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# A Comprehensive Study on Polymermodifiedbitumen Blends with PP H030 Mixing Parameters and Homogeneity

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**ABSTRACT**
The effective inclusion of polypropylene (PPH030) into bitumen during road building is essential for improving the qualities of the material. This research examined the impact of mixing factors on the homogeneity and effectiveness of PP-bitumen blends. The experiment conducted by using granules with a size of 4.3 mm. The mixing process took place at temperatures between 158 and 160°C for a duration of 1.5 hours. Nevertheless, this procedure proved inadequate in achieving enough blending and uniformity, resulting in the existence of unabsorbed particulate matter in the mixing nozzle and vessel walls. Further tests were carried out to enhance the mixing process. The temperature was adjusted to a range of 168-175 °C, and the mixing period was prolonged to 2 hours. Additionally, the PP content was increased to 4 percent. The findings showed a significant improvement in consistency, with no visible undissolved particles. In addition, examination of the mixed samples indicated a rise in the softening point from 53.4 to 61.2 °C when the PP content was increased, accompanied by a loss in penetration and elongation capabilities. The comparison with prior findings demonstrated that the adjusted circumstances resulted in a reasonable degree of mixing, as seen by the constant softening point and decreased penetration and elongation values.

***Keywords:*** bitumen, polymermodifiedbitumen, mixing temperature, mixing time, asphaltconcrete.

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## Introduction

Asphalt has been extensively used in road construction during the last several decades because of its excellent adhesion, temperature sensitivity, friction characteristics, resistance to ageing, and long-lasting nature. Nevertheless, the ongoing increase in traffic volume and the adverse effects of climate change, including global warming, need enhanced performance standards for bituminous pavement [1].

Out of all the efforts made to modify bitumen, adding polymer to bitumen has been one of the most widely used methods. Polyethylene (PE) and polypropylene (PP), as well as thermo-plastic elastomers like styrene-butadiene-styrene (SBS) and styrene-isoprene-styrene (SIS), have been identified as very effective modifiers for bitumen [2]. These polymers may enhance the qualities of bitumen, including increased stiffness at high temperatures, improved resistance to cracking at low temperatures, and extended fatigue life. PE and PP, being the most prevalent polyolefins, are extensively used in the manufacturing of plastics for various applications [3]. Plastic items are essential in today's lifestyle since they are lightweight, waterproof, versatile, and inexpensive to produce. Nevertheless, the escalating utilization of plastics has produced a substantial quantity of plastic trash, leading to a significant environmental issue owing to their inability to decompose naturally [4].

Consequently, there is now great interest in altering bitumen or asphalt to create polymer-modified bitumen. However, no one technique or technology can be universally applied to all types of polymers. The size of the polymers, their characteristics, and the exceptionally large surface area all contribute to enhancing the physical properties of bitumen. These improvements include increased tensile strength and modulus, reduced gas permeability, lower coefficient of thermal expansion, and maintaining the optical homogeneity of the bituminous material [5]. Various techniques may be used to integrate polymer into bitumen, including increasing the temperature, adjusting the mixing speed, and controlling the duration of mixing [6].

Through the process of high-temperature and high-shear mixing, the polymer is able to combine with the asphalt molecules, creating a cohesive network that encompasses the whole binder. This leads to a substantial enhancement of the viscoelastic characteristics when compared to the unmodified binder. This process faces challenges due to the low solubility of polymers, which restricts the number of macromolecules capable of both creating and preserving such a structure under high-temperature storage in stationary conditions, which may be required prior to applying the binder [7]. Consequently, there have been many research works focused on comprehending and enhancing the structure and storage stability of polymer-modified asphalts [8].

The uniqueness of this study is to ascertain the optimal temperature and rotation speed required to generate a homogeneous polymer-bitumen product while considering the specific properties of the polymer and bitumen produced in Kazakhstan.

## Experimental part

The selected base bitumen with penetration mark BND 100/130 used in this study was supplied from the Pavlodar refinery with physical qualities in Table 1 and polymer material is polypropylene PPH030, also produced in Kazakhstan with specific characteristics including a melt flow rate of -3.3 g/10min, a yield indicator scatter within the batch of 4.6%, a bending modulus of elasticity of 1187 MPa, a mass fraction of volatile substances of 0.04%, tensile yield strength of 33.0 MPa, an elongation at the yield point of 11%, a granule size of 4.3 mm, and a smell intensity of 1 point.

**Table 1** - Physical characteristics of bitumen B

| Properties | Results |
|---|---|
| Penetration (25ºC, 100 gr, 5sec) 0.1 mm | 118.4 |
| Softening point, ºC | 46.0 |
| Flashpoint, ºC | >220 |
| Specific gravity (25 ºC), gr/cm$^3$ | 1.017 |

*The sample preparation.* The polymer-modified bitumen was created by combining base bitumen with different amounts of polymers as mentioned earlier [9]. The specific percentages of polymers were selected based on the findings of review articles and research conducted by professors worldwide, which showed favourable outcomes when using 2.5-4% of the total weight of bitumen. To achieve this objective, a laboratory high-shear mixer equipped with an electronically controlled stirrer model, capable of operating at stirrer speeds ranging from 30 to 2000 rpm, was used to carry out the mixing process in Figure 1. The polymers were incrementally introduced to the bitumen by weight during the first 15 minutes of mixing, after 90 minutes of heating at a temperature of 165° C [[10], [11]]. After a two-hour interval, the mixing operation recommenced. The mixing temperature was adjusted to a range of 170-175°C, and the temperature was periodically measured using a thermometer every 30 minutes.

**Figure 1 -** A laboratory high-shear mixer

*The test methods.* Penetration testing is a widely used laboratory technique for assessing the elastic characteristics of bituminous materials, including both unblended and polymer-modified bitumen (PMB). It offers a method for assessing the rheological characteristics of bitumen at a certain temperature, namely its level of hardness or softness [12]. The penetration test entails the insertion of a standardized needle into a bitumen sample, following the parameters specified in ST RK 1226-2003. Experiments are often carried out at various temperatures, such as 25°C and 0°C. The sample is subjected to the designated testing temperature. The needle's vertical location on the surface of the specimen is guaranteed. A designated force is exerted on the needle for a certain duration of time (5 seconds). The needle's penetration into the bitumen in Figure 2, is measured in increments of tenths of a millimeter or hundredths of an inch [[13], [14]].

**Figure 2 -** The needle's penetration

The softening point test assesses the thermal properties of bituminous materials, specifically the viscosity of bitumen at elevated temperatures. To get precise and consistent results, it is essential to adhere to recognized guidelines such as AASHTO T 53 or ST RK 1227-2003, and ensure that the equipment is appropriately calibrated, as is customary for any other examination. A "ring-ball" gadget typically comprises of two metal rings that are concentric and a steel ball. The specimen is located inside the central cavity of the ring, while the ball is positioned directly above it. The sample is positioned inside the metal ring, with the steel ball positioned on top of it, and then exposed to regulated heating at a consistent rate of 5°C per minute [[15], [16]]. The softening point is the temperature at which the bituminous material becomes soft enough to contact the base of the ring, causing the ball to pass through the specimen in Figure 3. This change may be seen visually.

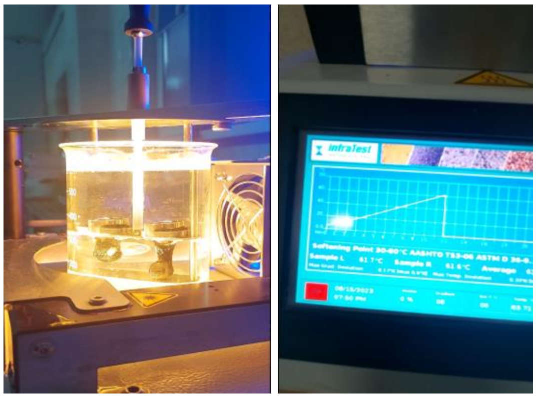

**Figure 3 -** The softening point test

A ductility test machine generally comprises a water bath, a collection of brass or metal molds, and a mechanism designed to apply pressure to an asphalt briquette until it reaches its breaking point [17]. The well-recognized benchmarks for evaluating the malleability of bitumen are ST RK 1374-2005 and AASHTO T 51. The procedure involves placing a representative sample of polymer-modified bitumen (PMB) in a mold and using a shaping process to create dense briquettes in Figure 4. The briquette is shaped with a predetermined cross-sectional area. A vertically aligned plasticizer is used to accommodate the cooled briquette. The briquette is regularly exposed to a consistent tensile stress, at a pace of 50 mm per minute. The bituminous material undergoes continual length measurements until it reaches the point of fracture [[18], [19]]. Ductility measures are determined by calculating the extent to which bitumen can stretch before it breaks, often measured in millimeters [[20], [21]].

**Figure 4 -** A ductility test briquette

## Results and Discussion

The study was conducted on both unmodified and polymer-modified polymer bituminous binders to ascertain the appropriate technological temperature, mixing time, and speed. This was achieved by analyzing the correlation between penetration, softening point, and ductility tests. The optimal dosage suggested by global researchers initially began at 3%. To implement this technology, we established the ideal blending temperature and duration as 160-175 °C and 1.5 hours, respectively.

Despite using a granule size of 4.3 mm and subjecting polypropylene PPH030 to processing duration of 1.5 hours at a temperature range of 158-160 degrees Celsius, the intended level of mixing and homogeneity was not attained. An analysis of the mixing procedure revealed the existence of unabsorbed particulate matter in both the mixing nozzle and the surfaces of the mixing container. This discovery highlights a notable difficulty in attaining complete scattering and merging of the polypropylene particles within the given circumstances.

Moreover, a thorough examination of the data revealed disparities in the actual levels of penetration, softening point, and elongation features in comparison to the forecasts produced by well-established international scientific approaches and theoretical frameworks. The discrepancies are visibly shown in Figure 5 emphasizing the need for further examination and improvement of processing parameters to enhance the polymer blending process.

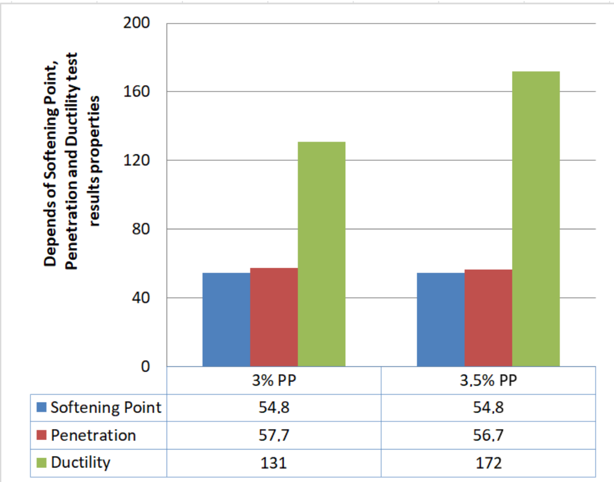


**Figure 5** - A relationship between 3% and 3.5% of PP H030

Figure 5 illustrates a relationship between the quantity of polypropylene H030 and several key properties. According to theoretical expectations, an increase in the polypropylene content should correspond to an increase in consumption point while leading to a decrease in tensile properties and penetration. However, the observed elongation increase at 3.5 per cent suggests inadequacies in the mixing conditions, specifically regarding temperature and duration. This suboptimal process results in a polymer bitumen blend that lacks homogeneity, with a significant portion of polypropylene remaining undissolved.

To enhance the dissolution of polypropylene H030 and achieve homogeneity, we made the following adjustments: we increased the temperature to a range of 168-175 degrees Celsius, lengthened the mixing duration to 2 hours, and raised the polypropylene content to 4 per cent. The results of these modifications are shown in Figure 6 below.

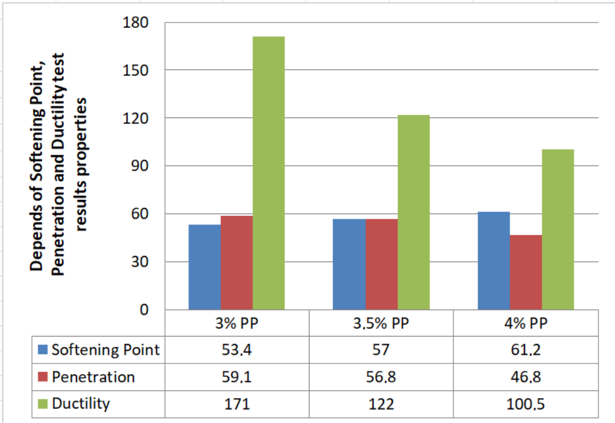


**Figure 6** - A relationship between 3% and 4% of PP H030 at the new condition of mixing temperature

Figure 6 analysis reveals a homogeneous dispersion of polymer bitumens with no remaining particles. When comparing the findings obtained at temperatures below 160°C to those obtained between 168-175 °C, it was seen that the polymer bitumen mixture treated at the higher temperatures had little oxidation impact on the 3% polypropylene content. This effect was attributed to the longer processing period. The softening point exhibited a substantial rise, rising from 53.4 degrees to 61.2 degrees Celsius, as a result of a 4% increase in polypropylene content. Additionally, the data shows that the penetration decreased from 59.1 mm to 46.8 mm and the elongation decreased from 171 mm to 100.5 mm as the polypropylene content increased.

In addition, when comparing the findings at a polypropylene H030 concentration of 3.5% with the prior data, there was a rise in the softening point from 54.8 °C to 57 °C. Furthermore, the penetration and elongation values changed from 56.7 mm and 172 mm to 56.8 mm and 122 mm, respectively. The data indicate a reasonable degree of blending in the polymer bitumen mixture.

## Conclusions

In conclusion, our extensive collection of over 30 experimental studies demonstrates that the homogeneity of our polymer-bitumen investigations can be significantly enhanced by employing a mixing temperature ranging from 168°C to 175°C, along with a two-hour mixing duration. Specifically, using 4.3 mm granules of polypropylene H030 ensures that the mixture achieves the desired consistency. The addition of polypropylene at a concentration equal to or exceeding 4% meets the regional technical standards for polymer bitumen. However, as polypropylene exhibits high tensile strength, chemical resistance, and a melting point of around 160°C it tends to increase the hardness of bitumen, it is essential the inclusion of plasticizers or other modifiers such as oil components or other types of polymers, to achieve the required softness and flexibility and balance the mechanical properties of the polymer-modified bitumen to incorporate additional additives. By carefully adjusting these parameters, it is ensured that the polymer bitumen meets the standards outlined in the local technical documentation while providing improved performance for road construction applications. This optimization process highlights the importance of precise control over mixing conditions and additive selection to achieve the desired material properties.

***Conflicts of interest.*** On behalf of all authors, the corresponding author states that there is no conflict of interest.

***CRediT author statement:*** **S. Kosparmakova**: Conceptualized the research and designed the experimental methodology. **Zh. Nurakhmetova**: Reviewed international literature and gathered information on the chemical properties changes of bitumen and polymer. **G. Seitenova**: Conducted negotiations with factory members to procure materials for the experiment. **R. Dyusova**: Provided assistance with the experimental work. **A. Jexembayeva**: Secured funding for the publication.

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# PP H030 маркалы полимерлі битум қоспаларының араластыру параметрлерін және біртекті алынуын кешенді зерттеу

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Қабылданды: *4 қыркүйек 2024*

**ТҮЙІНДЕМЕ**
Жол құрылысында битумға полипропиленді (PPH030) тиімді қосу материалдың сапасын жақсарту үшін қажет. Бұл зерттеуде араластыру факторларының PP-битум қоспаларының біркелкілігі мен тиімділігіне әсері зерттелді. Экспериментте 4,3 мм түйіршіктер қолданылды. Араластыру процесі 158-160°C температурада 1,5 сағат бойы жүрді. Дегенмен, бұл процедура жеткілікті араластыру мен біркелкілікке қол жеткізу үшін жеткіліксіз болды, бұл араластырғыш саптамада және контейнер қабырғаларында сіңірілмеген қатты заттардың болуына әкелді. Араластыру процесін жақсарту үшін қосымша сынақтар жүргізілді. Температура 168-175 °C диапазонына дейін көтерілді және араластыру кезеңі 2 сағатқа дейін ұзартылды. Сонымен қатар, полипропиленнің мөлшері 4%-ға дейін өсірілді. Нәтижелер консистенцияның айтарлықтай жақсарғанын көрсетті, көрінетін ерімеген бөлшектер болмады. Сонымен қатар, аралас үлгілерді зерттеу PP мөлшерінің жоғарылауымен жұмсарту температурасының 53,4-тен 61,2 ° C-қа дейін артатынын көрсетті, бұл ену және ұзару қабілетінің төмендеуімен бірге жүрді. Алдыңғы нәтижелермен салыстыру шарттарды реттеу арқылы араластырудың қолайлы дәрежесіне қол жеткізілгенін көрсетті, бұл тұрақты жұмсарту нүктесінен және ену мен ұзартудың төмендеуінен көрінеді. Алдыңғы нәтижелермен салыстыру шарттарды түзету нәтижесінде қолайлы араластыру дәрежесіне қол жеткізілгенін көрсетті, бұл жұмсарту температурасынан және ену (пенетрация) және ұзарту көрсеткіштерінің төмендеуінен көрінеді.

***Түйін сөздер:*** битум, полимерленген битум, араластыру температурасы, араластыру уақыты, асфальтбетон.

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# Комплексное исследование параметров смешивания и получения однородности полимербитумных смесей с PP H030

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**АННОТАЦИЯ**
Эффективное добавление полипропилена (PPH030) в битум при строительстве дорог необходимо для улучшения качества материала. В данном исследовании изучалось влияние факторов смешивания на однородность и эффективность ПП-битумных смесей. В эксперименте использовались гранулы размером 4,3 мм. Процесс смешивания проходил при температуре 158-160°C в течение 1,5 часов. Тем не менее, эта процедура оказалась недостаточной для достижения достаточного смешивания и однородности, что привело к наличию неабсорбированных твердых частиц в смесительной насадке и на стенках емкости. Были проведены дополнительные испытания для улучшения процесса смешивания. Температура была отрегулирована до диапазона 168-175 °C, а период смешивания был продлен до 2 часов. Кроме того, содержание полипропилена было увеличено до 4 %. Результаты показали значительное улучшение консистенции, без видимых нерастворенных частиц. Кроме того, исследование смешанных образцов показало повышение температуры размягчения с 53,4 до 61,2 °C при увеличении содержания ПП, что сопровождалось снижением проникающей способности и способности к удлинению. Сравнение с предыдущими результатами показало, что в результате корректировки условий была достигнута приемлемая степень смешивания, что видно по неизменной температуре размягчения и снижению показателей пенетрации и удлинения.

***Ключевые слова:*** битум, полимермодифицированный битум, температура смешивания, время смешивания, асфальтобетон.

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