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Visualizing Polymer Dispersion in PmB: Practical Aspects and Methodological Considerations

Abstract: The relevance of this study is determined by the increasing use of polymer-modified bitumen (PmB) in road pavement construction, where binder performance depends not only on macroscopic rheological characteristics but also on the stability and morphology of the polymer–bitumen two-phase system. The research problem lies in the methodological uncertainty of fluorescence microscopy for PmB analysis, since sample preparation, reheating, stirring, cooling rate and surface selection may substantially distort the observed microstructure and reduce the reliability of interpretation. The scientific novelty of the study consists in clarifying practical methodological conditions for visualising polymer dispersion in PmB and in demonstrating the analytical potential of digital image processing for estimating polymer phase volume and polymer concentration within that phase. The object of the study is polymer-modified bitumen containing styrene-butadiene-styrene block copolymer and, additionally, a thermoreactive polymer capable of interacting with bitumen components. The aim of the research is to analyse the practical aspects of polymer dispersion visualisation in PmB, assess the influence of sample preparation on the observed micromorphology, and determine how microstructural parameters may be used to evaluate binder stability and polymer–bitumen compatibility. The methods include storage stability testing according to EN 13399, penetration, softening point and elastic recovery tests according to EN 1426, EN 1427 and EN 13398, fluorescence microscopy according to EN 13632, UV-based micromorphological observation, and digital image processing of PmB specimens. The source base of the study includes European standards for bituminous binders and polymer dispersion visualisation, as well as research on polymer-modified bitumen morphology, storage stability, rheological performance, image texture analysis and SBS-modified asphalt binders. The study examines how reheating and hand stirring may change the original PmB microstructure, how internal and external specimen surfaces differ in their representativeness, and how phase dispersion is related to storage stability. It also analyses the correlation between the penetration of the initial bitumen and the scale of polymer dispersion, showing that a decrease in oil content leads to coarser morphology and higher destabilisation risk. In addition, the paper considers a specific case of apparent polymer phase autodispersion in PmB modified with a thermoreactive polymer and demonstrates that digital processing of fluorescence microscopy images can provide quantitative parameters of polymer–bitumen interaction. The results show that pouring PmB into moulds immediately after production provides a more reliable preservation of the original microstructure than reheating and hand stirring. The analysis of drop surfaces may be used only as a rapid field-oriented comparative check, because surface tension and cooling conditions may distort the volumetric representation of the polymer phase. Microstructural analysis cannot fully replace standard storage stability testing, but it can quickly indicate PmB systems at risk of phase separation during storage. The study concludes that fluorescence microscopy combined with digital image analysis is a promising additional method for operational control and research evaluation of PmB, since it enables the estimation of polymer phase volume, polymer concentration in the phase, compatibility of bitumen and polymer, and the stability of PmB as a multicomponent road binder system.

Keywords: polymer modified bitumen; luminescence; micromorphology; storage stability; epifluorescence microscope.

Abbreviations:

DIs is Destabilization Indices,

PmB is polymer modified bitumen,

SBS is styrene-butadiene-styrene block copolymer,

UV is ultraviolet radiation.

Introduction

Over the last century, global requirements for road pavement performance have increased substantially. In many cases, conventional road bitumen used as a component of asphalt mixtures can no longer provide the required performance characteristics under growing traffic loads, more intensive exploitation conditions and higher expectations regarding pavement durability. To meet these requirements, neat bitumen is increasingly replaced with PmB, which is more expensive but provides improved performance parameters, higher resistance to permanent deformation, better fatigue behaviour and enhanced durability of asphalt pavements (*Pyshyev et al., 2016*; *Kashkool & Hamdan, 2024*; *Zofka et al., 2021*).

The relevance of the present study is determined by the fact that the quality of PmB depends not only on traditional macroscopic rheological and empirical indicators, but also on the internal state of the polymer–bitumen system formed at the microscopic level. Polymer modification usually produces a two-phase system in which the polymer-rich phase and the bitumen-rich phase interact with each other. The morphology of this system, including the fineness of polymer dispersion, the size and distribution of polymer-rich domains, and the degree of interaction between polymer and bitumen components, has a direct influence on binder performance and asphalt mixture behaviour (*Wang et al., 2017*; *Emtiaz et al., 2023*). Therefore, the study of PmB micromorphology is an important direction in both road material science and practical quality control.

Despite the widespread use of polymer-modified bitumen in road construction, its quality indicators remain the subject of academic and industrial discussion. Traditionally, researchers and practitioners have paid considerable attention to macroscopic rheological parameters of PmB, such as complex modulus, temperature susceptibility, penetration, softening point and elastic recovery. These characteristics are undoubtedly important and are standardised in technical practice (*European Committee for Standardization, 2024, 2015, 2017a*). However, they do not always provide sufficient information about the internal structure of the binder, the degree of polymer dispersion and the stability of the polymer-rich phase. In this respect, microstructural analysis provides critical insights into the internal condition of the material and allows for a more comprehensive understanding of polymer–bitumen interaction.

The analysis of the PmB phase structure is facilitated by the fact that the polymer-rich phase typically exhibits luminescence under ultraviolet radiation. This makes it possible to observe polymer dispersion directly by means of fluorescence microscopy. The European standard EN 13632 provides a methodological basis for the visualisation of polymer dispersion in polymer-modified bitumen (*European Committee for Standardization, 2010*). At the same time, the method is sensitive to sample preparation, reheating, hand stirring, cooling conditions and the selection of the surface to be analysed. Therefore, the same PmB may produce different microscopic images depending on how the specimen was prepared. This creates a methodological problem because the observed morphology may reflect not only the actual structure of the binder, but also structural changes induced during sample treatment.

The research problem of this article lies in the insufficiently clarified practical conditions under which fluorescence microscopy can provide reliable information about PmB micromorphology. Although the method has high analytical potential, its reproducibility and interpretative value depend on the control of sample preparation procedures. Reheating, stirring and surface selection may alter the original microstructure of the binder and thus lead to inaccurate conclusions regarding polymer dispersion, storage stability and polymer–bitumen compatibility. This problem is especially important for operational control at asphalt plants and for laboratory research where rapid and reliable information about the internal structure of PmB is required.

The scientific novelty of the study consists in the methodological clarification of practical aspects of polymer dispersion visualisation in PmB and in the demonstration of the potential of digital image processing for quantitative evaluation of polymer–bitumen interaction. The study does not treat fluorescence microscopy merely as an illustrative technique, but considers it as an analytical method capable of providing additional structural parameters, including polymer phase volume and polymer concentration within the polymer-rich phase. This makes it possible to connect visual micromorphological observations with the assessment of storage stability, compatibility of bitumen and polymer, and the expected performance of the modified binder.

The object of the study is polymer-modified bitumen as a multicomponent two-phase binder system used in road pavement construction.

The subject of the study is the micromorphological structure of PmB, the visualisation of polymer dispersion under ultraviolet radiation, and the influence of sample preparation procedures on the reliability of fluorescence microscopy results.

The study aims to analyse the practical and methodological aspects of polymer dispersion visualisation in PmB, to determine how sample preparation affects the observed micromorphology, and to assess the possibility of using fluorescence microscopy and digital image processing for evaluating PmB stability and polymer–bitumen interaction.

To achieve this aim, the following research tasks are set:

- to describe the methodological basis of polymer dispersion visualisation in PmB by fluorescence microscopy;
- to analyse the influence of reheating and hand stirring on the observed PmB microstructure;

- to compare the representativeness of internal and external specimen surfaces for microscopic analysis;
- to examine the relationship between PmB microstructure and storage stability indicators;
- to evaluate the influence of the initial bitumen properties on the scale and character of polymer dispersion;
- to analyse the specific behaviour of PmB modified with a thermoreactive polymer during storage;
- to demonstrate the possibility of using digital image processing for estimating polymer phase volume and polymer concentration within the polymer-rich phase;
- to determine the practical applicability of micromorphological analysis for laboratory research and rapid operational control of PmB.

The methodological basis of the study includes storage stability testing of modified bitumen according to EN 13399, determination of needle penetration according to EN 1426, determination of softening point by the Ring and Ball method according to EN 1427, determination of elastic recovery according to EN 13398, and visualisation of polymer dispersion according to EN 13632 (*European Committee for Standardization, 2017b, 2024, 2015, 2017a, 2010*). The core analytical method is fluorescence microscopy under ultraviolet radiation, supported by digital image processing of PmB microstructure images. The study focuses primarily on SBS block copolymer as one of the most widely used polymer modifiers for road bitumen, while also considering a thermoreactive polymer capable of chemical interaction with bitumen components.

The theoretical significance of the study lies in deepening the understanding of PmB as a two-phase polymer–bitumen system whose performance is governed not only by composition and macroscopic properties, but also by microstructural organisation. The study contributes to the interpretation of the relationship between polymer dispersion morphology, bitumen composition, polymer swelling, phase separation and storage stability. It also develops the methodological discussion on the reliability of fluorescence microscopy in PmB analysis and highlights the need to account for specimen preparation as a factor that may transform the observed structure.

The practical significance of the results lies in the possibility of improving laboratory and field control of polymer-modified bitumen. The findings may be useful for researchers, road material laboratories, asphalt plant technologists and quality control specialists who use fluorescence microscopy to assess polymer dispersion. The proposed approach can help identify PmB systems at risk of phase separation, support rapid preliminary assessment of storage stability, and provide additional quantitative indicators of polymer–bitumen compatibility. At the same time, the study emphasises that micromorphological analysis should not replace standard testing procedures, but may serve as an effective complementary method for faster and more informative evaluation of PmB quality.

Thus, the present article addresses a practically significant methodological issue in the analysis of polymer-modified bitumen. By examining how sample preparation affects fluorescence microscopy results and by demonstrating the potential of digital image analysis, the study contributes to the development of more reliable procedures for evaluating PmB microstructure, storage stability and polymer–bitumen interaction.

Materials

The PmB research objects were prepared under laboratory conditions by modifying base pavement bitumen with varying concentrations of SBS copolymer and a thermoreactive polymer. SBS was selected as a commonly used modifier for road bitumen, the thermoreactive polymer was included due to its capacity for chemical interaction with bitumen components. All PmB samples were produced in low shear mixture with a consistent mixing duration of one hour at a temperature of 180°C.

Methods

In this study, to assess the storage stability of PmB, fresh samples were heated in sealed tubes in a vertical position, with no air allowed in the sample, for a total of 24 hours, divided into three 8-hour cycles, at 180 °C in accordance with the EN 13399 procedure (*European Committee for Standardization, 2017b*). After the heating period, only the top and bottom sections of the sample, corresponding to one-third of the specimen, were collected for further analysis.

To quantitatively evaluate the storage stability of PmB, penetration, softening point and elasticity tests were performed for the top and bottom parts of the sample (*European Committee for Standardization, 2024, 2015, 2017a*). The discrepancy in properties between the top and bottom sections of the sample indicates PmB destabilisation.

The core method employed in this study is the visualisation of polymer dispersion in the PmB matrix by fluorescence microscopy, in accordance with the EN 13632 standard (*European Committee for Standardization, 2010*). UV radiation within the 360 to 440 nm range induces fluorescence in specific bitumen components. The fluorescence of low-molecular-weight bitumen fractions, namely bitumen oils, is particularly intense within the visible spectrum ranging from orange to green, enabling their visual detection (*Jelčić et al., 2016*).

In this study, the polymer phase of PmB is observed under UV radiation owing to the capacity of the SBS polymer to absorb bitumen oils. For this purpose, a specialised fluorescence, or epifluorescence, microscope configured to irradiate the sample with UV rays through the optical system was used. A set of filters isolates the required UV wavelengths from the broad-spectrum light source, which are then directed onto the sample by a beam splitter. This dichroic mirror reflects wavelengths shorter than 440 nm towards the specimen, while transmitting the resulting fluorescence, with wavelengths greater than 440 nm, into the binocular system for characterisation of sample morphology.

While the homogeneous distribution of components in neat bitumen makes this method ineffective, the internal structure changes significantly in PmB. The polymer typically forms a two-phase system with bitumen components. One phase consists of the polymer, which swells by absorbing bitumen oils, while the other phase is a residual bitumen composition of resins and asphaltenes, depleted of bitumen oils. The morphology of a PmB sample can be observed because of the distinct fluorescence intensity of both phases under UV radiation.

The resulting digital image, captured by a camera with the required resolution, allows for quantitative assessment of the PmB structure (*Gümüştekin et al., 2011*). The ratio of the polymer phase to the bitumen phase of the PmB was calculated as follows. The resulting images of the PmB specimens were corrected to eliminate uneven illumination of the sample surface within the microscope field, after which they were converted into a black-and-white image without greyscale.

The three stages of the process are shown in the Appendix (*Figure 2*). For further image processing, a software package developed in our laboratory was used to determine the ratio of the area painted black in the frame to the area of the entire frame. If the sample was highly homogeneous, two frames were selected for analysis. For a non-homogeneous sample, the number of frames was increased, up to four.

Literature Review

The modification of bitumen with polymers has become a common technology in contemporary road construction. According to published data, the share of modified bitumen among other binders used in European road construction exceeds 10% and shows a consistent upward trend (*Pyshyev et al., 2016*). Numerous studies have analysed the influence of polymer modifiers on the performance of both bitumen and asphalt. Despite the specific features of each research work, most authors conclude that polymer incorporation significantly reduces the temperature susceptibility of the binder by increasing its viscosity at elevated environmental temperatures (*Kashkool & Hamdan, 2024*; *Zaumanis et al., 2026*).

Although the Fraass breaking temperature often remains unchanged, the softening point of polymer-modified bitumen is substantially higher, which results in greater resistance of road pavement to permanent deformation, or rutting. At intermediate temperatures, PmB exhibits higher stiffness, which is indicated by lower penetration values. This provides an important advantage in material design. For bitumen and PmB with the same penetration value, that is, with equal stiffness, the Fraass breaking temperature will be lower for PmB because the Fraass breaking temperature of the initial bitumen was lower and the polymer keeps it unchanged. Consequently, cracking of asphalt pavement with PmB occurs at lower temperatures compared with unmodified bitumen. An additional effect of PmB is the increase in asphalt fatigue resistance, which has also been reported in the literature (*Pyshyev et al., 2016*; *Zofka et al., 2021*).

Many researchers have emphasised the decisive influence of PmB morphology on the quality indicators of the binder and asphalt produced with it. At the microscale, the polymer forms a dispersion within the bitumen matrix. The geometry of this dispersion, including its fineness, particle size and distribution, as well as the degree of crosslinking between the polymer-rich phase, is considered an influential factor affecting the behaviour of PmB (*Emtiaz et al., 2023*; *Wang et al., 2017*). In turn, the morphology of PmB depends on the chemical composition of the bitumen, the amount and type of polymer, and the mixing parameters, such as shear rate, mixing temperature and mixing duration.

Despite these advantages, PmB is generally not recommended for storage because of its tendency towards phase separation. If storage without mixing cannot be avoided in the technological process, PmB should be tested for its ability to maintain sufficient homogeneity under static storage conditions. This test includes a comparison between the properties of the top and bottom parts of the PmB sample after long-term heating (*Zani et al., 2017*; *Zhu & Kringos, 2015*). Usually, this procedure takes several days if 24 hours of storage can be maintained in one cycle. Otherwise, four or five days may be required to obtain the results. For this reason, it is impossible to perform operational control during storage and make a quick decision concerning PmB stability.

The potential of fluorescence microscopy as a tool for evaluating the quality of PmB and predicting its performance characteristics has been demonstrated in numerous publications (*Larsen* *et al., 2009*; *Hanyu et al., 2005*). The micromorphology of PmB significantly affects the entire complex of properties enhanced by polymer modification. Hanyu et al. (*2005*) found that PmB samples differing only in the scale of their internal microstructure show superior asphalt performance when the phases are more finely dispersed. This effect becomes stronger as the polymer concentration increases.

This fact has drawn the attention of researchers to the analysis of PmB microstructure. However, Kou et al. (*2015*) showed that sample preparation methods significantly influence the resulting structure of PmB specimens. Various uncertain and uncontrolled factors during specimen sampling for analysis may affect the observed morphology, reduce reproducibility and distort the resulting image. Therefore, it is reasonable to examine several key aspects of the analysis in a single set of test samples prepared under controlled conditions using the same equipment.

Results

Analysis of Reheated PmB Samples

A primary challenge in the PmB sampling for microstructure analysis is the necessity in reheating the samples. The EN 13632 standard for visualisation of polymer dispersion in polymer modified bitumen prescribes a homogenization of the sample by the "gentle hand stirring" of the sample for a duration of 1 to 5 minutes. To prevent localized overheating during the process the basin with the sample placing on a sand bath. However, in the text of this standard noted that any operations with samples (sample preparation and treatment) influenced a lot on the test results. This suggests that the process of homogenization of the melted sample creates the conditions for the microstructural changes. The question is: to what extent does the minimal sample treatment alter the original PmB morphology?

Figure 3 illustrates one of the most heterogeneous samples produced via hand steering. The left image captures the edge of the sample (dark field on the top of the image is the void space), while the right image displays the central part of the sample. The variations in structure are observable throughout the entire volume of the sample and cannot be attributed to different rates of cooling on a surface and in core. Regardless of process that cause the change of the structure during the sample treatment, the observed scale of microstructure change in the field of view varies by a factor five or more.

As a result, the analysis of such samples becomes complicated. The significant change in structure scale is accompanied by a transition in the type of structure. Large-scale formations relate to the intermediate type of PmB, where it is hard to say which phase is continuous, bitumen or polymer one. Small-scale formation clearly exhibits polymer phase as continuous. While the stirring of reheated sample may help reveal the difference in PmB structure if it changes in specimen volume (for instance if the top of PmB tube after storage stability test is under analysis), the reheating and stirring process themselves may induce these very changes. This applies certain limitations on the "hand stirring" method, included in standard EN 13632 as one of necessary steps in test sample preparation.

Internal Versus External Surfaces

The standard methodology requires freezing the sample of PmB to a brittle state and breaking it into pieces. For microscopic analysis, fragments are selected from the central part of the specimen, provided they have at least one sufficiently smooth surface. This methodology has two primary complications. First, this process is taking time to pour a PmB sample into the prepared mold and freeze the sample to the brittle state to break it, which requires a refrigerator. Second, samples with high polymer content (this cam be the top of the tube PmB sample that lost its stability) can exhibit a glass transition temperature that lower than minus 40 °C. In most cases it’s hard to break this kind of sample, because even at low temperatures it is still maintains its elastic properties. It should mention that even after breaking you can get surfaces unsuitable for the microscope analysis.

The increasing in the speed of the test procedure can be achieved through alternative option, however it induces structural discrepancies. Figure 4 compares the same PmB sample, but the method of preparation differs. Left the traditional preparation method is presented. The piece of the sample core provides PmB morphology as it is. The right image is the surface of the drop of PmB. It`s morphology differs in two aspects. The surface of bitumen phase occupies larger area and the polymer dispersion appears finer. The last one can be explained with the high rate of cooling the small-scale drop surface.

Figure 5 illustrates the structural difference between the core and the edge of the same sample. The core cools at a relatively low rate, it has more time for phase separation. The coalescence of polymer dispersion results in rougher sample structure in this case. Near the side surface, where the sample is in contact with the mold, its edge cooling rapidly, which preserve the initial dispersion. This explains the difference in size of PmB structure on the drop surface and in the core of the larger sample. The difference in the area of PmB phases much more dangerous, because its observation on the drop surface can lead to wrong conclusions.

This phenomenon is driven by surface tension within the liquid sample. On surface of PmB drop at the interface with air polymer and bitumen phases form a classical three phase system, that has its own contact angles. The surface tension of the PmB phase seems to be higher than the bitumen one, so the polymer phase dipping into the sample to minimize its surface area at the air interface. This migration stops (or slowing down to a very low rate) when PmB cooling to the environmental temperature and its viscosity increases, but the result of it is noticeable. It can prevent the objective volumetric estimation of PmB structure, but it still remains valid for comparison analysis.

Correlating the PmB Storage Stability with Microstructural Parameters

For the set of the PmB specimens the stability assessment was performed according to the EN 13399 method, using penetration, softening point, and elasticity values given in the Appendix (*Table 1*). DIs were calculated as the difference between the values of the top and bottom sections of the sample, expressed as a percentage of their arithmetic mean. The four analyzed PmB samples differed in the penetration of initial bitumen. All initial bitumen spacemen were obtained from one source to minimize the side chemical variables that might influence the PmB stability. Before stability testing for the PmB there were obtained images of their microstructure, presented in the Appendix (*Figure 6*).

The images reveal a clear correlation between PmB microstructure and the base bitumen penetration. A decrease in penetration reflects a reduction in the concentration of bitumen oils, that makes polymer swell. For PmB a deficiency in bitumen oils leads to the formation of coarser "rougher" polymer dispersion in the PmB sample, which is inherently less stable.

Consequently, this allows for the preliminary estimation of a storage stability based on microstructure analysis of PmB. The scale of PmB microstructure can point on its tendency to keep stability at storage, or to lose it. Though for each case, depending on the type of mixer that produces the PmB, type and amount of polymer, the critical size of dispersion that indicates the risk of destabilization can change, in a consistent technological process it can be a reliable indicator. This method offers a rapid "field check" to identity PmB batches at risk of phase separation during storage.

The Phenomenon of PmB Autodispersion during Storage

Under several specific conditions during the storage of PmB without mixing, a phenomenon of polymer phase autodispersion may occur. In this research, this process was observed in the specimen modified with thermoreactive polymer, as shown in the Appendix (*Figure 7*). The left one image displays the initial PmB microstructure. The central and right images represent the top and bottom parts of the tube sample of the PmB after storage. The distinct phase dispersion after the storage is no longer observable. The evidence of the polymer's presence in the sample after heating is provided by the retention of penetration, softening point, and elasticity of the modified binder, presented in Table 2. The difference between top and bottom of the sample is minimal, so the polymer keeps stable in the bitumen matrix.

A possible explanation for the observed changes in the PmB microstructure lies is the capacity of the thermoreactive polymer to form chemical bonds between its chain complexes and the chemically active components of the bitumen. This interaction makes the polymer dissolve in the bitumen matrix to an undetectable degree of dispersion or release oils from the polymer phase, preventing identification of the polymer phase dispersion using their luminescence.

Quantitative Analysis of PmB Microstructure Via Digital Image Processing

The result of the computation of digital images of selected PmB samples is shown in the Appendix (*Table 3*). A comparative analysis of PmB samples with 3% and 9% SBS, prepared using the same initial BM bitumen, demonstrates that the volume of the polymer phase in the PmB is directly proportional to the amount of polymer added. Thus, as the polymer concentration in the BM bitumen increases from 3% to 9%, the volume of the polymer phase increases from 13.3% to 36.8%.

At the same polymer concentration, the volume of the polymer phase depends on the chemical composition of the initial bitumen. In high-penetration bitumens, characterized by a higher oil content, the volume of the polymer phase in the PmB ranges from 43% to 45%. With decreasing penetration, accompanied by a reduction in oils and maltenes overall, the volume of the polymer phase consistently decreases from 37% to 32%.

With the known polymer content in the PmB samples and the determined volume of the polymer phase, the polymer concentration in the polymer phase of the PmB can be calculated. For PmBs on the same bitumen with 3% and 9% SBS, the polymer concentrations in the phase are similar—21.8% and 22.4%, respectively. However, polymer concentrations in the polymer phase of PmBs on bitumens with different penetrations vary significantly—from 18.5% to 26.1%.

The similarity of polymer concentrations in the phase for PmBs on the same initial bitumen indicates that, when bitumen is modified with polymer, a process of limited polymer swelling occurs in the oil environment of the bitumen. The magnitude of polymer swelling at a concentration of up to 9% is constant and depends on the composition of the maltene environment, deteriorating with decreasing penetration of the initial bitumen.

Discussion

The sampling of PmB influence its microstructure, so this process must be minimized in time and number of operations with binder. The described in EN 13632 method must be used when the sample delivered to laboratory in the cooled state. If it is possible (during the research work or field control) to pure the sample in the molds right after its producing, the analysis will be more reliable. The analysis of polymer drops surface may be used in a limited cases such as quick check of PmB stability during the operation storage. The visual comparison of two drops of PmB from top and bottom of the storage container under UV radiation can provide the quick information for operation control. The size of phase dispersion in PmB directly depends on compatibility of polymer and bitumen. The higher compatibility results in forming the finer dispersion during PmB mixing, that more stable in time. The potential of this analysis is high and it can become the alter method of storage stability estimation. Here, using this method, is possible to quickly indicate PmB systems that is under a risk of losing storage stability and shouldn't storage without mixing. With this the digital image analysis of PmB microstructure allows to create the complex of indicators that can improve the operation control of PmB. The assessment of PmB morphology can fulfill the need in parameters that can be checked quickly during the operations on asphalt plant not cancelling of the other indicators. For the research work the calculation of parameters such as polymer concentration in polymer phase in PmB can provide the valuable information on expected parameters of PmB and ways to improve them.

Conclusion

One of the best decisions to obtain the unchanged PmB structure is to pour samples into molds right after the PmB producing. With the rapid cooling of the samples in the molds the structure changes less than in other methods and its visualization gives more reliable information on the PmB structure. The reheating and the hand stirring of the sample according the EN 13632 standard is not objective method because the microstructure of PmB changes in the process.

The changes in microstructure on the surface of the PmB drop not allow using this method for sample preparation. But for the quick field estimation of the PmB stability this method can be used. Two drops from the top and the bottom of the tank with PmB will differ will differ in fluorescent intensity under UV radiation that can be checked even visually.

In the case where operative information about stability risks of PmB is required, the test of PmB storage stability takes several days, but the microstructural analysis can provide the quick preliminary estimation of the PmB storage stability. Though it can`t replace the whole analysis, it can quickly indicate the polymer-bitumen combinations that has large-scaled microstructure. Such a structure inherent to fewer compatible combinations and indicates a high risk to lose stability at storage.

The traditional phase separation can be replaced with the opposite process that close to autodispersion if the polymer able to react with bitumen components. It can create situation when polymer dispersion that can be observed after PmB preparation disappear after storage process.

The digital processing of the PmB microstructure images can be made on modern equipment with rather simple devices and programs. The results of microstructural analysis can be used for calculation of specific parameters of PmB which provides valuable additional information on polymer-bitumen interaction. It can be useful analytical method to understand how the performance of PmB can be improved. The estimation of the volume of polymer phase and concentration of polymer in it gives two key parameters that can show the compatibility and stability of PmB as a multicomponent system.

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Conflict of Interest

The author declares that there is no conflict of interest.

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Appendix

Table 1. Destabilization of PmB with 3% SBS depending on the initial bitumen

Binder index	Penetration at 25 °C, 0.1 mm			Softening point, °C			Elasticity at 25 °C, %		
	Top	Bottom	DI, %	Top	Bottom	DI, %	Top	Bottom	DI, %
GM P3	243	256	-5.2	48.2	47.2	2.1	95	94	1.1
BMK P3	123	109	12.1	48.6	46.1	5.3	80	59	30.2
BM P3	72	53	30.4	57.6	53.1	8.1	93	47	65.7
BMO P3	52	32	47.6	78.0	64.9	18.3	95	60	45.2

Table 2. Stability of PmB with termoreactive polymer

Binder index	Penetration at 25 °C, 0.1 mm				Softening point, °C				Elasticity at 25 °C, %			
	Before	Top	Bot-tom	DI, %	Before	Top	Bot-tom	DI, %	Before	Top	Bot-tom	DI, %
Tr P2	95	90	83	8	50	56	57	2	67	68	72	6

Table 3. Structural properties of PmB by digital image analysis

Binder index	BM P3	GM P9	BMK P9	BM P9	BMO P9
Polymer concentration	3	9	9	9	9
Penetration at 25 °C, 0.1 mm	67	99	53	35	24
Softening point, °C	54.3	110.1	108.3	103.2	100.6
Volume of bitumen phase, %	86.7	57.0	55.3	63.2	68.4
Volume of polymer phase, %	13.3	43.0	44.7	36.8	31.6
Concentration of polymer in polymer phase, %	21.8	19.2	18.5	22.4	26.1

Amount of bitumen components, absorbed by polymer, %	10.4	34.7	36.4	28.6	23.4

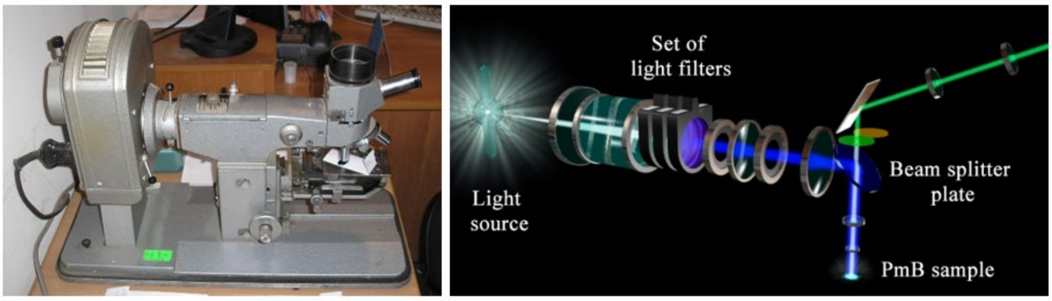

Figure 1. The fluorescence microscope and its optical scheme

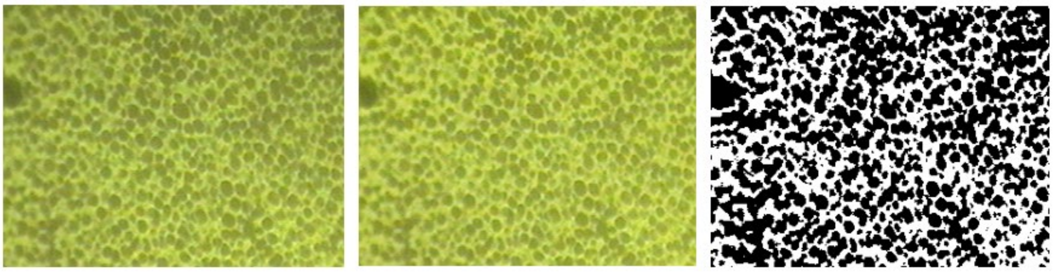

Figure 2. Stages of image processing for a polymer phase volume estimation

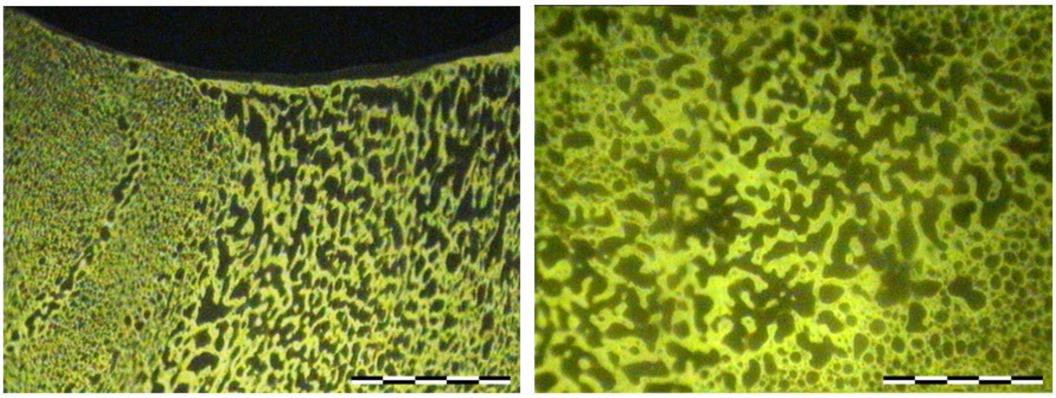

Figure 3. The heterogenity in PmB sample structure after hand stirring

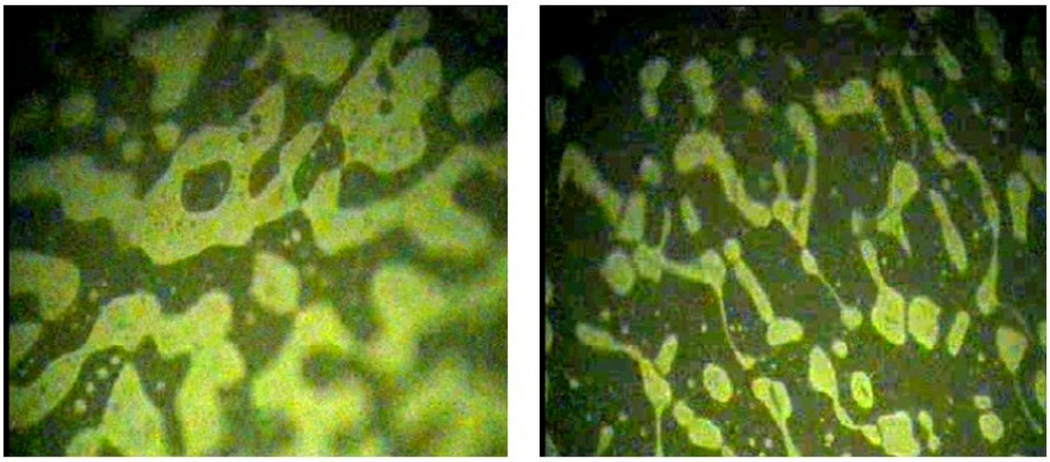

Figure 4. The inner surface (left) versus external (right) surface of the same PmB sample

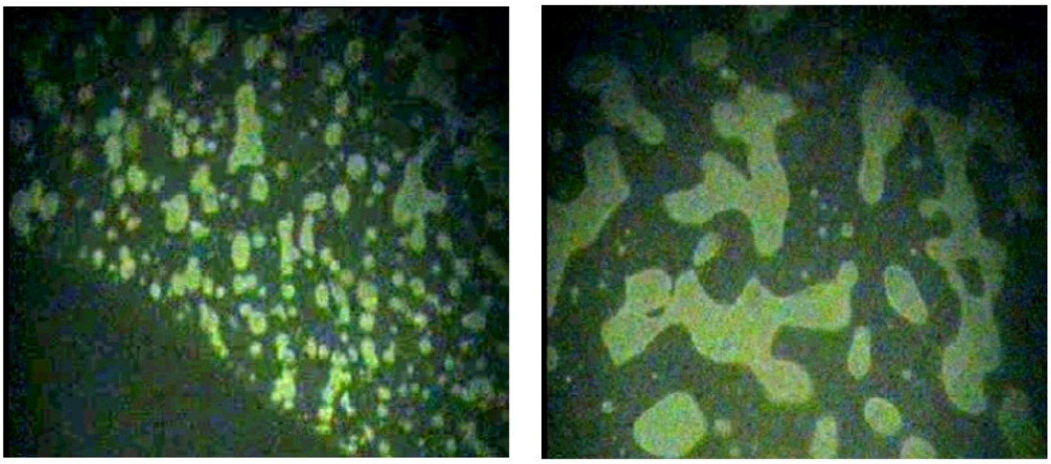

Figure 5. The difference between the edge (left) and the core (right) of the same PmB sample

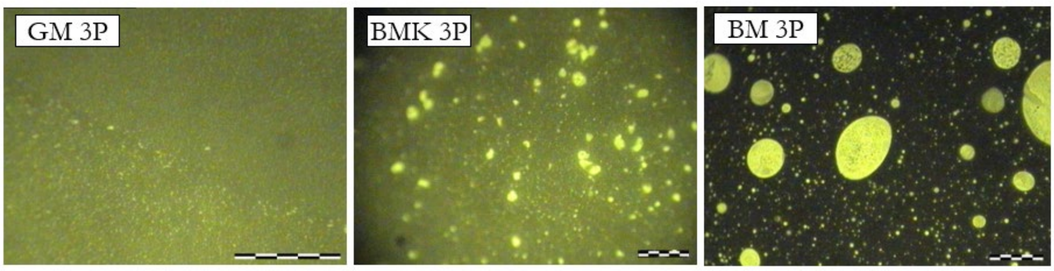

Figure 6. Difference in microstructure of PmB samples with 3% of SBS polymer depending on the initial bitumen

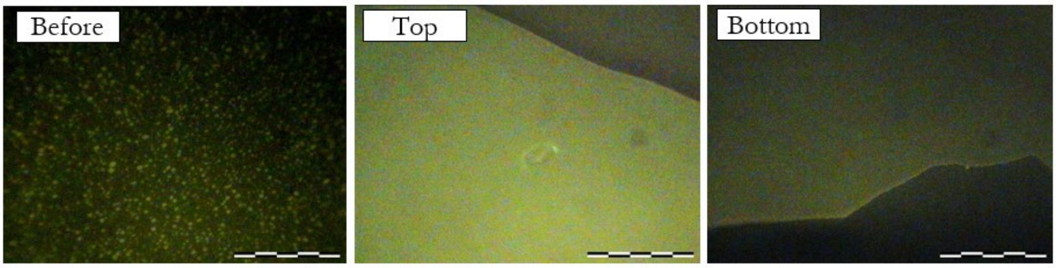

Figure 7. The results of the storage stability test for the sample with termoreactive polymer