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# STUDY OF THE PHYSICO-CHEMICAL PROPERTIES OF THE ROAD BITUMEN ORB 70/100

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**Abstract.** *Introduction.* The practice of the motor roads operation in the Republic of Kazakhstan shows that the durability of asphalt concrete pavements on them is much lower than the standard terms. Therefore, maintaining roads in a condition, which meets the requirements of traffic flows is impossible without the use of new, progressive materials and technologies. The main factor influencing a sharp decrease in the service life of the road surfaces is the use of low-quality bitumen as a binder in asphalt concrete mixtures, since microcracks develop mainly in its film. *The goal of the work*. In this paper, the physical and mechanical properties of bitumen of the grade ORB(oil road bitumen) 70/110 of the Aktau bitumen plant have been studied. *Methods.*To improve the operational characteristics of bitumen, modification with polyethylene and polystyrene waste has been carried out. *Results and discussion.* It has been shown that after the addition of the modifying additives, the main indicators of bitumen have improved. For polyethylene: the depth of needle penetration has decreased from 70 down to 61 mm, the extensibility of bitumen has decreased by 52 cm, which indicates an improvement in the plasticity and elasticity, the softening temperature along the ring and ball has increased from 49 up to 59 °C, which leads to reducing the tendency of bitumen deformation, and the brittleness temperature has been within the normal range - not less than -20 °C. In case of using polystyrene, the penetration characterizing the bitumen hardness decreases from 70 mm down to 61 mm; the extensibility of bitumen increases by 10 cm, which indicates an improvement in the elasticity and strength, due to the presence of the resulting structural network. *Conclusion.* The softening temperature of bitumen increases, which leads to an improvement in the heat resistance and viscosity.

**Key words:** petroleum road bitumen, ORB 70/110, polymer waste, polyethylene, polystyrene, penetration, extensibility, softening and brittleness temperature

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## 1. Introduction

One of the topical issues in the oil refining industry is the problem of improving the quality of petroleum products, which include petroleum bitumen. Despite the fact that the performance properties of bitumen meet the necessary requirements, the road surfaces based on them do not always meet the climatic conditions of operation in our country.

Road oil bitumen is sensitive to the temperature changes, i.e. become brittle in the cold, and soften at elevated temperatures, leading to punching and deformation of road surface [1].

The performance properties of bitumen under the influence of the aggressive environment also deteriorate, and may not always meet the desired performance requirements.

Thus, petroleum bitumen is the cheapest and most versatile material for using as a binder for the construction of the road surfaces [2].

Often, up to 30% of various products are added to tars and heavy residues of oil refining, which is necessary to improve the quality of the binder produced. If the additives are not added, the resulting binders become brittle and lose their elasticity.

The main physical and chemical indicators of bitumen, which affect its performance properties include: penetration, brittleness temperature, softening temperature, extensibility. Improvement of these indicators can be achieved by introducing waste polymers into the composition of the bituminous compositions [3-7].

The addition of polymer waste to oil road bitumen increases its elasticity and strength, making the road surface more durable and resistant to the thermal and mechanical stress. Also, the addition of a polymeric material improves the spatial structure of a binder [8-11].

The construction industry occupies one of the first places among the largest consumers of polymeric materials. The widespread use of polymeric materials in construction is facilitated not only by the high chemical resistance, good decorative properties of many of them, but also by the comparative ease of use, manufacturability, etc.

Therefore, at present, the problem of processing the waste polymer materials is becoming relevant not only from the standpoint of environmental protection, but also due to the fact that in the conditions of a shortage of polymer raw materials, the plastic wastes often become a raw material and energy resource [12].

The involvement of a number of wastes from the petrochemical industries will significantly improve the technogenic situation at the enterprises and make it possible to more efficiently use the useful potential of the secondary wastes.

However, the use of the waste polymeric materials as additives in the Republic of Kazakhstan has been little studied. Therefore, the research in the field of improving the physical and mechanical properties of road bitumen by introducing the polymer waste remains relevant to this day.

## 2. Experimental part

The study object is the oil road bitumen ORB 70/100 of the Aktau bitumen plant. Bitumen of this grade is a large-tonnage product of oil refining, has a complex of valuable technical properties and is widely used in the manufacture of asphalt concrete mixtures in the road construction. The raw material for the production of bitumen is tar (heavy oil residue of vacuum distillation). The physical and chemical properties of ORB 70/100 bitumen are presented in Table 1.

**Table 1** - Physical and chemical properties of ORB 70/100

| Indicator | Value |
|---|---|
| Needle penetration depth, 0.1 mm:<br>- at 25 °C<br>- at 0 °C | <br>70<br>22 |
| Softening temperature for ring and ball, °C | 49 |
| Extensibility at 25 °C, cm | 71 |
| Brittleness temperature, °C | -21 |

To improve the performance properties of bitumen, various modifying additives are used, in particular the polymer waste. The use of the waste polymers can significantly save the primary raw materials and electricity. For example, the production wastes of polystyrene and polyethylene do not differ from primary raw materials in their physical, mechanical and technological properties. They are returnable and are mainly used at the enterprises where they are formed. They can also be used as independent raw materials in the production of various products. And in order to improve ecological and economic situation in our country, polymer waste can be effectively used as modifying additives.

Secondary polyethylene and polystyrene are taken as the road bitumen modifiers. Before the modification process, polystyrene and polyethylene are processed, washed with distilled water, dried and turned into a homogeneous material. Secondary polyethylene is added together with the used industrial oil grade I-40, which is a plasticizer. The plasticizer reduces the mixing time of bitumen with the polymer, increases the viscosity and improves the properties of the resulting polymer-bitumen binder.

Polystyrene is introduced into bitumen without a plasticizer, because it simultaneously serves as a modifier and plasticizer, due to its cyclic structure, which in turn leads to the rapid adhesion of bitumen and polystyrene molecules.The experiments have been carried out as part of the laboratory studies, so yogurt waste has been taken as polystyrene.

## 3. Results and discussion

To improve the performance characteristics of bitumen, a modification of polyethylene and polystyrene with waste has been carried out.

*Method for the preparation of polymer bitumen binder.* The required amount of bitumen is heated in a metal container, a plasticizer is added in an amount of

3% by weight of bitumen, and then heating is turned on. At a temperature of 150-160 °C, secondary polyethylene is introduced into the molten bitumen in the form of flakes, in the amount of 1, 2, 3% by weight of bitumen, then the heating temperature is brought to 180-200 °C. Mixing is carried out for 30-40 minutes. Bitumen is modified with polystyrene without a plasticizer by a similar method. Table 2 shows the component composition of a polymer bitumen binder based on polyethylene and polystyrene.

**Table 2** - Component composition of bitumen, modified with polyethylene and polystyrene

| Materials | Bitumen + polyethylene | | | Bitumen + polystyrene | | |
|---|---|---|---|---|---|---|
| | SampleNo. | | | SampleNo. | | |
| | 1 | 2 | 3 | 1 | 2 | 3 |
| ORB 70/100, g | 300 | 300 | 300 | 300 | 300 | 300 |
| Secondary polyethylene, g | 3 | 6 | 9 | - | - | - |
| Secondary polystyrene, g | - | - | - | 3 | 6 | 9 |
| I-40, g | 9 | 9 | 9 | - | - | - |

Physical and mechanical properties of bitumen have been evaluated by the penetration, ductility, softening points, viscosity and brittleness, which give an almost complete picture of it.

The parameters of polymer-bitumen binder modified polyethylene have been studied: the needle penetration depth, ring and ball softening temperature, extensibility at 25 °C, brittleness temperature. The experiment results are presented in Table 3.

**Table 3 -** Characteristics of bitumen modified with polyethylene

| Indicator | Value | | | |
|---|---|---|---|---|
| Modifier amount, % | 0 | 1 | 2 | 3 |
| Needle penetration depth, 0.1 mm:<br>at 25°C<br>at 0°C | <br>70<br>22 | <br>67<br>24 | <br>64<br>23 | <br>61<br>23 |
| Extensibility at 25 °C, cm | 71 | 47 | 27 | 19 |
| Softening temperature according to ring and ball, °C | 49 | 51 | 55 | 59 |
| Brittleness temperature, $^0$C | -21 | -21 | -21 | -20 |

As can be seen from Table 3, the required performance properties of bitumen can be achieved by varying the modifier content i.e. recycled secondary polyethylene. From the data obtained, it can be seen that in case of introducing polyethylene into bitumen at 25 °C: penetration decreases down to 61 mm, extensibility decreases from 71 down to 19 cm, which indicates an improvement in the plasticity and elasticity of bitumen. The softening temperature along the ring and ball has increased from 49 up to 59°C, which leads to a decrease in the tendency for bitumen deformation. The brittleness temperature is within the normal range - not less than -20°C. As an example, Figure 1 shows the graphical

dependence of the needle penetration depth on the quantitative content of polyethylene.

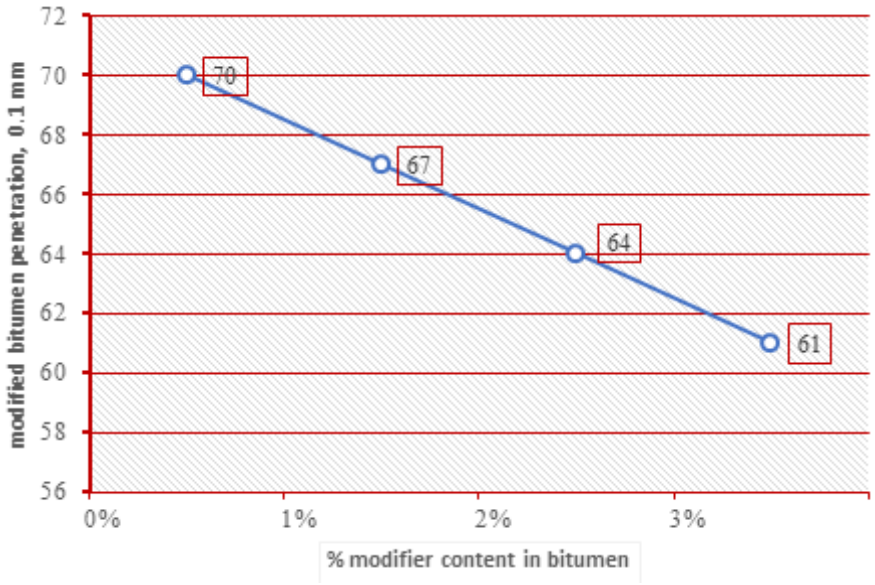


**Figure 1** - Dependence of the needle penetration on the percentage of polyethylene

Table 4 shows the results of modifying the ORB 70/100 bitumen, using the secondary polystyrene.

**Table 4** - Characteristics of bitumen, modified with polystyrene

| Indicator | Value | | | |
|---|---|---|---|---|
| Modifier amount, % | 0 | 1 | 2 | 3 |
| Needle penetration depth, 0.1 mm: | | | | |
| at 25°C | 70 | 65 | 63 | 61 |
| at 0°C | 22 | 24 | 23 | 23 |
| Extensibility at 25°C, cm | 71 | 74 | 75 | 81 |
| Softening temperature according to ring and ball, °C | 49 | 50 | 54 | 57 |
| Brittleness temperature, °C | -21 | -21 | -21 | -20 |

Table 4 shows a decrease in the penetration depth of the needle at 25°C from 70 mm down to 61 mm, which characterizes bitumen hardness. The extensibility increases by 10 cm, which indicates an improvement in the elasticity and strength of bitumen, due to the presence of the resulting structural network. The softening temperature increases, which leads to an improvement in the heat resistance and viscosity of bitumen. Figure 2 shows a graphical dependence of the softening point on the % content of polystyrene.

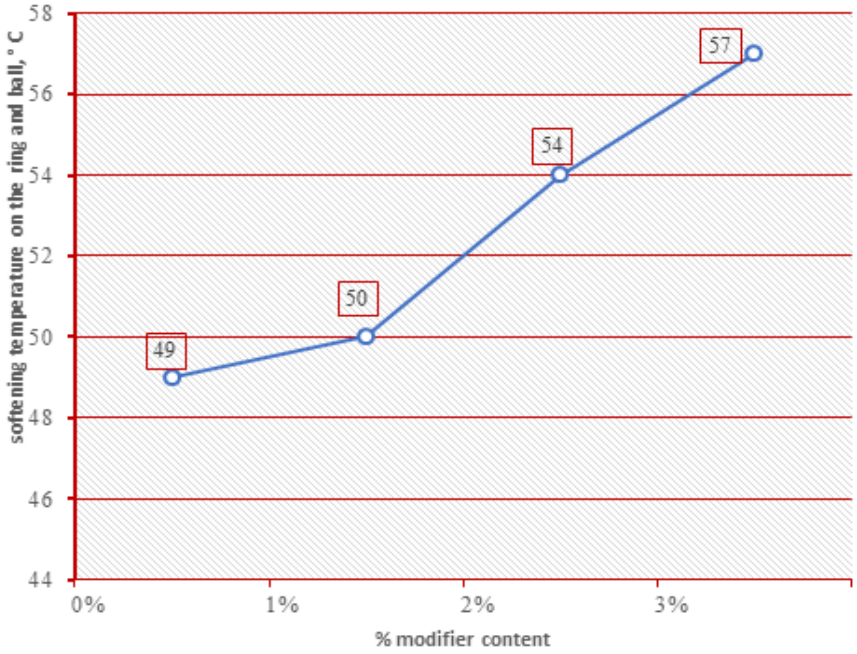


**Figure 2** - Dependence of the softening temperature on the percentage of polystyrene

Thus, according to the study results, it can be concluded that the use of polymer waste as a modifier significantly improves the performance of the road bitumen of the grade ORB 70/100. The best results are obtained with the addition of 3% polymers, in the both cases. With an increase in the percentage of polymer waste in bitumen, the softening point increases and thereby increases the heat resistance.With a decrease in the bitumen penetration, its rigidity increases and resistance to the thermal and mechanical tiredness increases, wear resistance increases. The temperature resistance, hardness and elasticity of the obtained polymer-bitumen binder allow the road structure to have high resistance to deformation and an ability to operate in the regions with the elevated temperature climate.

## 4. Conclusion

In this paper, bitumen of the grade ORB 70/110 from the Aktau oil refinery has been studied. To improve the physical and mechanical properties of bitumen, a modification with polyethylene and polystyrene waste has been carried out. It should be noted that by choosing the right mixing conditions, the type and ratio of the polymer components, it is much easier to obtain materials with the required properties than to synthesize new ones. The resulting composite materials have

improved the physical, mechanical and thermal properties as compared with the materials from the traditional raw materials [13].

Polymer waste polyethylene and polystyrene in the form of flakes are mixed with hot oil bitumen, while bitumen penetrates into the polymer particles, causing them to swell and melt.

The efficiency of the modification process of the bitumen depends on a number of factors: the smaller the particle size of the polymer, the greater their surface area and the faster its penetration. The higher the process temperature, the faster the polymer particles penetrate into the bitumen; the better the mixing, the faster the uniform distribution of the polymer and its complete fusion with bitumen is ensured.

In the process of modifying bitumen, an intermolecular force of adhesion of structural elements in a dispersion medium is created. The combination mechanism takes place at the elevated temperatures and constant stirring, followed by the formation of a homogeneous system. An important factor in this case is the structural stability of the polymer bitumen binder, which prevents the further separation of bitumen and polymer.

Thus, the use of recycled polyethylene and polystyrene waste can save primary raw materials, and also has a positive impact on the country's ecology, making it possible to process the stocks of the secondary polymer raw materials and waste oils, while improving the performance of the organic binders.

**БНД 70/100 МАРКАЛЫ ЖОЛ БИТУМЫНЫҢ ФИЗИКАЛЫҚ-ХИМИЯЛЫҚ ҚАСИЕТТЕРІН ЗЕРТТЕУ**

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**Түйіндеме.** *Kipicne.* Қазақстан Республикасының автомобиль жолдарын пайдалану тәжірибесі асфальтбетонды жабындардың төзімділігі стандартты мерзімнен әлдеқайда төмен екенін көрсетеді. Сондықтан жаңа, прогрессивті материалдар мен технологияларды қолданбай жолдарды көлік ағынының талаптарына жауап беретін жағдайда ұстау мүмкін емес. Жол төсемінің қызмет ету мерзімінің күрт төмендеуіне әсер ететін негізгі фактор асфальтбетон қоспаларында байланыстырғыш ретінде сапасыз битумды пайдалану болып табылады, өйткені микрожарықтар негізінен оның қабығында пайда болады. *Жұмыс мақсаты* - полимер қалдықтарын пайдалана отырып, эксплуатациялық қасиеттері жақсартылған асфальтбетон алу. *Әдістер.* Алынған өнімнің құрамы мен қасиеттерін зерттеу үшін химиялық және физика-химиялық талдау әдістері: рентгенфлюоресценті спектроскопия және растрлі электронды микроскопия қолданылды. *Аталған әдістермен* Актау битум өңдеу зауытының БНД 70/110 маркалы битумының физика-механикалық қасиеттері зерттелді. Битумның эксплуатациялық қасиеттерін жақсарту үшін полиэтилен (ПЭ) және полистирол (ПС) қалдықтарымен модифицирлеу жүргізілді. Екінші реттік ПЭ И-40 маркалы (пластификатор) өнеркәсіптік маймен бірге қосылды. Пластификатор битумды полимермен араластыру уақытын азайтады, тұтқырлықты арттырады және алынған ПБВ қасиеттерін

жақсартады. ПС битумға пластификаторсыз енгізіледі, өйткені ол бір уақытта модификатор және пластификатор ретінде қызмет етеді. *Нәтижелер және талқылау.* Модифицирлеуші қоспаларды қосқаннан кейін битумның негізгі көрсеткіштері жақсарғаны көрсетілген. Полиэтилен қоспасы үшін иненің ену тереңдігі (пенетрация) 70-тен 61 мм-ге дейін, созылғыштығы 52 см-ге азайды, бұл битумның пластикалық және серпімділік қасиеттері жақсарғанын көрсетеді, КиШ бойынша жұмсарту температурасы 49-дан 59 $^0$С-қа дейін өсті, бұл битумның деформацияға бейімділігінің төмендеуіне алып келеді, ал сынғыштық температурасы қалыпты диапазонда, яғни -20 °С төмен емес. Полистиролды пайдаланған жағдайда битумның қаттылығын сипаттайтын пенетрация 70 мм-ден 61 мм-ге дейін төмендейді; созылғыштық 10 см-ге артады, бұл пайда болатын құрылымдық желінің болуына байланысты битумның серпімділігі мен беріктігінің жақсарғанын көрсетеді. Жұмсарту температурасы жоғарылайды, бұл битумның ыстыққа төзімділігі мен тұтқырлығының жақсаруына алып келеді. *Тұжырым.* ПЭ және ПС қалдықтарын пайдалану бастапқы шикізатты үнемдеуге мүмкіндік береді. Сондай-ақ органикалық тұтқыр материалдардың эксплуатациялық сипаттамаларын жақсарта отырып, қайталама полимерлі шикізат пен пайдаланылған майлардың қалдықтарын қайта өңдеуге мүмкіндік береді және экологияғада оң әсер ететіні анықталды.

**Түйінді сөздер:** мұнай жол битумы, БНД 70/110, полимер қалдықтары, полиэтилен, полистирол, ену, созылу, жұмсарту және сынғыштық температуралары

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## ИССЛЕДОВАНИЕ ФИЗИКО-ХИМИЧЕСКИХ СВОЙСТВ ДОРОЖНОГО БИТУМА МАРКИ БНД 70/100

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**Резюме.** *Введение.* Практика эксплуатации автомобильных дорог РК показывает, что долговечность асфальтобетонных покрытий на них значительно ниже нормативных сроков. Поэтому поддержание автомобильных дорог в состоянии, соответствующем требованиям транспортных потоков невозможно без применения новых, прогрессивных материалов и технологий. Основным фактором, влияющим на резкое снижение сроков службы дорожных покрытий, является применение в асфальтобетонных смесях в качестве вяжущего, битума низкого качества, так как микротрещины развиваются преимущественно в его пленке. *Цель* - Получение асфальтобетона с улучшенными эксплуатационными характеристиками с использованием отходов полимеров. *Методология* работы включала исследование физико-механических свойств битума марки БНД 70/110 Актауского битумного завода. Для повышения эксплуатационных харктеристик битума проведено модифицирование отходами полиэтилена (ПЭ) и полистирола (ПС). Вторичный ПЭ добавляли вместе с отработанным индустриальным маслом марки И-40, который является

пластификатором. Пластификатор уменьшает время смешения битума с полимером, повышает вязкость и улучшает свойства получаемого ПБВ. ПС вводят в битум без пластификатора, т.к. он одновременно служит как модификатор и пластификатор. *Результаты и обсуждение*: Полученные данные анализа показали, что после добавления модифицирующих добавок основные показатели битума улучшились. Для ПЭ: глубина проникания иглы (пенетрация) уменьшилась с 70-ти до 61 мм, растяжимость снизилась на 52 см, что свидетельствует об улучшении пластичности и эластичности битума, температура размягчения битума по КиШ повысилась от 49 до 59°С, что приводит к снижению склонности битума к деформации, а температура хрупкости находится в пределах нормы, т.е. не менее -20 °С. В случае использования ПС пенетрация, характеризующая твердость битума уменьшается с 70 мм до 61 мм; растяжимость увеличивается на 10 см, что свидетельствует об улучшении эластичности и прочности битума, за счет наличия образовавшейся структурной сетки. Повышается температура размягчения, которая ведет к улучшению теплостойкости и вязкости битума. *Заключение*: Установлено, что применение вторичных отходов ПЭ и ПС позволяют сэкономить первичное сырье, а также оказывает положительное влияние на экологию, позволяя переработать отходы вторичного полимерного сырья и отработанных масел, при этом улучшаются эксплуатационные характеристики органических вяжущих материалов.

**Ключевые слова:** нефтяной дорожный битум, БНД 70/110, полимерные отходы, полиэтилен, полистирол, пенетрация, растяжимость, температура размягчения и хрупкости

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