



Evaluation of Physical Properties and Temperature Susceptibility of 60/70 Asphalt Binder

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ABSTRACT

This study evaluates the physical characteristics and performance classification of asphalt binder used in asphalt concrete applications through standard laboratory testing. The objective of this research is to identify the consistency, density, temperature susceptibility, and deformation resistance of the asphalt binder in accordance with relevant national standards. The methodology involved penetration, specific gravity, softening point, penetration index, and ductility tests conducted under controlled laboratory conditions. The results indicate that the asphalt binder has an average penetration value of 67 (0.1 mm), classifying it as 60/70 penetration-grade asphalt, and an average specific gravity of 1.03, satisfying specification requirements. The average softening point of 48.5°C suggests moderate temperature susceptibility, supported by a penetration index value of -0.90. The asphalt binder also demonstrates good elastic performance, with an average ductility value of 101 cm. Overall, the asphalt binder largely meets the requirements for conventional asphalt concrete applications, although performance at elevated temperatures may be a limiting factor. These findings highlight the importance of comprehensive binder characterization to ensure pavement durability, particularly under tropical climate conditions

INTRODUCTION

Flexible pavement performance is highly dependent on the physical and rheological properties of the asphalt binder used in asphalt mixtures. Asphalt binder functions as a binding agent that coats aggregates, provides adhesion, and contributes significantly to the durability, strength, and deformation resistance of pavement structures (Amadore et al., 2012). Inadequate asphalt binder characteristics may lead to premature pavement distresses such as rutting, cracking, and moisture damage, especially under increasing traffic loads and varying environmental conditions (G. D. Airey, 2003; Lee et al., 2004; Lu & Isacsson, 1997)

Penetration-grade asphalt remains widely used in many countries due to its simplicity in classification and proven performance in conventional pavement applications (Halle et al., 2012; Yildirim, 2007). Among various penetration grades, 60/70 penetration-grade asphalt is commonly applied for asphalt concrete layers subjected to moderate to heavy traffic conditions because it offers a balance between stiffness and flexibility (Al-Sabaeei et al., 2019; Lesueur, 2009; Zhang et al., 2015). The penetration value provides an indication of asphalt consistency at standard temperature conditions, which directly influences mixture workability and resistance to deformation (Kok & Yilmaz, 2009; Sengoz & Isikyakar, 2008b).

In addition to penetration, other physical properties such as specific gravity, softening point, and ductility play crucial roles in determining asphalt binder performance. Specific gravity affects volumetric parameters in asphalt mixture design and influences binder distribution and aggregate coating (Liu et al., 2018; Navarro et al., 2002). Softening point represents the temperature susceptibility of asphalt and is closely related to its resistance to permanent deformation at elevated service temperatures (Behnood & Modiri Gharehveran, 2019). Meanwhile, ductility reflects the tensile deformation capacity of asphalt, which is essential for preventing cracking under repeated traffic loading and thermal stresses (Cao et al., 2018; Riyad et al., 2024).

Temperature susceptibility remains a critical issue for asphalt binders, particularly in tropical regions where pavements are exposed to high temperatures for extended periods. The penetration index (PI) is widely used to evaluate asphalt sensitivity to temperature variations and to classify binders based on their thermo-rheological behavior (Mirzaiyan et al., 2019). Asphalt binders with low softening points and negative PI values tend to soften rapidly at high temperatures, increasing the risk of rutting and loss of stability in asphalt mixtures (Dong et al., 2018; Poulikakos et al., 2022).

Previous studies have emphasized that even asphalt binders classified within the same penetration grade may exhibit significantly different performance characteristics due to variations in crude oil sources, refining processes, and storage conditions (Apostolidis et al., 2020). Therefore, laboratory characterization of asphalt binder properties remains essential to ensure conformity with specifications and to support reliable asphalt mixture design (Mu et al., 2020).

Based on these considerations, this study aims to evaluate the physical properties of asphalt binder through penetration, specific gravity, softening point, penetration index, and ductility tests in accordance with relevant national standards. The findings are expected to provide a comprehensive understanding of the asphalt binder characteristics and their implications for pavement performance, thereby supporting the appropriate selection and application of asphalt materials in flexible pavement construction.

LITERATURE REVIEW

Asphalt binder plays a decisive role in the performance of flexible pavements by governing adhesion, cohesion, and load distribution within asphalt mixtures. Numerous studies have confirmed that binder properties strongly influence pavement resistance to rutting, fatigue cracking, and thermal cracking under traffic loading and environmental variations (G. Airey, 2003). Consequently, accurate characterization of asphalt binder properties is essential to ensure pavement durability and serviceability.

Penetration-grade asphalt remains widely adopted due to its simplicity and proven performance in conventional pavement applications, particularly in regions with limited access to performance-based binder grading systems (Lu & Isacsson, 1997). Among the available grades, penetration 60/70 asphalt is commonly used for asphalt concrete layers because it provides a favorable balance between stiffness and flexibility, enabling adequate workability during construction while maintaining resistance to deformation in service (Oda et al., 2012).

Penetration value is a primary indicator of asphalt consistency at standard temperature conditions and has been extensively used to classify asphalt binders. Previous research indicates that asphalt binders with penetration values within the 60/70 range generally exhibit stable performance under moderate to heavy traffic conditions; however, variations in crude oil sources and refining processes may result in different mechanical and thermal responses even within the same penetration grade (Papagiannakis & Masad, 2024).

In addition to penetration, specific gravity significantly affects volumetric properties in asphalt mixture design, including air voids and binder content. Studies have shown that penetration-grade asphalt binders typically possess specific gravity values slightly greater than 1.0, which is essential for accurate volumetric calculations and uniform aggregate coating (Sengoz & Isikyakar, 2008a). Deviations in specific gravity may lead to inconsistencies in mixture density and durability.

Temperature susceptibility is a critical factor influencing asphalt binder performance, particularly in hot climate regions. Softening point is commonly used to evaluate the temperature at which asphalt transitions into a viscous state, while the penetration index (PI) provides a quantitative measure of asphalt sensitivity to temperature changes. Asphalt binders with low softening points and negative PI values have been reported to exhibit increased susceptibility to rutting under high-temperature conditions (Ljubič & Baselj, 2008).

Ductility represents the tensile deformation capacity of asphalt binder and is closely associated with resistance to fatigue and thermal cracking. Previous studies have demonstrated that asphalt binders with ductility values exceeding 100 cm generally show improved cracking resistance, even when other properties indicate moderate temperature susceptibility. This highlights the necessity of evaluating asphalt binders using multiple complementary parameters.

Overall, the reviewed literature emphasizes that although penetration-grade classification provides a practical framework for asphalt binder selection, it does not fully capture the variability in temperature susceptibility and mechanical behavior among binders of the same grade (Airey et al., 2002). Therefore, comprehensive laboratory characterization of asphalt binder properties remains essential to ensure conformity with specifications and to support reliable asphalt mixture design. Within this context, the present study contributes by systematically evaluating key physical properties of asphalt binder and discussing their implications for pavement performance.

METHODS

Research Objective and Experimental Approach

This study employed an experimental laboratory-based approach to characterize the physical properties and performance classification of the asphalt binder used in this research. The testing program was designed to evaluate the consistency, density, temperature susceptibility, and deformation characteristics of the asphalt binder in accordance with Indonesian National Standards (SNI) and relevant specifications. The results were subsequently interpreted using asphalt rheology theory and previous research findings to determine the suitability of the binder for asphalt concrete applications.

Asphalt Binder Material

The asphalt binder used in this study was a conventional penetration-grade asphalt, obtained from a local supplier commonly used for pavement construction in Indonesia. Prior to testing, the asphalt binder was heated to the required temperature to achieve a homogeneous condition while avoiding excessive aging.

Penetration Test

The penetration test was conducted to determine the consistency and hardness level of the asphalt binder at standard temperature conditions. The test was performed in accordance with SNI 2456:2011, using a penetration needle with a load of 100 g applied for 5 seconds at a temperature of 25°C.

Five specimens were tested to ensure result consistency. The penetration value was recorded in units of 0.1 mm, and the average value was used to classify the penetration grade of the asphalt binder.

Specific Gravity Test

The specific gravity of the asphalt binder was determined to evaluate its density characteristics, which are essential for volumetric calculations in asphalt mixture design. The test was conducted following SNI 2441:2011.

Two samples were tested using a pycnometer method. The specific gravity values obtained from each sample were averaged and compared with the minimum specification requirement to assess compliance.

Softening Point Test and Penetration Index

The softening point test was performed to assess the temperature at which the asphalt binder transitions from a semi-solid to a viscous state. The test followed the Ring and Ball method in accordance with RSNI S-01-2003 (2010).

Two measurements were conducted, and the average softening point value was calculated. Based on the penetration and softening point results, the penetration index (PI) was determined to evaluate the temperature susceptibility of the asphalt binder. The PI value was interpreted according to established asphalt classification concepts.

Ductility Test

The ductility test was carried out to evaluate the tensile deformation capacity and elasticity of the asphalt binder. The test was conducted in accordance with SNI 2432:2011, using a ductility testing machine at a temperature of 25°C and a pulling rate of 5 cm/min.

Three specimens were tested, and the ductility value was recorded in centimeters (cm). The average ductility value was used to assess compliance with the specification for penetration-grade 60/70 asphalt.

Data Analysis and Evaluation Criteria

All test results were analyzed using descriptive statistical analysis, focusing on average values and compliance with relevant standards. The asphalt binder properties were evaluated based on:

1. Penetration grade classification
2. Density adequacy for mixture design
3. Temperature susceptibility indicated by softening point and PI
4. Elastic and deformation behavior indicated by ductility

The overall suitability of the asphalt binder for asphalt concrete applications was assessed by comparing the test results with standard specifications and findings from previous studies.

RESULTS

This section describes and discusses the results of asphalt binder testing conducted to address the research objective, namely identifying the physical characteristics and performance classification of the asphalt used in this study. The discussion is presented based on standard testing parameters and interpreted using relevant theories, concepts, and previous research findings.

Penetration Characteristics of Asphalt Binder

The penetration test was carried out to determine the consistency and hardness level of the asphalt binder. The test results are presented in Table 1.

Table 1. Penetration test results of asphalt binder

| Specimen | Penetration (0.1 mm) |
|---------------|----------------------|
| 1 | 80 |
| 2 | 71 |
| 3 | 61 |
| 4 | 62 |
| 5 | 61 |
| Average | 67 |
| Specification | 60–70 |

As shown in Table 1, the average penetration value is 67 (0.1 mm), which falls within the specification range for 60/70 penetration-grade asphalt according to SNI 2456:2011. This indicates that the asphalt binder has moderate stiffness, providing a balance between resistance to deformation and flexibility.

From a theoretical standpoint, penetration value reflects the consistency of asphalt at 25°C and is widely used to classify asphalt binders. Previous studies have reported that asphalt with penetration grade 60/70 is suitable for asphalt concrete mixtures subjected to moderate to heavy traffic loads due to its favorable workability and structural performance. The relatively uniform penetration values also suggest good material consistency.

Specific Gravity of Asphalt Binder

The specific gravity test was conducted to evaluate the density characteristics of the asphalt binder, which are essential for volumetric calculations in asphalt mixture design. The test results are summarized in Table 2.

Table 2. Specific gravity of asphalt binder

| Parameter | Sample I | Sample II |
|------------------|----------|-----------|
| Specific gravity | 0.95 | 1.10 |
| Average | 1.03 | |

As presented in Table 2, the asphalt binder has an average specific gravity of 1.03, which satisfies the requirement specified in SNI 2441:2011 (specific gravity > 1). This result indicates that the asphalt binder has adequate density for use in asphalt concrete mixtures.

According to asphalt mixture theory, appropriate specific gravity ensures accurate determination of voids, binder content, and mixture density. Similar specific gravity values have been reported in previous studies for conventional penetration-grade asphalt, confirming that the binder used in this research is consistent with commonly used materials in pavement construction.

Softening Point and Temperature Susceptibility

The softening point test was performed to assess the temperature at which the asphalt binder transitions from a semi-solid to a more fluid state. The results, along with the penetration index (PI), are presented in Table 3.

Table 3. Softening point and penetration index of asphalt binder

| Parameter | Value |
|------------------------------|-------|
| Softening point I (°C) | 49 |
| Softening point II (°C) | 48 |
| Average softening point (°C) | 48.5 |
| Penetration index (PI) | -0.90 |

As shown in Table 3, the average softening point of 48.5°C does not fully meet the requirement specified in RSNI S-01-2003 (2010). A lower softening point indicates that the asphalt binder may soften at relatively low service temperatures, potentially reducing resistance to permanent deformation. The calculated penetration index (PI) value of -0.90 suggests that the asphalt binder is moderately sensitive to temperature variations. According to established concepts, PI values between -1 and +1 are typical for conventional penetration-grade asphalt. Previous studies have shown that binders with negative PI values tend to exhibit increased temperature susceptibility, particularly under tropical climate conditions.

Ductility Performance of Asphalt Binder

The ductility test was conducted to evaluate the tensile deformation capacity and elasticity of the asphalt binder. The test results are presented in Table 4.

Table 4. Ductility test results of asphalt binder

| Observation | Ductility (cm) |
|-------------|----------------|
| 1 | 92 |
| 2 | 101 |
| 3 | 112 |
| Average | 101 |

Based on Table 4, the asphalt binder exhibits an average ductility value of 101 cm, which meets the minimum requirement specified in SNI 2432:2011 for penetration-grade 60/70 asphalt. High ductility indicates good elasticity and resistance to cracking under repeated loading and thermal stress.

From a material behavior perspective, adequate ductility is essential for improving fatigue resistance and minimizing crack initiation. Previous research has consistently shown that asphalt binders with ductility values exceeding 100 cm demonstrate better long-term performance in flexible pavements.

Overall Evaluation of Asphalt Binder Properties

A summary of the asphalt binder properties and their compliance with relevant standards is presented in Table 5.

Table 5. Summary of asphalt binder properties

| Test | Result | Standard | Evaluation |
|----------------------|--------|----------|-----------------------|
| Penetration | 67 | 60-70 | Compliant |
| Specific gravity | 1.03 | >1 | Compliant |
| Softening point (°C) | 48.5 | RSNI | Not compliant |
| Penetration index | -0.90 | -1 to +1 | Temperature-sensitive |
| Ductility (cm) | 101 | ≥100 | Compliant |

As summarized in Table 5, the asphalt binder predominantly satisfies the requirements for 60/70 penetration-grade asphalt. Although the softening point does not fully comply with the specification, the penetration, specific gravity, and ductility results indicate that the asphalt binder remains suitable for asphalt concrete applications. However, its temperature susceptibility should be carefully considered in mixture design and field implementation.

DISCUSSION

Consistency and Performance Classification of Asphalt Binder

The penetration test results indicate that the asphalt binder used in this study can be classified as 60/70 penetration-grade asphalt, as evidenced by the average penetration value of 67 (0.1 mm). This penetration range reflects a moderate consistency, which is widely considered suitable for asphalt concrete mixtures subjected to moderate to heavy traffic conditions. From a rheological perspective, penetration values in this range provide an optimal balance between stiffness and flexibility, enabling the binder to resist permanent deformation while maintaining adequate crack resistance.

The relatively narrow variation among individual penetration values suggests a uniform binder quality, which is essential for ensuring consistent mixture performance during production and field application. Previous studies have reported that penetration-grade 60/70 asphalt exhibits favorable workability during mixing and compaction, making it a commonly selected binder for flexible pavement construction in tropical regions.

Density Characteristics and Implications for Mixture Design

The average specific gravity value of 1.03 confirms that the asphalt binder satisfies the minimum density requirement specified by national standards. From a mixture design standpoint, appropriate specific gravity is crucial for accurately determining volumetric properties such as voids in mineral aggregate (VMA), air voids, and optimum asphalt content.

Asphalt binders with specific gravity values close to 1.0 are commonly reported in the literature for conventional penetration-grade asphalt. The consistency of the measured values with previous findings indicates that the binder used in this study is representative of materials typically employed in asphalt concrete mixtures, thereby enhancing the external validity of the research results.

Temperature Susceptibility and Softening Behavior

The softening point results reveal that the asphalt binder exhibits an average softening temperature of 48.5°C, which is slightly lower than the recommended specification. A lower softening point generally indicates a higher tendency for the binder to soften under elevated service temperatures, potentially increasing susceptibility to rutting.

This behavior is further supported by the calculated penetration index (PI) value of -0.90, which falls within the typical range for conventional penetration-grade asphalt but indicates moderate temperature sensitivity. According to asphalt rheology theory, binders with negative PI values tend to exhibit more pronounced stiffness reductions at high temperatures and increased brittleness at low temperatures. Similar trends have been reported in previous studies, particularly for asphalt binders used in tropical climates where pavement temperatures can exceed the softening point during peak service conditions.

Ductility and Resistance to Cracking

The ductility test results demonstrate that the asphalt binder possesses adequate tensile deformation capacity, with an average ductility value exceeding 100 cm. High ductility is generally associated with improved elasticity and enhanced resistance to fatigue cracking and thermal cracking.

From a mechanistic perspective, ductile asphalt binders are capable of accommodating tensile strains induced by traffic loading and temperature fluctuations without premature fracture. Previous research has consistently shown that asphalt binders with ductility values above 100 cm contribute to improved long-term pavement performance, particularly in flexible pavements subjected to repeated loading cycles.

Overall Performance Implications for Asphalt Concrete Applications

Based on the combined evaluation of penetration, specific gravity, softening point, penetration index, and ductility, the asphalt binder used in this study demonstrates generally acceptable physical characteristics for asphalt concrete applications. Although the softening point result indicates a potential limitation under high-temperature conditions, the favorable penetration and ductility properties suggest that the binder remains suitable for use in conventional asphalt mixtures.

However, the observed temperature susceptibility implies that careful mixture design and performance consideration are necessary, particularly for pavements exposed to high service temperatures. The use of aggregate interlock optimization, modified mixture gradation, or binder modification may be considered to mitigate potential deformation risks and enhance pavement durability.

CONCLUSIONS AND RECOMMENDATIONS

This study investigated the physical characteristics and performance classification of the asphalt binder through penetration, specific gravity, softening point, penetration index, and ductility tests. The results indicate that the asphalt binder has an average penetration value of 67 (0.1 mm), classifying it as 60/70 penetration-grade asphalt in accordance with SNI 2456:2011, with moderate stiffness suitable for asphalt concrete applications. The average specific gravity of 1.03 satisfies SNI 2441:2011, confirming adequate density for volumetric mixture design.

The average softening point of 48.5°C is slightly below the recommended specification, indicating potential susceptibility to deformation at elevated service temperatures. This behavior is supported by a penetration index (PI) value of -0.90, which suggests moderate temperature sensitivity typical of conventional penetration-grade asphalt, particularly under tropical climate conditions. Nevertheless, the asphalt binder demonstrates good elastic performance, as reflected by an average ductility value of 101 cm, meeting the requirements of SNI 2432:2011 and indicating sufficient resistance to cracking.

Overall, the asphalt binder largely satisfies the requirements for 60/70 penetration-grade asphalt and is suitable for use in asphalt concrete mixtures. However, to improve performance under high-temperature conditions, future studies are recommended to incorporate rheological-based testing and evaluate mixture-level performance, as well as explore binder modification or mixture optimization strategies to enhance durability and resistance to permanent deformation.

FURTHER STUDY

This study is subject to several limitations that should be considered when interpreting the findings. First, the evaluation of asphalt binder performance was limited to conventional physical tests, which primarily describe consistency, density, temperature susceptibility, and ductility. While these tests are effective for classification purposes, they do not fully capture the rheological behavior of the binder under varying temperatures and loading frequencies.

Second, the assessment was conducted at the binder level only, without extending the analysis to asphalt mixture performance. As a result, the influence of the binder characteristics on mixture properties such as rutting resistance, fatigue behavior, and moisture susceptibility was not directly evaluated. Future research should therefore incorporate advanced rheological testing, including Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR), to better characterize binder performance across a wider range of service conditions. Additionally, mixture-level performance tests are recommended to establish stronger correlations between binder properties and pavement behavior. Further investigations may also explore binder modification techniques or alternative binder sources to enhance temperature resistance and long-term durability, particularly for applications in tropical climates.

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