the optimal spread ability indices of mixtures prepared based on the aforementioned compositions have been determined. The analysis of a type I cast polymer-sulfur asphalt concrete mixture made of granite stone materials is presented in Graph 2.



Graph 2.

The graph above illustrates the spread ability index of the mixture corresponding to the bitumen content. According to the regulatory document requirements, the spread should be at least 30 mm. We can observe that when the binder content in the mixture is 7.7%, 7.9%, 8.1%, 8.3%, 8.5%, 8.7%, and 8,9%, the spread ability index satisfies the requirements of the regulatory document. When the binder content was 8,3%, the physical and mechanical properties of cast polymer-sulfur asphalt concrete samples showed the highest performance.

The analysis of the physical and mechanical properties of cast polymer-sulfur asphalt concrete samples is presented in the following graph 3.



Graph 3.

CONCLUSION

In conclusion, it can be said that the performance indicators of the cast polymer-sulfur asphalt concrete pavement, manufactured based on the newly developed composition, such as crack resistance and resistance to high temperatures, have been improved. By applying a mixture made from this composition, especially on highways in areas with hot climates, bridge decks, and during pavement repair work, we can enhance the performance characteristics of the pavement and, as a result, increase its service life.

REFERENCES:

1. Sodiqov Ibrohim Solihovich, Tilakov Suxrob Muxammadiyevich, Mamatmuminov Alisher Turaqulovich. "QUYMA SEROASFALTBETONNING CHET EL TAJRIBASINI TAHLIL QILIB O'ZBEKISTON SHAROITIDA QO'LLASH," Me′morchilik va qurilish muammolari, vol. 1, p. 4, 2022.
2. Иванов Владимир Борисович (RU), Валиев Тагир Шарифьянович (RU) and (73), "RU 2452748 C1 СПОСОБ ПОЛУЧЕНИЯ СЕРОБИТУМА"
3. Мотин Николай Васильевич (RU), and Я. В. В. (RU) Шубин Александр Николаевич (RU), "RU 2 554 585 C2 модификация серо," 2015
4. Obryvalina Anna Nikolaevna (RU), and N. I. G. (RU) ZHeleznov Mikhail Vladimirovich (RU), SHerstnev Oleg Aleksandrovich (RU), Spuskov Vladimir Aleksandrovich (RU), "RU2 585 618 C1 СПОСОБ ПОЛУЧЕНИЯ СЕРОБИТУМНОГО ВЯЖУЩЕГО," 2016
5. ПРОНИН ВЛФДИМР ВИКТОРОВИЧ, "ЛИТОЙ АСФАЛЬТОБЕТОН ПОВЫШЕННОЙ СДВИГОУСТОИЧИВОСТИ ДЛЯ ПОКРЫТИЙ АВТОМОБИЛЬНЫХ ДОРОГ," Ростов - на - Дону, 2000.
6. ГОСТ 22245. "БИТУМЫ НЕФТЯНЫЕ ДОРОЖНЫЕ ВЯЗКИЕ Технические условия."
7. ГОСТ 11501. "БИТУМЫ НЕФТЯНЫЕ. МЕТОД ОПРЕДЕЛЕНИЯ ГЛУБИНЫ ПРОНИКАНИЯ ИГЛЫ."
8. ГОСТ 11506. "БИТУМЫ НЕФТЯНЫЕ МЕТОД ОПРЕДЕЛЕНИЯ ТЕМПЕРАТУРЫ РАЗМЯГЧЕНИЯ ПО КОЛЬЦУ И ШАРУ," Москва, 2008.
9. МЕТОД ОПРЕДЕЛЕНИЯ. РАСТЯЖИМОСТИ, "ГОСТ 11505. Битумы нефтяные," 2005.
10. Sodiqov Ibrohim Solihovich, Tilakov Suxrob Muxammadiyevich, Sottiqulov Elyor Sotimboyevich, Mamatmuminov Alisher Turaqulovich. "SEROBITUM TAYYORLASH TEXNOLOGIYASINI TAKOMILLASHTIRISH," Me'morchilik va qurilish muammolari, vol. 3, p. 5, 2022.
11. S. M. Tilakov, I.S.Sodiqov, "ASFALTBETON QOPLAMALARINI YOTQIZISH JARAYONIDA ATROF MUHITGA CHIQAYOTGAN ZAHARLI GAZLAR MIQDORINI KAMAYTIRISH TEXNOLOGIYASI," Termiz muhandislik texnologiya institutida "Respublikamizda Ekol. va hayot faoliyati xavfsizligi muammolari va yechimlari" Resp. anjumani, vol. 4, no. 1, pp. 9–15, 2024.
12. ПНСТ 266-2018, "СМЕСИ СЕРОАСФАЛЬТОБЕТОННЫЕ ЛИТОЙ. ТУ".