

Performance Evaluation of Asphalt Mixtures with Modified Buton Asphalt and Bio-Binders Using Indirect Tensile Strength Test

Hamkah

Civil Engineering Department, Ambon State Polytechnic, Indonesia
hamkah27@yahoo.co.id (corresponding author)

Miswar Tumpu

Disaster Management Study Program, Hasanuddin University, Indonesia
miswartumpu@unhas.ac.id

Mansyur

Department of Civil Engineering, Sembilanbelas November University, Indonesia
mansyurusn14@gmail.com

Andung Yunianta

Department of Civil Engineering, Faculty of Engineering, Yapis University, Indonesia
andung.ay@gmail.com

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ABSTRACT

This research is part of a broader initiative aimed at optimizing the utilization of Buton Island's abundant natural asphalt reserves, which are distributed across several regions in Indonesia. In developing asphalt mixtures, energy efficiency and environmental sustainability are key considerations. This study investigates the performance of Asphalt Concrete-Wearing Course (AC-WC) mixtures modified with Buton asphalt (mBa) and enhanced using bio-binder technology incorporating Colophonium resin (rosin). The effectiveness of these modified asphalt mixtures is evaluated through the Indirect Tensile Strength (ITS) test under monotonic loading conditions. The mixture used includes Retona Blend 55—a product derived from mBa—and rosin extracted from pine bark sap and subsequently processed. The combination of Retona Blend 55 and rosin aims to improve critical mechanical properties, such as tensile strength and strain capacity. This study provides insights into the characteristics of Retona Blend 55, rosin, and the bio-binder technology, as well as their interactions within the AC-WC mixture. The ITS test results show that the incorporation of 2.5% rosin into the asphalt mixture significantly increased the ITS value from 0.387 MPa to 0.807 MPa, representing an improvement of 108.52%. This numerical outcome highlights that the addition of rosin effectively enhances the tensile strength, cohesion, and overall deformation resistance of the modified AC-WC mixtures.

Keywords-indirect tensile strength; asbuton modification; biobinder technology; AC-WC

I. INTRODUCTION

Sedimentary rocks containing hydrocarbon substances, known as Buton Natural Asphalt (BRA), are abundant in southern Buton Island, Indonesia, with estimated reserves of approximately 60.99 million tons (equivalent to 24.35 million barrels of oil) [1-4]. The bitumen content in BRA typically ranges from 15% to 35% of the rock weight, offering significant potential to reduce Indonesia's reliance on imported petroleum-based asphalt, which reaches around 600,000 tons annually. However, challenges, such as variability in quality,

brittleness, and inconsistent bitumen content, have limited its widespread application.

To improve BRA's usability, mechanical processing methods have been developed, resulting in semi-extracted products, like Retona Blend 55, produced by PT Pertamina [5-7]. Retona Blend 55 is derived from Buton asphalt rock and aims to address issues of brittleness and variable composition. Despite Indonesia being the world's largest producer of natural asphalt—with reserves reaching 650 million tons—the full

potential of this resource remains underutilized due to technical and economic constraints.

In tropical climates, such as Indonesia, road deterioration is accelerated by the high temperatures, heavy traffic loads, and intense rainfall, which contribute to cracking, rutting, and pothole formation. Improving asphalt mixtures to resist these conditions is crucial for infrastructure longevity. Previous studies have demonstrated that incorporating additives, like rubber, can enhance the asphalt mechanical performance, improving parameters, such as void content, stability, and flow [8-10].

Colophonium (rosin), a bio-based resin extracted from pine sap, presents another promising modifier for asphalt mixtures. Its heat sensitivity and cohesive properties enable improving road pavement durability under environmental stresses. However, limited research has explored the combined use of rosin with semi-extracted BRA products, like Retona Blend 55.

Therefore, this study focuses on evaluating the mechanical performance of AC-WC mixtures modified with Retona Blend 55 and rosin, particularly their behavior under ITS testing.

II. MATERIAL AND METHODS

A. Rosin

Rosin is an umbrella term used to describe the processed resin derived from pine tree sap. Historically, the term "rosin" originated from its traditional use as a sealant for patching leaks in wooden ships. In Indonesia, the rosin industry started in 1938. Rosin is an inexpensive, naturally sourced resin obtained through the distillation of pine sap. It typically appears as a yellow to yellowish solid. The quality of pine sap significantly affects both the yield and the quality of the resulting rosin. On average, pine sap contains approximately 70–75% resin (rosin) and 20–25% turpentine.

With the advancement of industrial technologies, rosin has found applications in various sectors. It is now widely used in

the manufacturing of paper sizing agents, adhesives, printing inks, chewing gum, and rubber products, such as tires. According to the Industrial Division of Perum Perhutani, this material continues to offer a cost-effective solution for a wide range of industrial applications [11]. Table I outlines the physical and chemical properties of rosin.

B. Retona Blend 55

The physical properties of modified Buton Asphalt (mBa), as presented in Table II, indicate its suitability for road construction applications, particularly as a binder in asphalt mixtures. The penetration value before weight loss is 69.6 mm, which signifies moderate hardness and plasticity—attributes desirable for resisting deformation under moderate traffic loads. A softening point of 52°C suggests that the asphalt maintains structural integrity in warm climates without excessively softening, which is essential for pavement stability. The ductility value of 121 cm at 25°C indicates that the modified Asbuton has good flexibility and tensile strength, helping prevent cracking due to temperature fluctuations or load-induced stress.

Furthermore, the flash point of 291°C indicates that the material is thermally stable and safe during handling and processing, as it will not easily ignite under typical asphalt mixing temperatures. The specific gravity of 1.16 shows that the material has a relatively high density, which aligns with the standards for road binder materials [12]. The low weight loss percentage (0.29%) signifies minimal volatilization under heating, supporting its thermal durability. The penetration after weight loss increases to 93 mm, which may suggest that the binder softens slightly upon prolonged heating, improving its flow characteristics. These combined properties demonstrate that modified Asbuton can serve as a competitive alternative to petroleum-based asphalt, particularly when appropriately processed and modified with additives, such as rosin.

TABLE I. QUALITY OF ROSIN

Properties	Standard			
	X (Rex)	WW (Water white)	WG (Window glass)	N (Nancy)
1. Ring and ball soft spot method	≥78°C	≥78°C	≥76°C	≥74°C
2. Colour test using Lovibond	Almost clear (water white) → transparent white / very light yellow	Water white → pure white / very pale yellow	Window glass → bright golden yellow	Neutral → dark yellow / slightly brownish yellow
3. Iodine value	5-25			
4. Saponification value	170-220			
5. Acid value	160-190			
6. Ash content	≤ 0.01%	≤ 0.04%	≤ 0.05%	≤ 0.08%
7. Dirt levels	≤ 0.02 %	≤ 0.05 %	≤ 0.07 %	≤ 0.10 %
8. Volatile oil content	≤ 2.0 %	≤ 2.0 %	≤ 2.5 %	≤ 3.0 %

TABLE II. PHYSICAL PROPERTIES OF MBA

No.	Test name	Results
1	Penetration before losing weight (mm)	69.6
2	Softening point (°C)	55
3	Ductility at 25 °C, 5 cm/min (cm)	121
4	Flash point (°C)	291
5	Specific gravity	1.16
6	Weight loss (%)	0.29
7	Penetration after weight loss (mm)	93

C. Characteristics of Aggregate

Two types of coarse aggregate fractions obtained from crushed river stones were used in this study: one with a particle size range of 5-10 mm and the other with a size range of 10-20 mm. Fine aggregates and stone dust were acquired from the stone crushing process, and were used as fine aggregate and filler materials, respectively. The characteristics of the fine aggregates, stone dust, and coarse aggregates are displayed in Tables III, IV, and V, respectively [13]. The aggregates used for the material components in the cold mix were collected from the Wai Sikula River on Ambon Island.

The physical properties of the fine aggregate (Table III) indicate its potential to hold moisture, with an absorption rate of 2.81%, which can influence the mix's workability and water demand. The Saturated Surface Dry (SSD) specific gravity, bulk specific gravity, and apparent specific gravity values suggest a dense aggregate that contributes to the stability of the mix. Furthermore, the sand equivalent value of 89.66% is considerably high, implying a minimal presence of clay-like or deleterious fines, which is beneficial for the strength and durability of the pavement mix. In comparison, the crushed dust (Table IV) exhibits slightly lower water absorption than the fine aggregate. Its specific gravity values are marginally higher, supporting its role as a dense filler material in the mix. However, the sand equivalent value is notably lower than that of the fine aggregate, suggesting a higher presence of fine or clay-like particles, which might affect the cohesiveness and long-term performance of the mix if not properly balanced.

The coarse aggregates (Table V), divided into two size fractions (5-10 mm and 10-20 mm), show water absorption values within acceptable ranges for use in asphalt mixtures. Their specific gravity values indicate good density and minimal porosity. The flakiness index is considerably higher in the smaller size fraction (19.80%) than in the larger one (9.52%), suggesting the need to monitor the particle shape in smaller aggregates to ensure optimal interlocking and strength. The aggregate wear test results, with values of 27.22 for the 5-10 mm fraction and 25.46 for the 10-20 mm fraction, indicate durable materials, suitable for withstanding abrasion and mechanical stresses in road construction.

D. Combined Aggregate Gradation and Mixture Design

The aggregate gradation shown in Figure 1, was maintained throughout the experiment. All asphalt mixtures were prepared under controlled laboratory conditions. The optimum content of Retona Blend 55 asphalt was determined to be 6.25% of the

total mixture weight, consisting of 6.094% base asphalt and 0.156% additive. Table VI presents the composition of the asphalt emulsion mixture, which contains 2.5% rosin by weight. The components—rosin, Retona Blend 55, aggregates, and filler—were thoroughly mixed and compacted into cylindrical molds with a capacity of 1,200 g and a diameter of 101.6 mm. Each specimen was compacted using a Marshall compactor, applying 75 blows to each face. The mixing and compaction procedures were carried out at a room temperature of 27°C.

TABLE III. PHYSICAL PROPERTIES OF FINE AGGREGATE

No.	Examination	Results (%)
1	Water absorption	2.81
2	SSD specific gravity	2.53
3	Bulk specific gravity	2.62
4	Apparent specific gravity	2.72
5	Sand equivalent	89.66

TABLE IV. PHYSICAL PROPERTIES OF CRUSHED DUST

No.	Examination	Results (%)
1	Water absorption	2.19
2	SSD specific gravity	2.57
3	Bulk specific gravity	2.72
4	Apparent specific gravity	2.83
5	Sand equivalent	70.64

TABLE V. PHYSICAL PROPERTIES OF COARSE AGGREGATES

No.	Examination	Results (%)
1	Water absorption	
	Crushed stones 5-10 mm	2.13
	Crushed stones 10-20 mm	2.14
2	Specific gravity	
	Crushed stones 5-10 mm	
	Bulk specific gravity	2.58
	Apparent specific gravity	2.81
	SSD specific gravity	2.72
	Crushed stones 10-20 mm	
	SSD specific gravity	2.69
Bulk specific gravity	2.73	
3	Apparent specific gravity	2.57
	Flakiness index	
	Crushed stones 5-10 mm	19.80
4	Crushed stones 10-20 mm	9.52
	Aggregate wear	
4	Crushed stones 5-10 mm	27.22
	Crushed stones 10-20 mm	25.46

E. Indirect Tensile Strength Test

The ITS test was conducted on the asphalt emulsion mixture specimens in accordance with ASTM D6931-12 [14]. Figure 2 illustrates the ITS testing equipment. The vertical deformation of the specimens was measured using two Linear Variable Displacement Transducers (LVDTs) to obtain accurate and reliable data. Both the deformation of the specimens and the load applied by the Universal Testing Machine (UTM) were continuously monitored and recorded using a computerized data acquisition system.

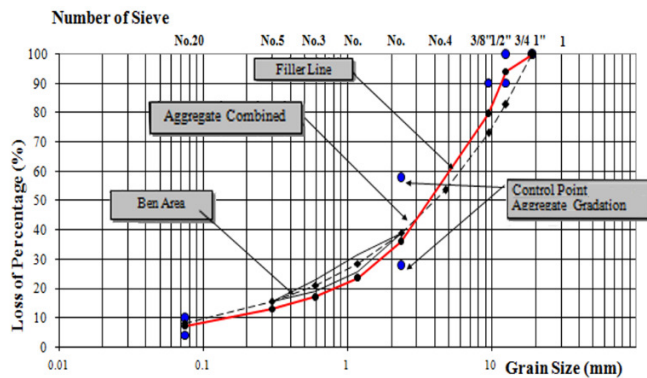


Fig. 1. Combined aggregate gradation.

TABLE VI. ASPHALT MIXTURE WITH 2.5% ROSIN

No.	Material mixture	Content	
		Weight	%
1	Retona blend 55 (g)	73.125	6.094
2	Coarse aggregate (g)		
	Crushed stone 10-20 mm	213.750	17.813
	Crushed stone 5-10 mm	405.000	33.750
3	Fine aggregate (g)	506.250	42.187
4	Rosin (g)	1.875	0.156
	Total (g)	1,200.0	100.0

The ITS test is a crucial method for evaluating the mechanical performance of asphalt mixtures, particularly regarding their resistance to tensile stress and cracking, since it simulates the tensile forces that occur on the road surface due to repeated traffic loads. The test involves applying a compressive load along the vertical diameter of cylindrical specimens, inducing tensile stress perpendicular to the applied load. This allows determining tensile strength indirectly, since direct tensile forces are often more complex to administer in practice.

III. RESULTS AND DISCUSSION

Prior to conducting the ITS test, a visual inspection of the compacted specimens was performed and revealed no evidence of bituminous bleeding or accumulation of bituminous binder and filler at the bottom of the specimens. When Retona Blend 55, which contains petroleum-based bitumen, is combined to form a mixture, a chemical interaction occurs between the petroleum bitumen and the Bitumen-Rich Asphalt (BRA) components. This reaction leads to the reorganization of the molecular structure and the formation of a membrane-like layer that coats the aggregate particles. The voids left by the evaporation of water from the asphalt emulsion are effectively filled by the fine mineral solids present in the BRA component of Retona Blend 55.

As depicted in Figure 3, the ITS value of the mixture without rosin was recorded at 0.387 MPa, while the mixture containing 2.5% rosin reached 0.807 MPa—a 108.52% increase.

These results are consistent with previous studies reporting similar enhancement of the mechanical properties due to rosin or comparable modifiers [15-18], attributing it to improved binder cohesion and internal bonding [17], as well as an

increased compatibility between the binder and aggregate [18, 19]. Such improvements important vital for the durability and performance of asphalt mixtures, especially in high-stress conditions, like those encountered in road surfaces.

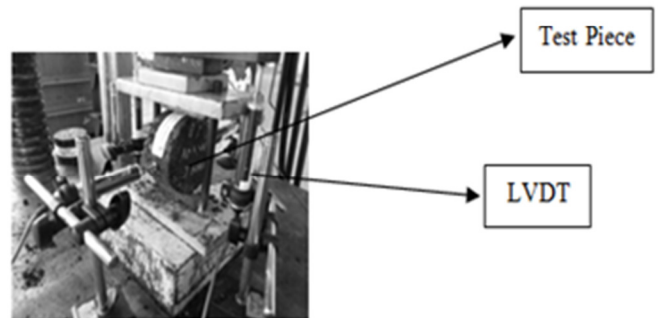


Fig. 2. ITS equipment.

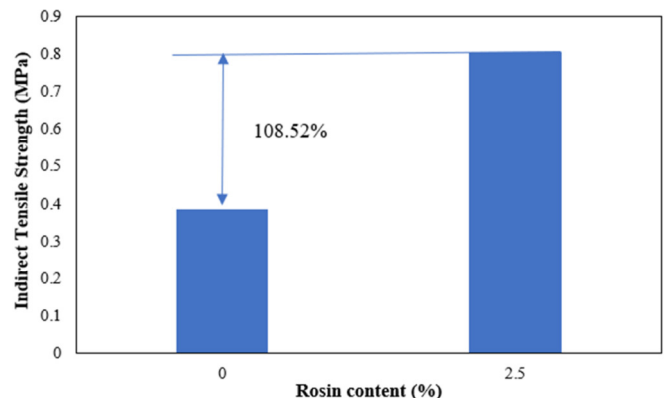


Fig. 3. Effect of Rosin content on ITS.

Beyond improving the mechanical properties, the addition of rosin contributes to the resistance of the asphalt mixture against the damage caused by high temperatures and freeze-thaw cycles, which are common issues for road surfaces. This is particularly relevant for applications in regions with sharp temperature variations, where maintaining the stability of the mixture is crucial for long-term performance [20].

Furthermore, the use of rosin as a modifier in asphalt mixtures can reduce the dependence on synthetic chemical additives, which are often more expensive and potentially harmful to the environment [21].

A series of ITS tests were conducted on the AC-WC mixtures with varying rosin contents. Each ITS test was repeated three times for every mixture composition to ensure

experimental consistency and reliability. Figure 4 presents the stress–strain curve for the mixture without rosin. The linear portion of the curve, observed between strain values of 0.1×10^{-3} and 0.2×10^{-3} , represents the elastic region of the unmodified mixture. At the average peak stress of 0.3865 MPa, the corresponding strain values for the three tested specimens were 2.0×10^{-3} , 2.3×10^{-3} , and 2.5×10^{-3} , respectively.

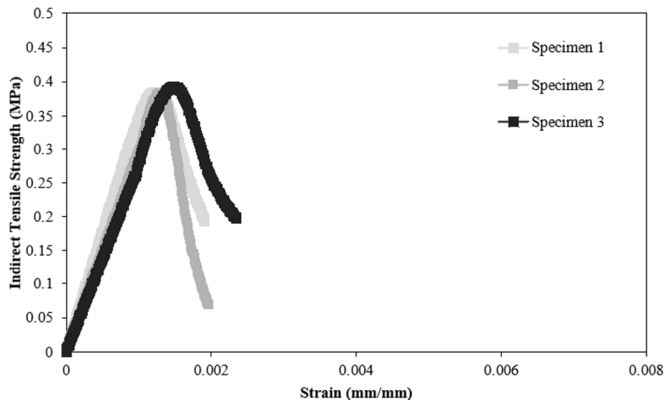


Fig. 4. ITS-strain of AC-WC mixture without Rosin.

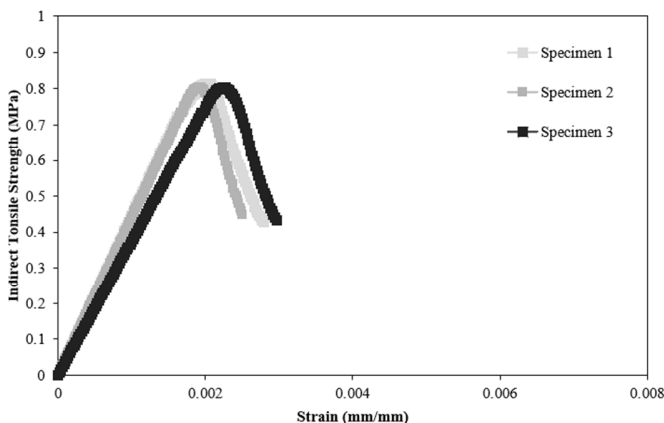


Fig. 5. ITS-strain of AC-WC mixture with 2.5% Rosin.

Figure 5 displays the stress–strain responses for the mixtures containing 2.5% rosin. The results show a consistent linear behavior between strain values of 0.2×10^{-3} and 0.3×10^{-3} . The peak tensile stresses for the three specimens were recorded as 0.8152 MPa, 0.8036 MPa, and 0.8036 MPa, respectively, and the curves exhibit a significant overlap before reaching the peak stress point. The corresponding peak strains were 2.6×10^{-3} , 2.8×10^{-3} , and 2.7×10^{-3} , indicating a relatively uniform deformation pattern. These results confirm the high repeatability of the ITS tests for the rosin-modified mixture and highlight the effectiveness of the additive in enhancing the tensile performance demonstrating a consistent behavior across specimens.

IV. CONCLUSION

1. Enhanced Adhesion: The strong adhesion between the bitumen and aggregate particles is primarily due to the cohesive interaction between the Buton Rock Asphalt

(BRA) bitumen and petroleum-based bitumen, which form a droplet phase in the Asbuton-modified binder, known as Retona Blend 55. This internal cohesion fosters a stable binder matrix that effectively coats and binds the aggregate surfaces.

2. Improved Binder Interaction with Rosin: The addition of rosin, a natural resin derived from pine sap, further enhances the interaction between the binder and aggregate by improving particle packing and interlocking. The rosin also contributes to better filler distribution and helps fill micro-voids within the asphalt matrix, creating a denser and more unified structure.
3. Improved Mechanical Performance: The Asphalt Concrete-Wearing Course (AC-WC) mixture modified with both Asbuton and rosin shows improved mechanical performance, particularly in terms of Indirect Tensile Strength (ITS). This enhancement results from the increased aggregate-binder adhesion and improved structural compactness, enabling the mixture to resist tensile loads and accommodate deformation without cracking.
4. Strength and Flexibility: The combination of strength and flexibility achieved through the modified binder and resin additive is crucial for asphalt pavement performance, especially under dynamic traffic loading and varying environmental conditions.
5. Durability and Sustainability: The synergy between the modified binder and the rosin additive offers a promising solution for developing durable, sustainable asphalt mixtures using locally available materials, contributing to both performance and environmental benefits in road construction.

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