Crossref
DOI: 10.31643/2027/6445.21
Mining & Mineral Processing

Polymer-bitumen compositions for improving the energy efficiency of road construction

[1*] Syzdyk A.G., [1] Seitenova G.Z., [2] Dyussova R.M., [1] Zhakmanova E.A., [1] Donbayeva E.

[1] L.N. Gumilyov Eurasian National University, Republic of Kazakhstan, Astana
[2] Toraighyrov University, Republic of Kazakhstan, Pavlodar

** Corresponding author email: ayazhanka.syzdyk@gmail.com*

Received: *May 6, 2025*
Peer-reviewed: *September 4, 2025*
Accepted: *November 26, 2025*

ABSTRACT

This article examines the effect of two types of polypropylene (H030 and H350) and petroleum residue on the bitumen modification process. Bitumen modification is one of the key methods for improving its physical and mechanical properties and enhancing the quality of road pavement. Currently, bitumen modification is widely used in road construction, playing a crucial role in improving its quality and energy efficiency. Studying the effect of polymers on the mechanical stability of bitumen is a relevant issue in increasing the durability of road surfaces. During the study, six different concentrations of polypropylene H030 and H350 were introduced into bitumen samples, and their main characteristics were compared. The obtained results demonstrated that polypropylene significantly alters the properties of bitumen, contributing to increased strength and durability of road pavements. Furthermore, the addition of petroleum residue enhances the rheological properties of the bitumen mixture, improving its adhesion. These studies provide essential data for improving bitumen used in road construction. The research results indicate that the use of polymer-modified bitumen increases the wear resistance of road surfaces, reduces crack formation, and enhances resistance to climatic factors. This, in turn, extends the service life of road pavements and reduces road maintenance costs. Long-lasting pavements help decrease energy consumption for bitumen production and road construction. The obtained data expand the possibilities for the effective use of polymer-modified bitumen mixtures in asphalt concrete production. Thus, the compatibility of bitumen and polypropylene has been studied, and their optimal compositions have been determined.

Keywords: bitumen, polypropylene, modified bitumen mixtures, petroleum residue, asphalt concrete, energy efficiency.

Information about authors:

Syzdyk Ayazhan Galymkyzy — *Master's student in the Faculty of Natural Sciences, L.N. Gumilyov Eurasian National University, Kazhymukan str., 13, 010000, Astana, Kazakhstan. E-mail: ayazhanka.syzdyk@gmail.com; ORCID ID: https://orcid.org/0009-0007-4435-0976*

Seitenova Gaini Zhumagalievna — *Candidate of chemical sciences, associate professor, Faculty of natural sciences, L.N. Gumilyov Eurasian National University, Satbayev str., 2, 010000, Astana, Kazakhstan. E-mail: gainiseitenova@gmail.com; ORCID ID: https://orcid.org/0000-0001-6202-3951*

Dyussova Rizagul Muslimovna — *Candidate of technical sciences, postdoctoral researcher, Toraighyrov University, Lomova str., 64, 140000, Pavlodar, Kazakhstan. E-mail: riza92@bk.ru; ORCID ID: https://orcid.org/0000-0003-3083-5255*

Zhakmanova Ekaterina Andreevna — *PhD student in the Faculty of Natural Sciences, L.N. Gumilyov Eurasian National University, Kazhymukan str., 13, 010000, Astana, Kazakhstan. E-mail: Ekaterina.zakmanova1998@gmail.com; ORCID ID: https://orcid.org/0000-0003-0545-5912*

Donbayeva Elvira — *Senior lecturer, Department of Chemistry, Faculty of Natural Sciences, L.N. Gumilyov Eurasian National University, 13 Kazhymukan str., 010000, Astana, Kazakhstan. E-mail: donbayeva_ek@enu.kz; ORCID ID: https://orcid.org/0009-0005-0762-1488*

Introduction

Research aimed at improving the quality of bitumen-based materials in road construction holds significant importance. Modification of bitumen is one of the key approaches to enhancing its physical and mechanical properties and ensuring the long-term durability of road pavements. Currently, polymer-modified bitumen mixtures are widely applied, as they improve thermal stability and increase mechanical strength [[1], [2]].

Bitumen is a complex organic binder composed of high-molecular-weight hydrocarbons and their derivatives. Its key properties include softening point, penetration depth, viscosity, plastic deformation capability, and wear resistance. These

parameters directly affect the quality of road surfaces [[3], [4]]. However, neat bitumen has several disadvantages; therefore, research is being actively carried out to improve its properties through various modifiers [5].

Among these, polymer modification occupies a special place. Polypropylene is one of the thermoplastic polymers frequently used in bitumen modification. It is characterized by high mechanical strength and chemical stability. Studies have shown that the addition of polypropylene increases the elastic modulus of bitumen, enhances its resistance to cracking, raises the softening point, and reduces penetration depth. These improvements make polymer-modified bitumen suitable for use under hot climatic conditions [[6], [7], [8], [9]].

Oil residues are also among the important compounds used to improve bitumen. Heavy fractions from oil refining reduce the viscosity of bitumen, enhance its low-temperature performance, and improve the homogeneity of the mixture [[10], [11]]. The combined use of polypropylene and oil residue enhances the elastic properties of bitumen and contributes to its long-term stability [12]. Such mixtures have been shown to exhibit greater crack resistance while also improving adhesion properties [13].

In recent years, research in this field has become increasingly relevant. First, studying the combined effect of polymers and oil residues aims to improve the quality of road pavements under various climatic conditions. Second, the use of recycled polymer waste is considered an environmentally friendly solution [[14], [15]]. In addition, current studies are also focused on investigating compatibility with nanocomposites and other functional additives [[16], [17]].

In this regard, the present study focuses on identifying the effect of polypropylene grades H030 and H350, together with oil residue, on the physical and mechanical properties of bitumen mixtures. Samples obtained at different concentrations were comparatively analyzed in terms of softening point and penetration depth. Moreover, the influence of the obtained results on the rheological characteristics of bitumen and asphalt concrete mixtures was also examined [[18], [19], [20]].

The scientific novelty of this study lies in the comparative analysis of the effects of polypropylene grades H030 and H350 on the properties of bitumen. Furthermore, for the first time, the combined use of polypropylene and oil residue has been comprehensively studied in relation to improving the structural stability and adhesion properties of the mixtures. The research was carried out on samples adapted to the climatic conditions of Kazakhstan, and the results obtained have practical significance for local road construction.

Experimental part

For the research, the following materials were used: bitumen of grade BND 100/130 provided by Pavlodar Oil Chemistry Refinery LLP (Kazakhstan). BND 100/130 bitumen possesses high viscosity and is widely applied in the production of road pavements with properties required for operation under various climatic conditions. Polypropylene grades PP H350 and PP H030 were supplied by “Neftekhim LTD” LLP and prepared in accordance with the National Standard of the Republic of Kazakhstan, ST RK 3191-2018. Polypropylene (PP) is a thermoplastic material based on propylene (propene). This polymer contributes to enhancing the strength, crack resistance, elasticity, and durability of polymer-modified bituminous (PMB) materials. Heavy oil residue of grade H603 was provided by Pavlodar Oil Chemistry Refinery LLP and used to regulate the viscosity and improve the technological properties of PMB mixtures. The addition of oil residue increased the fluidity of the material and ensured uniform distribution of the components within the mixture. This made it possible to achieve an optimal balance between viscosity and plasticity, thereby contributing to the durability and stability of road pavements.

The preparation of polymer-bitumen compositions is a multistage and complex process in which a modified structure is formed as a result of the physical and chemical interactions of the components. In this study, the compositions were prepared using a laboratory disperser unit.

Initially, the containers and equipment required for the experiment were thoroughly cleaned and dried to remove moisture residues. This step was essential to prevent the influence of external factors that could negatively affect the quality of the final product. Before use, all vessels were checked to ensure they were free of contamination and traces of moisture.

At the next stage, the bitumen was poured into a thermostable container and heated to the working temperature range of 120-150 °C. Such conditions reduce the viscosity of bitumen and allow better mixing with the polymer.

The required amount of polymer was then weighed in advance and calculated relative to the

mass of bitumen. The polymer concentration was selected depending on the modification level and the expected properties of the composition.

The preheated bitumen was combined with the measured polymer, and the mixture was stirred in the laboratory disperser. This process was carried out at 165-170 °C for up to 120 minutes. The mixing time and speed were determined based on the characteristics of the polymer used and the desired degree of dispersion. The high-speed stirrer ensured the uniform distribution of the components.

Once the mixture reached a homogeneous consistency, an additional maturation stage was carried out to strengthen the formation of molecular-level interactions between its constituents. During this period, the mixture was maintained at 160-170 °C for a specified duration.

The polymer-bitumen compositions prepared in this way were then subjected to standard testing. The softening point, penetration depth, and other characteristics were determined in accordance with the Standards of the Republic of Kazakhstan (ST RK). The compositions of the PMB mixtures are presented in the table below (Table 1):

Table 1 - Composition of PMB: proportion of bitumen, polypropylene, and oil residue

Sample No	1	2	3	4	5	6	7
Bitumen BND 100/130	100 %	95.7 %	95.1 %	94.5 %	93.5 %	93%	92%
PP H030 / PP H350	0	4%	4%	4%	4%	4%	4%
Oil residue	0	0.3%	0.9%	1.5%	2.5%	3%	4%

Table 1 presents the percentage composition of bitumen (BND 100/130), polypropylene (H030 or H350), and oil residue for each sample. These data characterize the exact formulations of the initial mixtures used in the study and form the basis for subsequent physical and mechanical testing.

Regarding the methods applied in the research, the penetration depth at 25 °C (with an accuracy of at least 0.1 mm) was evaluated in accordance with ST RK 1226-2003 using a digital automatic penetrometer, model 20-20670, produced by Infratest. According to the test procedure, PMB samples were first heated to 150 °C, then placed into a special container and cooled to 25 °C. A needle with a defined load (typically 100 g) was slowly applied to the surface of the sample. The penetration depth of the needle was measured in millimeters and recorded. This method makes it possible to objectively evaluate the viscosity of PMB materials and their suitability for various operating conditions.

The softening point (°C, minimum value) was determined using an automated device by Infratest, in accordance with ST RK 1227-2003. According to the test procedure, PMB samples were preheated to a temperature of 80-100 °C above the expected softening point but not lower than 120 °C and not exceeding 180 °C to remove moisture. The dehydrated PMB material was filtered, carefully stirred to eliminate air bubbles, and then poured in excess into two rings. After cooling to ambient temperature, the excess material was trimmed with a heated knife. The rings containing PMB material, along with steel balls cooled to (5 ± 1) °C, were placed into a water bath. The water temperature was then increased at a rate of (5.0 ± 0.5) °C per minute. The test continued until the steel ball penetrated the PMB material and touched the bottom plate, at which point the temperature was recorded as the softening point. Strict control of the heating rate ensured the accuracy of the test.

The ductility of bitumen was tested using a digital ductilometer, model 20-2356, in compliance with ST RK 1374-2005. Samples were prepared according to ST RK 1288-2004. Special “figure-eight” shaped molds were used, into which bitumen preheated to 150-180 °C was poured. The molds were then subjected to temperature conditioning. During testing, the samples were stretched in a water bath at 0 °C or 25 °C at a rate of 50 mm/min. The elongation length at break was recorded in centimeters. Each test was conducted on three parallel samples, and the arithmetic mean value was calculated. If the difference between results exceeded the allowable norm, the test was repeated. In cases where the sample did not break at an elongation of 1000 mm, the result was recorded as “>100 cm.”

Although standard testing methods were applied in this study, the influence of ecological factors, economic efficiency, and the probability of phase separation on the obtained results was not considered. These aspects represent the limitations of the study and require further in-depth investigation in the future.

Results and Discussion

In bitumen samples modified with polypropylene (PP H350) and oil residue, the penetration depth decreased with increasing concentration. This indicates an increase in bitumen hardness, meaning the transition of the material to a softened state at elevated temperatures slows down. In particular, for samples containing 1.5% and 2.5% oil residue, the penetration depth sharply decreased, reaching values of 31.4 mm and 47.5 mm, respectively.

The softening point generally showed an upward trend, indicating that the combined addition of polypropylene and oil residue improved the ability of bitumen to retain its shape at high temperatures.

In the sample with 4% oil residue, the softening point reached 66.2 °C, remaining at a relatively stable level compared to the initial value of 66 °C. This demonstrates enhanced thermal stability and strength of the bitumen.

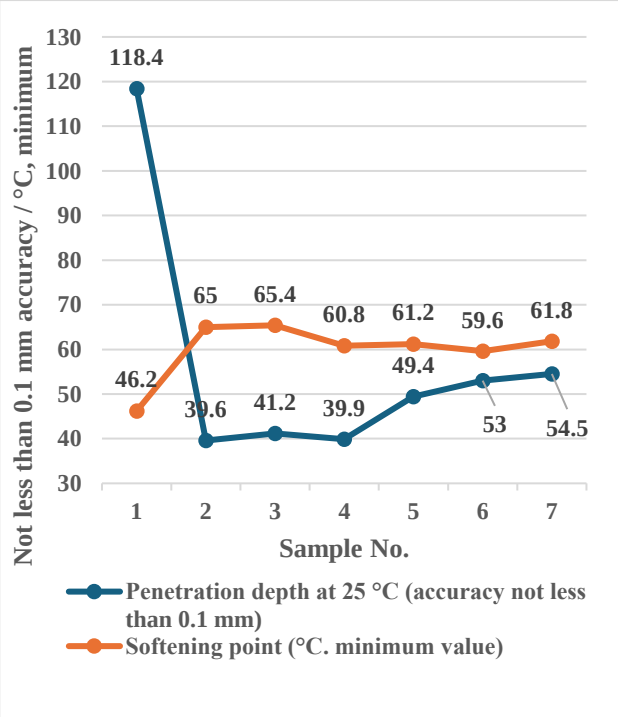

Figure 1 - Thermal Stability and Structural Changes of PMB Based on PP H030

In bitumen samples modified with polypropylene (PP H030) and 3-4% oil residue, the penetration depth increased from the initial 39.6 mm to 54.5 mm. At the same time, the softening point decreased from 65 °C to 61.8 °C.

Although the polypropylene content remained constant (4%), it was found that variations in the concentration of oil residue had a significant impact on the physical and mechanical properties of bitumen.

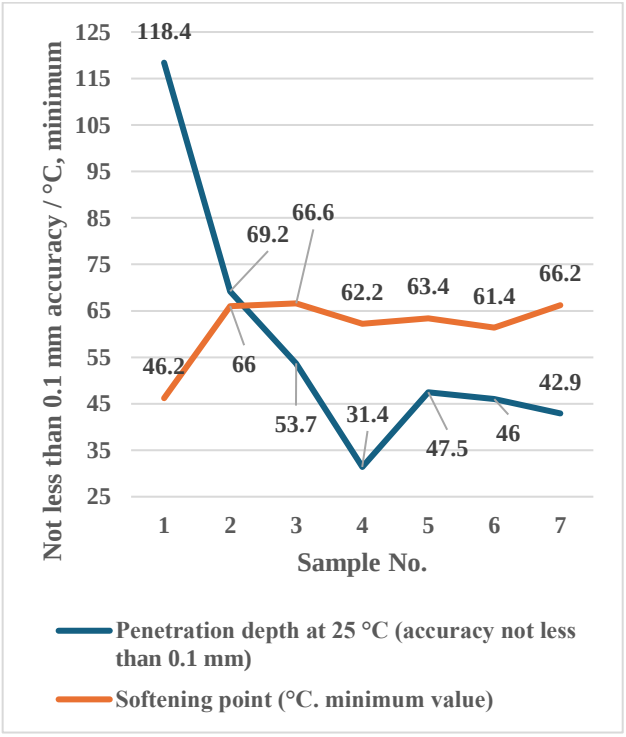

Figure 2 - Thermal Stability and Structural Changes of PMB Based on PP H350

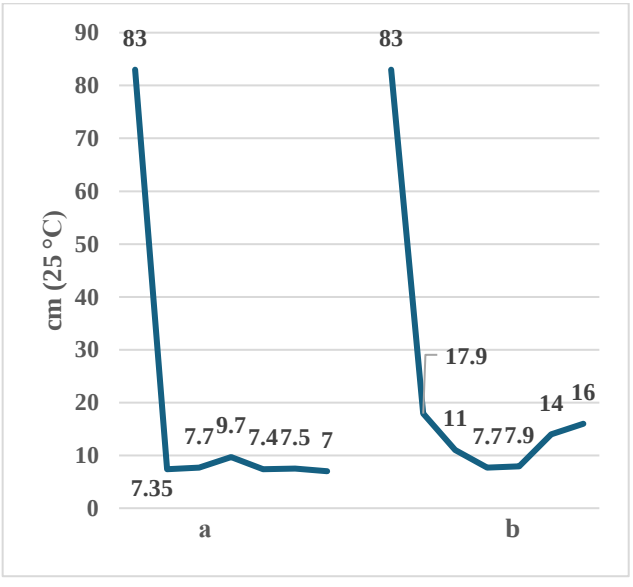

Figure 3 - Ductility of PMB mixtures (a - Bitumen + PP H030 + oil residue; b - Bitumen + PP H350 + oil residue)

As shown in Figures 1 and 2, all samples exhibited significant changes compared to the control sample (neat bitumen). This confirms the

combined effect of polypropylene and oil residue on the structure of bitumen.

While polypropylene increases the viscosity of bitumen and helps to maintain its softening point, oil residue partially balances this effect. Bitumen modified with H030 is sensitive to the concentration of oil residue: the softening point decreases slightly, but the penetration depth is initially higher. In contrast, H350-modified bitumen demonstrates greater stability and hardness at elevated temperatures, which makes it more suitable for roads subjected to heavy loads.

The ductility of bitumen samples modified with polypropylene (grades H030 and H350) and oil residue was evaluated at 25 °C. The results are presented in Figure 3.

Table 2 - Statistical data processing of the properties of polypropylene-modified bitumen

Parameters	PP H030	PP H350
Softening point (°C, minimum)	65.0-61.8	66.0-62.2
Standard deviation (°C)	1.8	2.0
Confidence interval (95%)	1.7	1.9
Penetration depth at 25 °C (accuracy 0.1 mm)	39.6-54.5	69.2-42.9
Standard deviation (mm)	5.5	10.1
Confidence interval (95%)	5.2	9.8
Ductility at 25 °C, cm	7-10	7-16
Mean value	8.2	11.3
Standard deviation	1.2	3.1
Confidence interval (95%)	7.5-8.9	9.8-12.8
Adhesion coefficient of oil residues	0.87	0.92
Standard deviation	0.03	0.04
Confidence interval (95%)	0.84-0.90	0.88-0.96

According to the results, the ductility of the original bitumen measured at 25 °C showed a high value (83 cm). In the modified mixtures, ductility values decreased significantly. This can be explained by the increase in hardness of the material and the limitation of its plastic deformation capacity as a result of polypropylene penetrating the bitumen structure. In the samples with grade H030, ductility was in the range of 7-10 cm, while in the mixtures based on H350 it was somewhat higher-ranging from 7 to 16 cm. This indicates that polypropylene of grade H350 possesses a better structure-forming ability and tends to distribute more uniformly within the bitumen matrix. As a result, mixtures based on H350 provide a more optimal balance between elasticity and strength. However, the decrease in ductility reflects a limitation of the plastic properties of bitumen, and therefore, future research should aim to identify compatible combinations of modifiers to improve this parameter.

The statistical data processing of the properties of polypropylene-modified bitumen is presented in the table (Table 2).

The data presented in Table 2 include the mean values, standard deviations, and 95% confidence intervals for the softening point, penetration depth at 25 °C, and adhesion coefficient of oil residues in bitumen samples modified with polypropylene. These results provide a quantitative basis for comparing the changes in the physical properties of the mixtures.

For each parameter, standard deviations and 95% confidence intervals were calculated to evaluate the reliability and stability of the obtained results. The data comparatively characterize the influence of PP H030 and PP H350 on the properties of bitumen. According to the results, mixtures based on polypropylene grade H350 demonstrated higher thermal stability, although they showed greater variability in penetration depth, indicating fluctuations in their properties. However, additional statistical methods (such as the t-test or ANOVA) were not applied to assess statistical significance. Therefore, future research should include a deeper statistical analysis of the results.

The reuse of polymer waste increases environmental efficiency, as it reduces the accumulation of plastic waste and transforms it into useful products for the construction sector. Oil residue, as an industrial by-product, can also be utilized, thereby reducing the environmental burden.

From an economic perspective, the application of polymer-bitumen mixtures reduces maintenance costs by extending the service life of road pavements. Moreover, with improved energy efficiency, expenditures on fuel and energy in bitumen production and road paving processes are also reduced.

Conclusions

The data, presented in this study, include the mean values, standard deviations, and 95% confidence intervals for the softening point, penetration depth at 25 °C, and adhesion coefficient of oil residues in bitumen samples modified with polypropylene. These results provide a quantitative basis for comparing the changes in the physical properties of the mixtures.

For each parameter, standard deviations and 95% confidence intervals were calculated to evaluate the reliability and stability of the obtained results. The data comparatively characterize the influence of PP H030 and PP H350 on the properties of bitumen. According to the results, mixtures based on polypropylene grade H350 demonstrated higher thermal stability, although they showed greater variability in penetration depth, indicating fluctuations in their properties. However, additional statistical methods (such as the t-test or ANOVA) were not applied to assess statistical significance. Therefore, future research should include a deeper statistical analysis of the results.

The reuse of polymer waste enhances environmental efficiency by reducing the accumulation of plastic waste and transforming it into useful products for the construction sector. Oil residue, as an industrial by-product, can also be utilized, thereby reducing the environmental burden.

From an economic perspective, the application of polymer-bitumen mixtures reduces maintenance costs by extending the service life of road pavements. Moreover, with improved energy efficiency, expenditures on fuel and energy in bitumen production and road paving processes are also reduced.

Conflicts of interest. The authors declare that they have no known financial or personal conflicts of interest that could have influenced the work reported in this paper.

CRediT author statement: **A. Syzdyk:** Concept development, research methodology, drafting of the initial manuscript; **G. Seytenova:** Scientific supervision, project leadership; **R. Dyussova:** Data analysis, document editing and revision; **E. Zhakmanova:** Research execution, preparation of materials, documentation; **E. Donbayeva:** Visualization, provision of available resources.

Acknowledgements. This research was conducted within the framework of program-targeted funding from the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan. (Grant No. BR24992883 Creation of a scientific and technological park for petrochemicals and polymer materials to provide services and implement applied R&D results in the priority sectors of the country's economy).

Cite this article as: Syzdyk AG, Seitenova GZ, Dyussova RM, Zhakmanova EA, Donbayeva E. Polymer-bitumen compositions for improving the energy efficiency of road construction. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2027; 341(2):97-104. https://doi.org/10.31643/2027/6445.21

Жол құрылысының энергия тиімділігін арттыруға арналған полимер-битум қоспалары

[1] Сыздық А.Ғ., [1] Сейтенова Г.Ж., [2] Дюсова Р.М., [1] Жакманова Е.А., [1] Донбаева Э.

[1] Л. Н. Гумилев атындағы Еуразия Ұлттық Университеті, Астана, Қазақстан
[2] Торайғыров университеті, Павлодар, Қазақстан

Мақала келді: *6 мамыр 2025*
Сараптамадан өтті: *4 қыркүйек 2025*
Қабылданды: *26 қараша 2025*

ТҮЙІНДЕМЕ

Бұл мақалада полипропиленнің екі түрі (H030 және H350) мен мұнай қалдықтарының битумды модификациялау процесіне әсері қарастырылады. Битумды модификациялау оның физикалық-механикалық қасиеттерін жақсарту арқылы жол жабындарының сапасын арттырудың маңызды тәсілдерінің бірі болып табылады. Қазіргі таңда битумды модификациялау жол құрылысында кеңінен қолданылып, оның сапасын және энергия тиімділігін арттыруда маңызды рөл атқарады. Полимерлердің битумның механикалық тұрақтылығына әсерін зерттеу жол жабындарының беріктігін арттыруда өзекті мәселе болып отыр. Зерттеу барысында битум үлгілеріне H030 және H350 полипропилендерінің 6 түрлі концентрациясы енгізіліп, олардың негізгі көрсеткіштері салыстырылды. Алынған нәтижелер полипропиленнің битум қасиеттерін айтарлықтай өзгертіп, жол жабынының

	беріктігі мен ұзақ мерзімділігін арттыруға ықпал ететінін көрсетті. Сонымен қатар, мұнай қалдығының қосылуы битум қоспасының реологиялық қасиеттерін жақсартуға мүмкіндік беріп, оның адгезиясын жоғарылатты. Бұл зерттеулер жол құрылысында қолданылатын битумды жақсарту үшін маңызды деректер береді. Зерттеу нәтижелері көрсеткендей, полимерлік модификацияланған битумның қолданылуы жол жабындарының тозуға төзімділігін арттырады, жарықшақтардың пайда болуын азайтады және климаттық факторларға төзімділігін күшейтеді. Бұл өз кезегінде жол төсемінің қызмет ету мерзімін ұлғайтуға және жол жөндеу шығындарын азайтуға мүмкіндік береді. Ұзақ мерзімді төсемдер битум өндірісіне және жол салуға жұмсалатын энергия шығындарын азайтуға көмектеседі. Алынған мәліметтер асфальтбетон өндірісінде полимер-модификацияланған битум қоспаларын тиімді пайдалану мүмкіндіктерін кеңейтеді. Осылайша, битум мен полипропиленнің үйлесімділігі зерттеліп, олардың оңтайлы құрамдары анықталды.
	Түйін сөздер: битум, полипропилен, модификацияланған битум қоспалары, мұнай қалдығы, асфальтбетон, энергия тиімділігі.
Сыздық Аяжан Ғалымқызы	***Авторлар туралы ақпарат:*** *Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Жаратылыстану ғылымдары факультетінің магистранты, Қажымұқан көшесі, 13, 010000, Астана, Қазақстан. E-mail: ayazhanka.syzdyk@gmail.com; ORCID ID: https://orcid.org/0009-0007-4435-0976*
Сейтенова Гайни Жумагалиевна	*Химия ғылымдарының кандидаты, Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Жаратылыстану ғылымдары факультетінің қауымдастырылған профессоры, Сәтпаев көшесі, 2, 010000, Астана, Қазақстан. E-mail: gainiseitenova@gmail.com; ORCID ID: https://orcid.org/0000-0001-6202-3951*
Дюсова Ризагуль Муслимовна	*Техника ғылымдарының кандидаты, Торайғыров университетінің пост докторанты, Ломов көшесі, 64, 140000, Павлодар, Қазақстан. E-mail: riza92@bk.ru; ORCID ID: https://orcid.org/0000-0003-3083-5255*
Жакманова Екатерина Андреевна	*Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Жаратылыстану ғылымдары факультетінің PhD докторанты, Қажымұқан көшесі, 13, 010000, Астана, Қазақстан. E-mail: Ekaterina.zakmanova1998@gmail.com; ORCID ID: https://orcid.org/0000-0003-0545-5912*
Донбаева Эльвира	*Л.Н. Гумилев атындағы Еуразия ұлттық университеті, жаратылыстану ғылымдары факультеті, химия кафедрасының аға оқытушысы, Қажымұқан көшесі, 13, 010000, Астана, Қазақстан. E-mail: donbayeva_ek@enu.kz; ORCID ID: https://orcid.org/0009-0005-0762-1488*

Полимер-битумные композиции для повышения энергоэффективности дорожного строительства

[1] Сыздык А.Г., [1] Сейтенова Г.Ж., [2] Дюсова Р.М., [1] Жакманова Е.А., [1] Донбаева Э.

[1] Евразийский национальный университет имени Л. Н. Гумилёва, Астана, Казахстан
[2] Университет имени Торайгырова, Павлодар, Казахстан

Поступила: *6 мая 2025*
Рецензирование: *4 сентября 2025*
Принята в печать: *26 ноября 2025*

АННОТАЦИЯ

В данной статье исследовано влияние двух марок полипропилена (H030 и H350) и нефтяного остатка на процесс модификации битума. Модификация битума является одним из важных способов улучшения его физико-механических свойств и повышения качества дорожного покрытия. В настоящее время модификация битума широко применяется в дорожном строительстве, играя важную роль в повышении его качества и энергоэффективности. Изучение влияния полимеров на механическую стабильность битума является актуальной задачей в повышении прочности дорожного покрытия. В ходе исследования в образцы битума были введены шесть различных концентраций полипропилена H030 и H350, после чего проведено сравнение их основных характеристик. Полученные результаты показали, что полипропилен существенно изменяет свойства битума, способствуя повышению прочности и долговечности дорожного покрытия. Кроме того, добавление нефтяного остатка улучшает реологические свойства битумной смеси, повышая её адгезию. Эти исследования предоставляют важные данные для улучшения битума, применяемого в дорожном строительстве. Результаты исследования показали, что использование полимермодифицированного битума повышает износостойкость дорожного покрытия, снижает образование трещин и улучшает его устойчивость к климатическим факторам. Это, в свою очередь, увеличивает срок службы дорожного полотна и снижает затраты на его ремонт. Долговечные покрытия позволяют сократить энергозатраты на производство битума и укладку дороги. Полученные данные расширяют возможности эффективного применения полимермодифицированных битумных смесей в производстве асфальтобетона. Таким образом, изучена совместимость битума и полипропилена, определены их оптимальные составы.

	Ключевые слова: битум, полипропилен, модифицированные битумные смеси, нефтяной остаток, асфальтобетон, энергоэффективность.
Сыздык Аяжан Галымкызы	***Информация об авторах:*** *Магистрант факультета естественных наук Евразийского национального университета им. Л.Н. Гумилёва, ул. Кажымукана, 13, 010000, Астана, Казахстан. E-mail: ayazhanka.syzdyk@gmail.com; ORCID ID: https://orcid.org/0009-0007-4435-0976*
Сейтенова Гайни Жумагалиевна	*Кандидат химических наук, ассоциированный профессор факультета естественных наук Евразийского национального университета им. Л.Н. Гумилёва, ул. Сатпаева, 2, 010000, Астана, Казахстан. E-mail: gainiseitenova@gmail.com; ORCID ID: https://orcid.org/0000-0001-6202-3951*
Дюсова Ризагуль Муслимовна	*Кандидат технических наук, постдокторант Торайгыров Университета, ул. Ломова, 64, 140000, Павлодар, Казахстан. E-mail: riza92@bk.ru; ORCID ID: https://orcid.org/0000-0003-3083-5255*
Жакманова Екатерина Андреевна	*PhD докторант факультета естественных наук Евразийского национального университета им. Л.Н. Гумилёва, ул. Кажымукана, 13, 010000, Астана, Казахстан. E-mail: Ekaterina.zakmanova1998@gmail.com; ORCID ID: https://orcid.org/0000-0003-0545-5912*
Донбаева Эльвира	*Старший преподаватель, кафедра химии, факультет естественных наук, Евразийский национальный университет им. Л.Н. Гумилёва, ул. Кажымукана, 13, 010000, Астана, Казахстан. E-mail: donbayeva_ek@enu.kz; ORCID ID: https://orcid.org/0009-0005-0762-1488*

References

[1] Case P A, White M A. Polypropylene-modified bitumen: A review of the properties and current developments. Materials. 2020; 13(7):1495. https://doi.org/10.3390/ma13071495

[2] Zhang H, Yu J, Wu S. Effect of polypropylene fibers on the performance of asphalt mixtures. Applied Sciences. 2019; 9(4):742. https://doi.org/10.3390/app9040742

[3] Sengoz B, Topal A, Isikyakar G. The Effect of polypropylene fibres on the tensile performance of asphalt mixtures for road pavements. Materials Science and Engineering. 2020; 888(1):012082. https://doi.org/10.1088/1757-899X/888/1/012082

[4] Kondyurina I V, Kondyurin A V. Influence of polymer modification on bitumen properties. Periodica Polytechnica Civil Engineering. 2020; 64(1):170–179. https://doi.org/10.3311/PPci.11570

[5] Polacco G, Filippi S, Merusi F, Stastna J. Effects of Recycled Asphalt Pavement on the Stiffness and Fatigue Performance of Multigrade Bitumen Asphalt. Journal of Materials in Civil Engineering. 2015; 30(2):04014215. https://doi.org/10.1061/(ASCE)MT.1943-5533.0002150

[6] Lu X, Isacsson U. Modification of road bitumens with thermoplastic polymers. Polymer International. 2020; 69(3):215–224. https://doi.org/10.1002/pi.6405

[7] Onishchenko A, Stolyarova L, Bieliatynskyi A. Evaluation of the durability of asphalt concrete on polymer modified bitumen. Web of Conferences. 2020; 157:06005. https://doi.org/10.1051/e3sconf/202015706005

[8] Yildirim Y. Polymer modified asphalt binders. Construction and Building Materials. 2018; 25(2):781–789. https://doi.org/10.1016/j.conbuildmat.2018.10.007

[9] Sharma D K, Goyal P. Performance evaluation of polypropylene modified bitumen. International Journal of Scientific Research and Management. 2017; 5(12):7590–7595. https://doi.org/10.18535/ijsrm/v5i12.28

[10] Desidery L, Lanotte M. Variation of internal structure and performance of polyethylene- and polypropylene-modified bitumen during blending process. 2020; 133(15):50142. https://doi.org/10.1002/app.50142

[11] Zhou J, Wu S. Rheological properties of asphalt binders containing various anti-aging agents. Advances in Science and Engineering Research. 2020; 10(1):119–125. https://doi.org/10.35877/454RI.asci1119

[12] Schaur A, Unterberger S H, Lackner R. Impact of molecular structure of PP on thermo-rheological properties of polymer-modified bitumen. Construction and Building Materials. 2021; 278:122981. https://doi.org/10.1016/j.conbuildmat.2021.122981

[13] Zhang F, Yu J, Han J. Effect of polymer modification on the aging properties of bitumen. Road Materials and Pavement Design. 2021; 22(3):567–579. https://doi.org/10.1080/14680629.2021.1893209

[14] Kezhen Y, Lingyun Y, Daocheng W. High-Temperature Performance of Polymer-Modified Asphalt Mixes: Preliminary Evaluation of the Usefulness of Standard Technical Index in Polymer-Modified Asphalt. Polymers (Basel). 2019; 11(9):1404. https://doi.org/10.3390/polym11091404

[15] Sabzoi N, Yeong JB, Filippo G. Sustainable Polymers from Recycled Waste Plastics and Their Virgin Counterparts as Bitumen Modifiers: A Comprehensive Review. Polymers (Basel). 2021; 13(19):3242. https://doi.org/10.3390/polym13193242

[16] Qilin Y, Jiao L, Xiaowei W, Dawei W, Ning X, Xianming S. A review of polymer-modified asphalt binder: Modification mechanisms and mechanical properties. Cleaner Materials. 2024; 12:100255. https://doi.org/10.1016/j.clema.2024.100255

[17] Hasanain JK, Amir M, Shakir AB. Rheological and microstructural properties of nano-composite bitumen modified by nano-alumina and low-SBS content. Case Studies in Construction Materials. 2024; 20:e03244. https://doi.org/10.1016/j.cscm.2024.e03244

[18] Garcia-Morales M, Partal P, Navarro F J, Gallegos C. Effect of waste polymer addition on the rheology of modified bitumen. International Journal of Polymer Analysis and Characterization. 2017; 22(7):569–580. https://doi.org/10.1080/10916466.2017.1356853

[19] Polacco G, Stastna J, Biondi D. Asphalt modification with different polyethylene-based polymers. Fuel. 2016; 150:159–166. https://doi.org/10.1016/j.fuel.2015.12.038

[20] Yu J, Feng P, Zhang H, Wu S. Effect of organo-montmorillonite on aging properties of asphalt. Road Materials and Pavement Design. 2015; 16(1):193–207. https://doi.org/10.1080/14680629.2015.1030832