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TECHNICAL NOTES

Enhancing Mid-Temperature Performance of Calcareous Mineral Filler Percentage in Asphalt Mastic for Asphalt Materials

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Abstract: Asphalt mixture consists of mineral aggregates, bitumen, mineral fillers, and void ratio. Mastic refers to a blend of bitumen and filler. Filler, as the smallest part of stone materials used in the preparation of asphalt concrete mixtures, plays a crucial role in determining their characteristics. It is utilized in asphalt to occupy voids, enhance durability, decrease permeability, and ultimately improve resistance to water infiltration. Even though filler constitutes a small fraction of stone materials, altering the filler type and quantity can significantly influence the properties of asphalt mixtures. The proportions of bitumen and filler can significantly impact the mastic's properties. Therefore, studying the filler-to-bitumen ratio's effect on mastic rheology is crucial. To analyze the influence of the mineral filler-to-effective bitumen ratio on the rheological properties of bitumen mastic, a comprehensive series of mastic samples were meticulously formulated at varying ratios of filler to effective bitumen, specifically 0, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, and 1.6 weight/weight. Importantly, results from Linear Amplitude Sweep testing show a clear trend: while fatigue life

improves with added filler up to a critical point, it declines with further increases in filler content. This underscores the necessity for careful consideration of filler ratios to optimize asphalt performance.

Keywords: Mid-temperature performance (MTP), Bitumen, Filler, Mastic, Rheology, Filler-to-bitumen ratio.

1. Introduction

Asphalt mixture is a versatile and essential material in the construction of various transportation infrastructures, including roads, parking lots, and airports. This composite material is primarily composed of mineral aggregates, typically including both fine and coarse particles, which are bound together by bitumen, a viscoelastic binder (Khanmoradi, & Modarres, 2024). The fine aggregates, measuring less than 2 mm in size, along with fillers smaller than 0.063 mm, combine with the bitumen to form a mastic. This mastic fills the gaps between the coarse aggregates, providing cohesion and structural integrity to the overall mixture. The coarse aggregates, in turn, play a crucial role in determining the mechanical performance of the asphalt mixture, contributing to its strength, stability, and durability(Awuah, Garcia-Hernandez, & Valentin, 2024). The careful selection and proportioning of these various components, guided by industry standards and engineering principles, ensure the optimal performance of asphalt mixtures in the demanding environments they are designed to withstand.

The physicochemical interaction between asphalt and filler is a crucial aspect of the performance of asphalt mixtures (Chaubey, & Mishra, 2024), such as limestone, hydrated lime, or fly ash, are commonly used in asphalt mixtures to improve their properties and performance.

Various factors can influence the optimal filler-bitumen ratio in asphalt mixtures, including the properties of the bitumen and filler materials, the gradation of the aggregate, and environmental conditions. The type and characteristics of the filler, such as particle size, surface area, and chemical composition, can affect the interaction with the bitumen and the resulting mixture properties. Numerous studies have been conducted to investigate the impact of the filler-bitumen ratio on the performance of asphalt mixtures. Experimental investigations have evaluated the mechanical properties, such as stiffness, tensile strength, and resistance to rutting, at different filler-bitumen ratios. Numerical modeling techniques, such as finite element analysis, have also been employed to simulate the behavior of asphalt mixtures and optimize the filler-bitumen ratio. The existing literature suggests that the optimal filler-bitumen ratio in asphalt mixtures can vary depending on the specific application and performance requirements. In general, a higher filler-bitumen ratio can improve the stiffness and resistance to permanent deformation, but may also lead to a reduction in flexibility and susceptibility to cracking. Conversely, a lower filler-bitumen ratio can result in a more flexible and ductile mixture but may be more prone to rutting and other distresses.

The performance and integrity of asphalt mixtures are heavily dependent on the intricate interaction between the asphalt binder and the filler material. This interaction involves a complex interplay of physical and chemical processes that ultimately determine the overall strength, stability, and durability of the resulting asphalt mixture. At the heart of this interaction lies the concept of adhesion and cohesion. Adhesion refers to the ability of the asphalt binder to effectively coat and bond with the filler particles, which is essential for the mixture's overall strength and longevity. This adhesion can be both physical, where the asphalt binder may partially penetrate the filler particles, as well as chemical, where strong bonds are formed between the dissimilar materials. The degree of physical adhesion and chemical bonding between the asphalt binder and the filler particles directly affects the performance of the asphalt mastic, the binding agent that holds the mixture together. When the adhesion and cohesion are strong, the filler becomes more effectively integrated into the asphalt mixture, enhancing its overall strength and durability. The chemical reactions that occur between the asphalt binder and the filler material can also play a significant role in the performance of the asphalt mixture. Certain filler materials, such as limestone or cement, can react with the asphalt binder, leading to the formation of new compounds that contribute to the mixture's cohesive properties and resistance to deformation. Furthermore, the amount of filler material used in the asphalt mixture can also impact the overall performance. An appropriate balance must be struck between the asphalt binder and the filler content, as an excess or deficiency of either can negatively affect the mixture's characteristics, such as its resistance to rutting, cracking, and other forms of distress (Rezaei, et.al. 2017; Eslami, et.al. 2019). Absorption, on the other hand, involves the ability of the filler particles to absorb the asphalt binder, which can affect the rheological properties of the mixture. Chemical reactions between asphalt and filler can also occur, leading to changes in the composition and properties of the mixture. Overall, understanding and optimizing the physicochemical interaction between asphalt and filler is essential for designing high-quality asphalt mixtures with improved performance and durability (Rezaei, et.al.2020; Usman, et.al.2025).

Mineral fillers have long been a crucial component in the formulation of asphalt mixtures. Despite their widespread use, the precise effects of the quantity and ratio of these materials, as well as the nature of the filler-bitumen interactions, continue to warrant deeper investigation.(Srikanth, et.al.2018) Studies have shown that varying the percentage of fillers can significantly impact the hardness, brittleness, or softness of the bitumen mastic. While previous research has addressed some of these aspects, the rheological behavior of the mastic and the viscosity characteristics of the filler-bitumen mixture have received comparatively less attention (Ahmad,et.al 2018;Nazary, & Kofteci, 2024).

Existing literature indicates that the appropriate dosage of mineral fillers in asphalt mixtures is primarily determined by the percentage passing through sieve No. 200 and the ratio of filler to effective bitumen (by weight). This is due to the importance of the volume ratio, which is influenced by the degree of compaction and the space between filler particles. It is not possible, however, to fully predict the impact of the void volume on the ease of mixing, the penetration of the bitumen, and the resulting changes in mastic behavior(Mahto, et.al.2024). In the research conducted, the effect of different mineral fillers such as limestone, fly ash, and cement on the rheological properties of adhesives and asphalt mixtures has been investigated, the results showed that the addition of filler can significantly improve stiffness and strength. Improve asphalt mixtures against permanent deformation. Researchers investigated the effect of filler type and content on the fatigue performance of bituminous mortars. They found that the optimal filler-to-bitumen ratio varies depending on the type of filler used, and adding certain fillers such as limestone can increase the fatigue life of the asphalt mixture(Guo, et.al.2017; Tauste-Martínez, et.al.2022). Another study focused on the effect of different filler materials, including limestone, fly ash, and baghouse fines, on the moisture sensitivity of asphalt mixtures. The results show that the selection and appropriate dosage of the filler can improve the resistance of the asphalt mixture against damage caused by moisture. The researchers developed a multi-objective optimization approach to determine the optimal filler-to-bitumen ratio in asphalt mixtures, considering multiple performance criteria, such as rutting resistance, fatigue life, and moisture sensitivity. This study presents a systematic framework for optimizing filler content in asphalt mixtures (Sakanlou, et.al.2018; Cheng, et.al.2019). Previous studies have indicated that determining the appropriate dosage of mineral fillers in asphalt mixtures is crucial for achieving optimal performance and durability of the pavement (Zaumanis, et.al.2024). The investigation of adhesive failure mechanisms in asphalt mixtures has revealed a significant influence on the properties of the binder-aggregate interface and the weight ratio of these two materials. However, the precise impact of interfacial interactions on adhesive properties in the vicinity of the interface remains poorly understood. Given the large volume of mineral aggregates in an asphalt mixture, these effects cannot be easily mitigated. Furthermore, with the growing emphasis on the use of more mineral fillers, there is a renewed interest in better understanding the effect of binder interactions with fresh aggregates and their weight percentages on both binder and mix properties (Cominsky, et.al.1994).

The use of stone powder as an active filler in asphalt concrete mixes has been shown to significantly improve the mechanical behavior, particularly the creep behavior, at high temperatures. Research has revealed that lime, a type of active filler, plays a crucial role in the growth and accumulation of micro-cracks, as well as the deformation of mixed elastic plastics. This phenomenon is heavily influenced by the chemical interaction between the lime filler compounds and the bitumen. The conducted research has further demonstrated that the settling behavior of asphalt concrete mixtures is closely tied to the characteristics of the bitumen, the filler characteristics, and their mutual interaction. Additionally, the occurrence and growth of micro cracks are directly influenced by the inherent characteristics of the filler material. This understanding underscores the importance of carefully selecting and optimizing the filler composition to achieve the desired performance characteristics in asphalt concrete applications. The complex interplay between the bitumen, filler, and their interaction presents a critical area of study for researchers and industry professionals alike (Cominsky, et.al.1994). By delving deeper into the mechanisms governing the mechanical behavior and microstructural changes in asphalt concrete mixes, researchers can contribute valuable insights that inform the development of more durable and resilient asphalt-based materials for various infrastructure applications (AI-MS-2, 2014).

The mineral filler-to-effective bitumen ratio plays a crucial role in determining the rheological behavior of the bitumen mastic. The addition of mineral fillers such as limestone, quartz, or granite to bitumen not only affects the mechanical properties of the resulting mixture but also influences its flow and deformation characteristics. A higher filler-to-bitumen ratio typically results in a stiffer and more viscous mastic, while a lower ratio leads to a softer and more flexible material. The distribution and size of the filler particles also have a significant impact on the rheological properties of the bitumen mastic. In general, a more uniform distribution of smaller filler particles tends to improve the stiffness and resistance to deformation of the mixture. However, an excessive amount of filler can also lead to an increase in viscosity and potentially compromise the workability of the mastic. Therefore, it is essential to carefully optimize the mineral filler-to-effective bitumen ratio to achieve the desired rheological behavior for specific applications in road construction or pavement engineering. Further research and experimentation are needed to better understand the complex interactions between bitumen and mineral fillers and to develop more accurate models for predicting the rheological properties of bitumen mastics. Advancing our knowledge in this area could lead to the development of more robust and durable asphalt mixtures, ultimately enhancing the performance and service life of transportation infrastructure.

2. Materials and methods

2.1 Materials and preparation of mixtures

The PG70-10 bitumen and sieve No. 200-passing mineral filler were procured from the Pasargadae Oil Company (Tehran, Iran) and a dolomite limestone mine in the vicinity of Kahak (Qom, Iran), respectively. The results of the

Filler Adequacy Test, as presented in Table 1, encompass various parameters crucial for evaluating the characteristics of the material under study. In Figure 1, a sample of the filler image is observed. The Atterberg Limits from AASHTO T89 and T90 methods reveal soil's plasticity and liquidity. The Plasticity Index indicates the material's behavior under varying moisture. These findings are crucial for assessing filler material's adequacy and suitability, guiding engineering and construction projects. Various filler-bitumen mixes were prepared by mixing the constituents at different filler-to-bitumen ratios (0, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, and 1.6 w/w) using a mechanical mixer operating at 150℃ for about 15 minutes for each mix. To maintain the experimental conditions between the control sample (base bitumen sample) and the mastic samples, the control sample was also subjected to the abovementioned procedure.

Table 1. Filler Adequacy Test Results

	Tests		**Test Results**	**The amount of instructions 234**	**Sufficiency**
Filler Aggregates	Atterberg Limits (AASHTO T89, 90)	Plasticity Index (PI)	Nonplastic soil	Maximum 4	Yes
	Special Weight (gr/cm^3) (AASHTO T100)		2.633	-	Yes

Fig. 1: Photo of filler Limestone powder.

2.2 Testing procedures

All samples underwent a series of tests, including the elastic recovery test (ASTM D6084M-18) at 25℃ and dynamic shear rheometer tests (ASTM D7175) using a 25-mm mold under both unaged and RTFO aged conditions at 70℃. Additionally, testing was conducted with an 8-mm mold for the RTFO+PAV aged condition at 34℃ at a frequency of 10 Rad/s, followed by the bending beam rheometer test (AASHTO T 314) at 0℃. The multiple-stress creep recovery test (ASTM D7405-15), with 10 replicates for two stress levels of 0.1 and 3.2 kPa, utilized a 25-mm mold at 70℃, totaling 200 seconds for data collection, alongside the linear amplitude sweep test (AASHTO TP 101-12) at 34℃ with an 8-mm mold. For all tests, the temperature was established based on the performance grading of PG70-10 as the base bitumen (Jenks;et.al,2011). Evaluation of tensile strain performance at annual average temperature is a common method in materials testing, as it helps to ensure the structural integrity and reliability of the asphalt mixture component or system under normal operating conditions. By subjecting the sample to cyclic loading at this temperature, researchers can gain valuable insights into the long-term durability of the material and identify any potential weaknesses.The experimental program outlined in Figure 2 encompasses a range of tests conducted as part of the present case study. These include the elastic recovery test at 25℃, dynamic shear rheometer tests using a 25-mm mold under unaged and RTFO aged conditions at 70℃, as well as with an 8-mm mold under RTFO+PAV aged condition at 34℃ at a frequency of 10 Rad/s. Additionally, the program involves a bending beam rheometer test at 0℃ and the multiple-stress creep recovery test with a 25-mm mold at 70℃ for two stress levels.

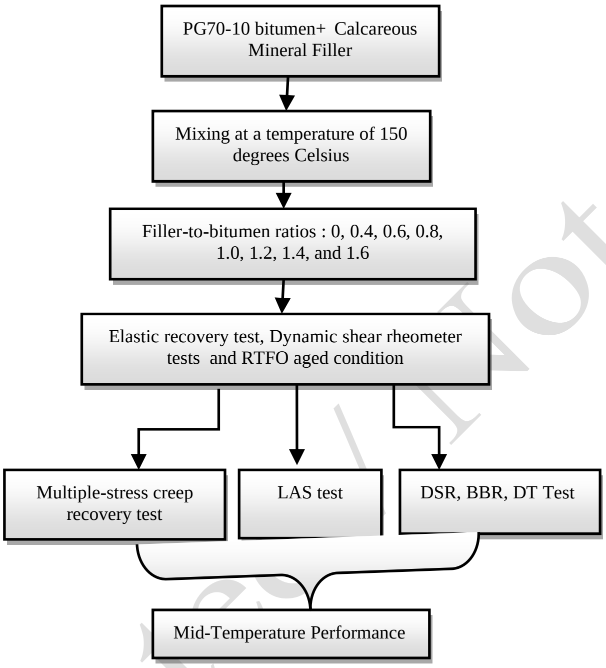


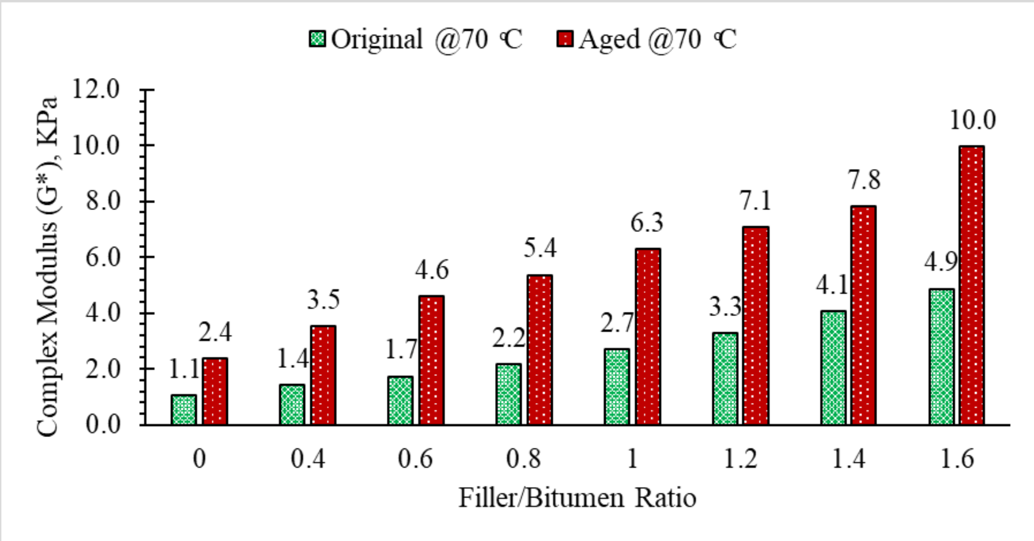
Fig. 2: Flowchart of the research and the steps taken for testing, as well as the collection and analysis of laboratory results

Mid-Temperature Performance (MTP) in asphalt mixtures plays a pivotal role in ensuring the longevity and functionality of pavement structures, making it a critical area of focus in contemporary road engineering research. The significance of MTP lies in its ability to assess the performance of asphalt mixtures under moderate temperature conditions, which are prevalent in various climatic regions. Studying MTP facilitates the understanding of the balance between rutting resistance and fatigue performance, enabling engineers to design asphalt mixes that can withstand the stresses imposed by traffic loads and thermal fluctuations without suffering premature failure. Furthermore, attention to MTP can enhance the durability of the pavement, reducing maintenance costs and extending service life, which is particularly important in the context of sustainable infrastructural development. As climate change continues to challenge conventional material performance expectations, incorporating MTP evaluations in the design process provides invaluable insights into the resilience of asphalt mixtures. This focus not only supports compliance with evolving industry standards but also fosters innovation in mix design and material selection, ultimately contributing to more resilient and cost-effective transportation networks.

3. Results and discussion

3.1 Complex modulus and phase angle

Figure 3 presents the results in terms of G* and δ for the unaged and RTFO-aged samples. As observed, for the mastic samples, the complex modulus increased although the phase angle remained almost unchanged with increasing the filler-to-bitumen ratio. This indicates that the addition of the filler would solely add to the mastic strength rather than affecting the response time of the material to the applied stress. In the study conducted, it was observed that as the filler-to-bitumen ratio increased, the complex modulus also increased. This indicates that the addition of filler to bitumen resulted in a stiffer and more rigid material. Interestingly, despite this increase in complex modulus, the phase angle remained almost unchanged. This suggests that the addition of filler did not significantly affect the ability of the material to dissipate energy under loading. These findings have important implications for the design and performance of bituminous materials, as they highlight the complex interplay between filler content, stiffness, and energy dissipation. Further research is needed to fully understand the mechanisms at play and to optimize the properties of bituminous materials for various applications.



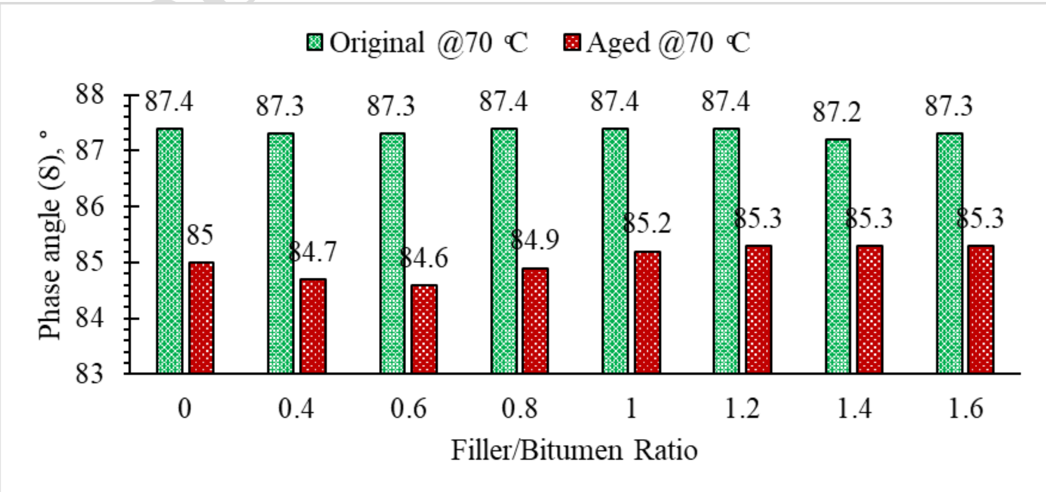


Fig 3: The results of complex modulus (Top) and phase angle (Down) from DSR test for different filler/bitumen ratios.

The complex modulus, a critical parameter reflecting the material's overall stiffness and resistance to deformation, displayed a marked enhancement upon the introduction of filler particles. This increase in stiffness can be logically attributed to the ability of the filler to establish a more interconnected network within the bitumen matrix. Such a network effectively restricts the mobility of the bitumen, consequently leading to the formation of a more rigid composite structure (Huang, et.al. 2024). This phenomenon aligns with classical rheological models, which often describe the relationship between filler concentration and the resultant moduli, showcasing that enhanced interactions at the molecular level can lead to improved material properties. Conversely, the phase angle-a critical indicator of the material's capacity to dissipate energy during applied loading-remained relatively stable throughout the experimentation, suggesting that the addition of filler does not significantly disrupt the viscoelastic behavior of the bitumen, particularly regarding its energy dissipation mechanisms. The constancy of the phase angle implies that although the filler enhances the stiffness of the material, it does not adversely affect the intrinsic ability of the bitumen to absorb and dissipate energy, which is essential for sustaining material performance under dynamic loading conditions.

Figure 4 presents a comprehensive analysis of the percent recoveries (R), non-recoverable compliances (J_{nr}), and the percent differences in both recoveries and non-recoverable compliances across varying filler/bitumen ratios at two specified shear conditions-100 Pa and 3.2 kPa-at a consistent temperature of 70 °C. The data indicates a discernible trend wherein increasing the filler/bitumen ratio corresponds to an enhancement in the recoveries, evidenced by an upward trajectory from 1.62% at a ratio of 0 to 16.67% at a ratio of 1.6. In contrast, the non-recoverable compliance (J_{nr}) diminishes with elevated filler content, reflecting a reduction in viscous deformation as the system's structural integrity improves. Notably, percent differences in recoveries and compliances exhibit variability, with the maximum percent difference in recoveries recorded at 100% for a ratio of 0, while the minimum was 82.58% at a ratio of 1.6.

By systematically analyzing the correlation between the filler-to-bitumen ratio and rheological outcomes, researchers have illuminated significant patterns that may have been previously underestimated. As the filler content within the bitumen matrix increases, it becomes evident that there is a consequential reduction in non-recoverable compliances (Jnr). This reduction illustrates a remarkable enhancement in the material's structural resilience, highlighting the critical role that fillers play in modifying the viscoelastic behavior of the asphalt binder. The presence of fillers not only improves the load-bearing capacity of the bitumen but also contributes to its stability under varying stress conditions, thus mitigating issues like permanent deformation and cracking (Khan, et.al. 2023). Moreover, a thorough understanding of the interplay between filler characteristics, such as particle size, shape, and surface area, and bitumen rheology is essential for optimizing asphalt mixtures for specific applications.

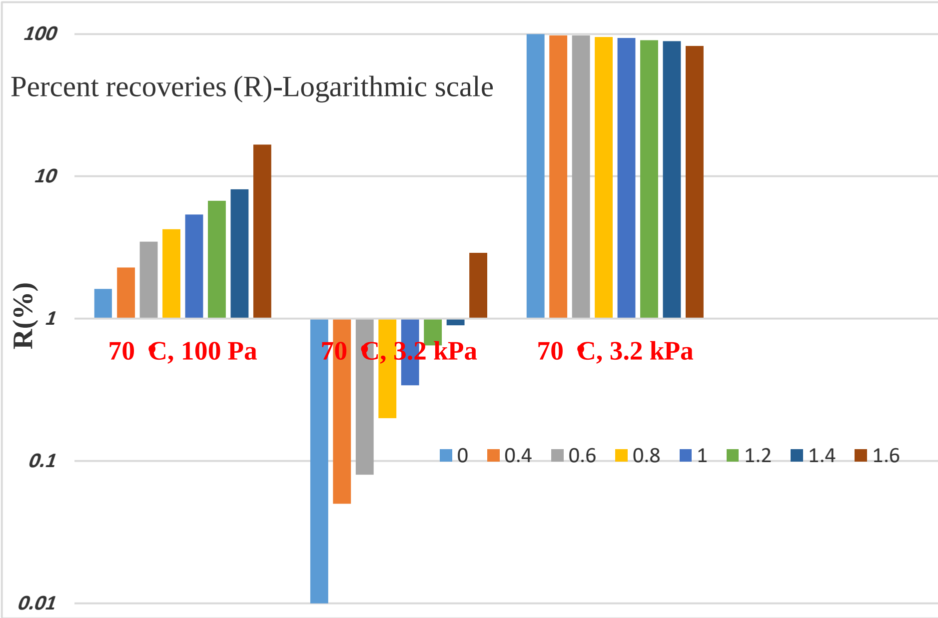


Fig 4: Percent recoveries, non-recoverable compliance, and percent differences in recoveries of filler/bitumen ratios.

3.2 Mid-temperature performance

In order to gain a thorough understanding of the mid-temperature bitumen performance, it is essential to conduct a detailed investigation into the results of the elastic recovery test in mastic. The elastic recovery test is a critical component of assessing the performance of bitumen at mid-temperatures, as it provides valuable insights into the material's ability to recover its original shape after being subjected to deformation. By analyzing the results of this test, researchers and industry professionals can determine the extent to which a particular bitumen sample is capable of withstanding the stresses and strains associated with typical road conditions. This information is crucial for ensuring the long-term durability and reliability of asphalt pavements, as it allows for the identification of potential weaknesses or deficiencies in the material that could lead to premature failure. The extreme air temperatures of 49°C in summer and -24°C in winter that the asphalt mixture is exposed to in the field reflect a wide temperature range. While opting for a test temperature of 34°C might aim to simulate an average temperature scenario, it could fall short in encompassing the full spectrum of stresses and deformations encountered by the asphalt mixture over its lifespan. Moreover, adjusting the filler content can significantly impact the rheological characteristics and performance of the asphalt matrix. Introducing fillers may enhance rigidity while diminishing tensile stress tolerance, potentially compromising the material's fatigue resistance..By carefully examining the results of the elastic recovery test in mastic, researchers can make informed decisions regarding the selection and use of bitumen in various asphalt applications, ultimately contributing to the development of more sustainable and cost-effective road construction practices. In order to investigate the mid-temperature performance, the results of the elastic recovery test are demonstrated in Figure 5, while the results of the DSR test ($G^* \times \sin \delta$) and LAS test are shown in Figure 6.

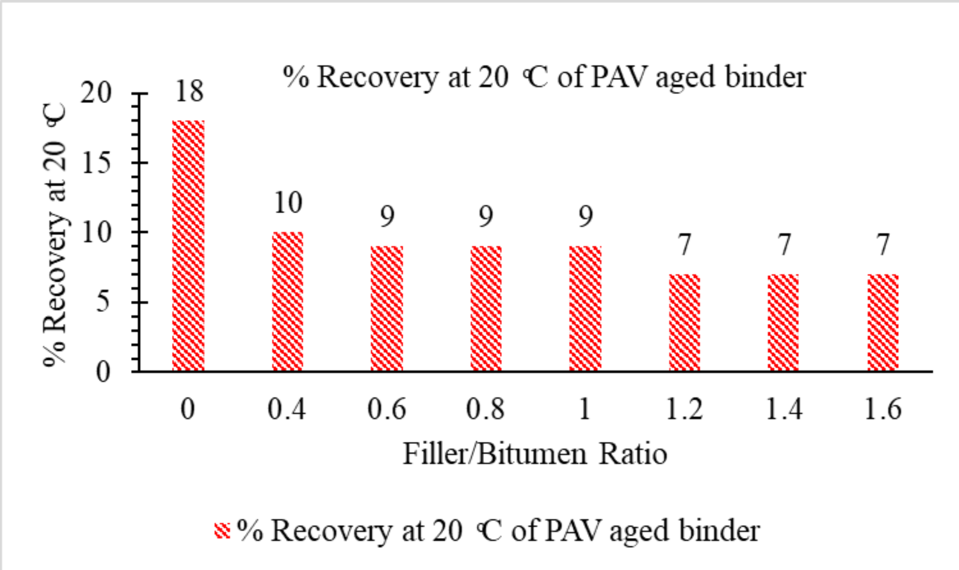


Fig 5: The elastic recovery results for filler/bitumen ratios.

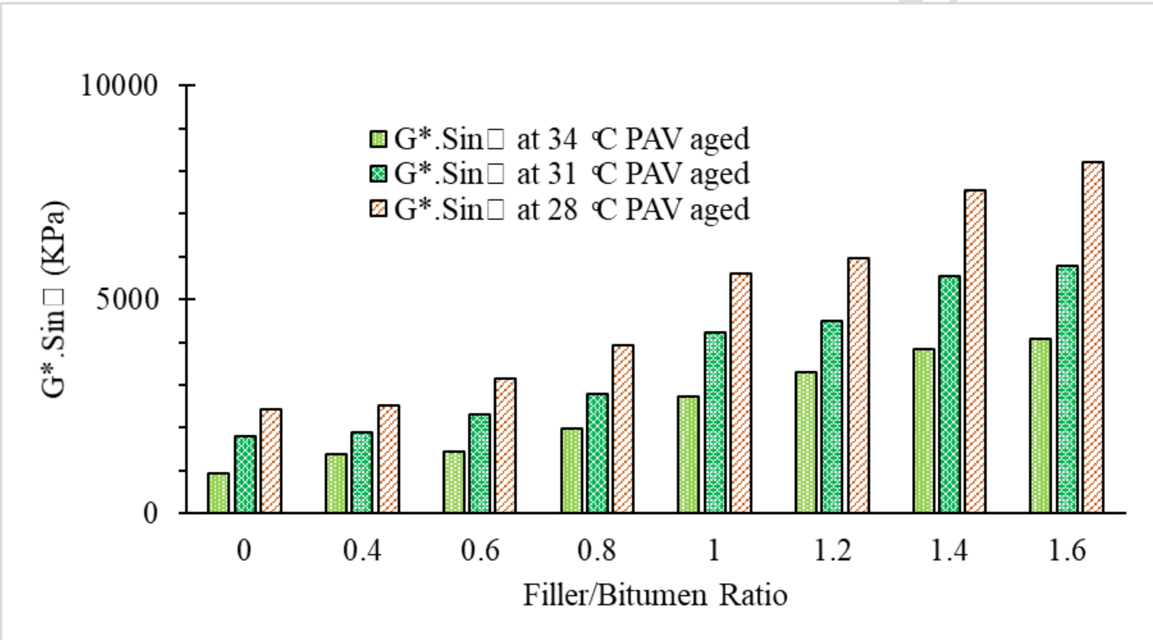


Fig 6: The results of G*×sinδ rom DSR test for filler/bitumen ratios.

The investigation into the results of the Laboratory Asphalt Shear (LAS) test provides significant insights into the performance characteristics of various asphalt mastic samples when subjected to different filler-to-bitumen ratios. As illustrated in Figures 5 and 6, an increase in the filler-to-bitumen ratio (w/w) correlates with an uptick in the value of G* × sin δ, signifying an escalation in the material's stiffness. However, this upward trend in stiffness is accompanied by a notable reduction in the percentage of elastic recovery. This decline signifies a deterioration in the material's ability to resist tensile strain and cracking, which is particularly alarming for applications where enduring flexibility is paramount. The trends observed became markedly pronounced once the filler-to-bitumen ratio surpassed 1.2, indicating a critical threshold beyond which the performance metrics begin to diverge significantly. Figure 7 presents the stress-strain curves obtained from the LAS (Load and Stability) testing, illustrating the relationship between various filler and bitumen ratios. This analysis is crucial for understanding the mechanical behavior of the composite materials under different loading conditions, providing valuable insights into their structural performance and durability.

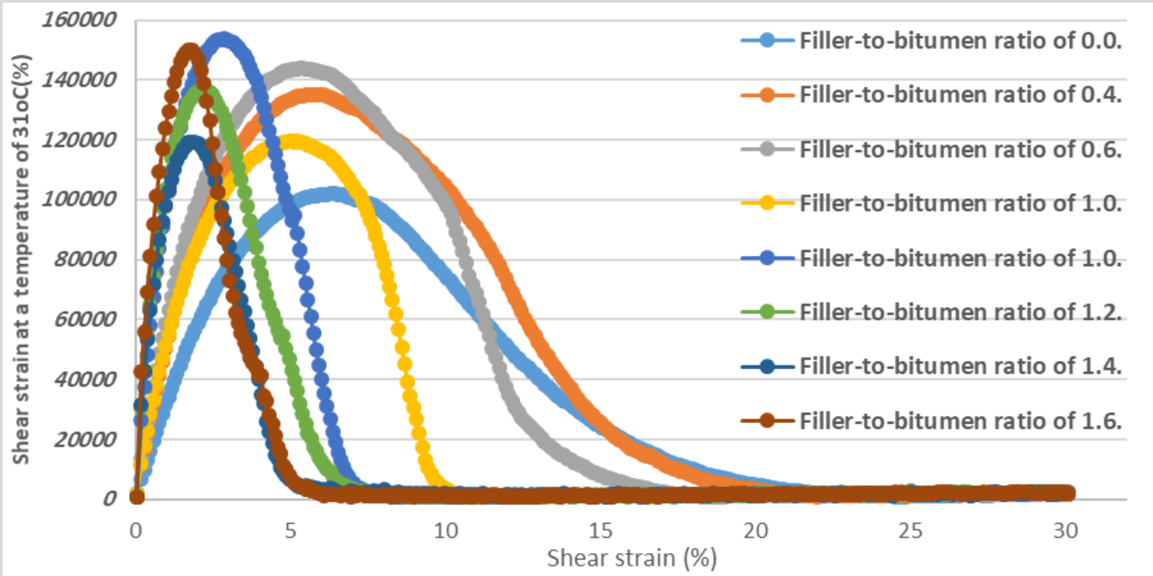


Fig 7: Stress-strain curves extracted from LAS testing of filler/bitumen ratios.

The data gathered reveal a complex interplay between the degree of aging in the binder and the resultant fatigue life across a range of strain applications.The findings suggest that in unaged asphalt, an increase in aging levels generally leads to a decrease in fatigue life across a wide range of strains. However, this relationship diverges under specific conditions; for varying filler percentages asphalts, an increase in aging results in an increase in fatigue life at lower strain levels, contrasting with the decrease observed at strains exceeding approximately 1 percent. This phenomenon can be attributed to the viscoelastic properties of asphalt, where a higher filler-to-bitumen ratio enhances fatigue performance in the low strain domains due to improved stiffness and resistance to deformation. The interplay between physical relationships and rheological properties significantly influences the fatigue performance and longevity of asphalt mixtures, particularly concerning the varying percentages of filler added to bitumen. As the filler-to-bitumen ratio increases, the inherent viscoelastic characteristics of the asphalt matrix become more pronounced, leading to an improvement in fatigue life under lower strain conditions. This enhancement can be attributed to the filler's contribution to the overall stiffness and strength of the mixture, which mitigates deformation and prolongs the material's resistance to fatigue cracking. while lower strain conditions can benefit from the increased rigidity provided by fillers, high strain scenarios may expose the material to excessive stress, resulting in a decreased fatigue lifespan. Conversely, under prolonged aging conditions, the effects of varying filler percentages enhance the fatigue life compared to the base bitumen. Hence, our investigation underscores that the relationship between filler content and the performance characteristics of asphalt mixtures is contingent upon the specific properties of the mixture and the aging state, indicating that direct comparisons to previous studies may not yield accurate conclusions.Furthermore, through the Linear Amplitude Sweep testing, a notable trend is observed where the fatigue life initially increases with the addition of filler but subsequently declines beyond a certain threshold, corroborating the mechanistic and structural underpinnings of asphalt's behavior. The adjustments in mechanical and physical properties, driven by variations in the filler-to-bitumen ratios, play a pivotal role in predicting the fatigue life across various asphalt composites, directing future research toward optimizing blending techniques and understanding the microstructural adaptations that accompany filler modifications. In a comprehensive study on asphalt pavement design, Cheng et al. (2016) investigated the relationship between filler to bitumen ratio and medium temperature performance characteristics with a similar result (Cheng, et.al., 2116; Remisova, Briliak, & Holy, 2023)

4. Conclusions

The present research focused on examining the influence of the mineral filler-to-effective bitumen ratio on the rheological properties of bitumen mastic. To achieve this, a range of mastic samples was prepared utilizing varying filler-to-bitumen ratios (w/w). Subsequently, a comprehensive series of SHRP tests were conducted to assess the performance characteristics of the mastic across a spectrum of temperature conditions, thereby providing insights into its behavior under different thermal regimes. This investigation aims to deepen the understanding of how the composition of bitumen mastic impacts its overall performance, which is critical for optimizing its application in various engineering contexts.

The findings from the investigation indicate that there is no universally optimal filler-to-effective bitumen ratio that guarantees superior performance under varying temperature conditions. The results suggest that, to effectively manage performance at elevated temperatures with a particular focus on mitigating rutting damage, a filler-to-bitumen ratio exceeding 1.2 should be considered as the preferred option. In contrast, to enhance performance at intermediate temperatures, which involves addressing tensile strain, as well as to ensure resilience against cracking damage, it is advisable to select a filler-to-bitumen ratio below 1. These conclusions highlight the necessity for a nuanced and contextual approach to the design of bituminous materials, where the specific performance requirements in relation to diverse environmental scenarios need to be carefully assessed in order to achieve the most effective and durable results.

Given the lack of definitive incorporation of the studied ratio into the anticipated performance of the asphalt mixture within the established codes and procedures, it is prudent to revise the relevant codes and guidelines. This revision is essential to address the issue and ensure the optimal performance of the material in practical applications. Until the studied ratio is adequately accounted for in the existing frameworks, it is vital to re-evaluate and adapt the codes, in order to fully address this matter and enable the material to perform at the expected level in real-world scenarios. The investigation highlights that optimizing the percentage of calcareous mineral filler in asphalt mastic significantly enhances fatigue performance. LAS testing results demonstrate that appropriate filler-to-bitumen ratios improve mechanical properties and extend fatigue life, particularly at lower strain levels, reinforcing the importance of tailored asphalt compositions for enhanced durability.

Optimizing the material performance of asphalt mixtures is a critical consideration in any revisions to construction codes. The ratio of key components directly influences the functionality and effectiveness of these mixtures in various projects. Thorough evaluations and updates to the codes are strongly recommended to ensure they accurately reflect the significance of this ratio in determining the overall performance of asphalt mixtures. By prioritizing material performance, engineers and policymakers can enhance the reliability and longevity of asphalt-based infrastructure, ultimately contributing to more sustainable and cost-effective construction practices. The correlation between the test results of asphalt mixture and mastic is a crucial aspect in the field of pavement engineering. While the article primarily focused on the performance of bitumen and bituminous mastic, the relationship between these individual components and the overall behavior of the asphalt mixture remains an important area for further investigation. The performance of the asphalt mixture is not directly addressed in the current literature, and a deeper understanding of the linkage between the test results of mastic and the overall mixture properties would contribute significantly to the development of more reliable and durable pavement systems.

Conflict of Interest

In conducting this study, the authors wish to disclose that there is no conflict of interest that could potentially bias the results or interpretation of the findings. We are committed to upholding the highest standards of integrity and transparency in our research.

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