

The Effect of Anti-Stripping Agent Addition on the Performance of Asphalt Concrete-Wearing Course (AC-WC) Mixture with Madura Local Aggregate

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Abstract: This study investigates the use of the Morlife 300 anti-stripping agent to improve the performance of Asphalt Concrete-Wearing Course (AC-WC) mixtures incorporating local aggregates from Madura Island, Indonesia. The objective of this research is to determine the Marshall characteristics of the mixture and to identify both the optimum asphalt content and the optimum anti-stripping dosage based on the 2018 Bina Marga Specifications (Revision 2). Laboratory testing was conducted using asphalt contents of 5%, 6%, and 7%, resulting in an optimum asphalt content of 5.2%, while additive variations of 0%, 0.1%, 0.3%, and 0.5% were used for performance evaluation. The results show that the incorporation of Morlife 300 enhances mixture performance, as indicated by decreasing Air Voids and Voids in Mineral Aggregate and increasing Voids Filled with Asphalt, along with improved stability and Marshall Quotient values. Compared to the mixture without additive, the use of 0.3% Morlife 300 increases stability by 30.57% and the Marshall Quotient by 29.38%, marking this dosage as the optimum level among all variations tested. Overall, the use of the Morlife 300 anti-stripping agent is proven to improve the volumetric and mechanical performance of AC-WC mixtures.

Keywords: AC-WC, Anti-Stripping Agent, Morlife 300, Marshall Test, Madura Aggregate

Introduction

Flexible pavement is one of the most widely used pavement types worldwide, including in Indonesia, and consists of several layers with the Asphalt Concrete-Wearing Course (AC-WC) serving as the uppermost layer that directly receives traffic loads (Yasin, Sholichin, & Estikhamah, 2024). Damage to flexible pavements remains a common issue, often caused by increasing traffic volume and moisture intrusion, which weakens the adhesion between asphalt and aggregates and eventually leads to stripping and pothole formation (Nasrulloh, Sholichin, & Fatikasari, 2024).

In several asphalt mixing plants on Madura Island in Indonesia, coarse aggregates sourced from Pasuruan Regency (East Java, Indonesia) are still preferred because they are perceived to yield better asphalt mixture performance. Previous comparative research demonstrated that AC-WC mixtures using Pasuruan aggregates exhibit better Marshall characteristics compared to those using local Madura Island aggregates. This dependence

on materials sourced from outside Madura increases production costs, even though aggregates from Madura Island have been shown to meet the quality standards of the Indonesian National Standard (SNI) (Kurniawati & Sholichin, 2023).

One of the efforts to improve the performance of asphalt mixtures utilizing local aggregates is the incorporation of anti-stripping agents. These additives enhance binder–aggregate adhesion and improve resistance to moisture-induced damage (Sawaluddin, Widodo, & Sulandari, 2016). According to the Bina Marga Specifications (2018 Revision 2), which is the national road construction standard in Indonesia, the recommended dosage of anti-stripping agent ranges from 0.2% to 0.4% by weight of asphalt. These additives are commonly used to enhance the overall quality of asphalt mixtures, particularly by improving stability and retained Marshall stability.

Various types of anti-stripping materials have been developed to enhance the moisture resistance of asphalt mixtures, and one of the most widely used is the liquid anti-stripping agent. Liquid Anti-Strip is a surface active agent that functions by increasing aggregate wettability and strengthening adhesion at the asphalt–aggregate interface, thereby preventing moisture-induced stripping (Guha & Kumar, 2018). This additive is typically amine-based and is incorporated into the asphalt binder prior to mixing with aggregates in order to optimize bonding performance and reduce the risk of stripping during the service life of the pavement (Simajuntak & Radam, 2021).

Given the continued reliance on aggregates sourced outside Madura Island and the limited research on optimizing the performance of local aggregates through chemical additives, further investigation is required to evaluate the effectiveness of anti-stripping agents in improving the quality of AC-WC mixtures using Madura aggregates. Therefore, this study aims to analyze the influence of the amine-based anti-stripping agent Morlife 300 on the Marshall characteristics of AC-WC mixtures produced with local aggregates from Madura Island. The findings of this research are expected to provide scientific evidence for enhancing the performance of locally sourced materials and to support broader utilization of Madura aggregates in asphalt pavement construction, thereby reducing dependence on externally sourced aggregates and lowering production costs.

Methodology

The methodological framework for this research involved a structured sequence of laboratory-based evaluations designed to assess the performance differences between asphalt concrete mixtures incorporating the anti-stripping agent Morlife 300 and those produced without additives. The workflow commenced with material preparation and preliminary characterization of the asphalt binder, aggregates, and chemical additives. Aggregates were obtained from the Banyuwates area in Madura Island, whereas the Morlife 300 additive was provided by PT Multi Bangun Indonesia (Merak Jaya Group) operating in Gempol, Pasuruan Regency. The binder used in the mixture was Pertamina penetration grade 60–70. All constituent materials underwent initial physical property testing to confirm compliance with standard specifications prior to mix production.

Specimen production took place at the Road Materials Laboratory, Department of Civil Engineering, Universitas Pembangunan Nasional “Veteran” Jawa Timur. Aggregates

were heated to the designated mixing temperature, after which the pre-heated asphalt was incorporated according to the selected binder content. For mixtures containing the additive, Morlife 300 was first introduced into the asphalt binder and thoroughly blended to ensure uniform dispersion before mixing with the aggregates. Once a consistent mixture was achieved, the material was placed into Marshall molds and compacted using a mechanical hammer delivering 75 blows on each face.

Following compaction, the specimens were subjected to a series of measurements encompassing volumetric parameters Air Voids, Voids in Mineral Aggregate, and Voids Filled with Asphalt as well as Marshall performance indicators including stability, flow, and the Marshall Quotient. Data obtained from each dosage of the Morlife 300 additive were subsequently compared with the control mixture to determine the influence of the additive on the mechanical response and overall mixture performance.

Results and Discussion

a. Material Test Result

The material characterization conducted in this study includes a series of tests on *asphalt penetration grade 60/70* as well as on the aggregates used in the mixture. The asphalt binder was evaluated through penetration measurements, determination of flash and fire points, softening point testing, and ductility. Meanwhile, the aggregates were examined through specific gravity testing, and water absorption measurements. All procedures were carried out in accordance with applicable SNI testing methods and the 2018 Bina Marga Specifications (Purnomo, Sholichin, & Estikhamah, 2024).

- Aggregate Physical Testing Results

In this experimental study, the aggregates employed were sourced from a production site in Jatra Timur Village, Banyuates District, Sampang Regency, on Madura Island, Indonesia. The Madura aggregates were subjected to preliminary characterization prior to their incorporation into the asphalt mixture, consisting of specific gravity and water absorption tests, as these parameters represent the most fundamental indicators of aggregate quality (Ali, 2022). The selection of aggregate sources must consider several criteria, including asphalt absorption capacity, a maximum water absorption limit of 3%, and minimum bulk specific gravity values of 2.5 for both coarse and fine aggregates (Gazalie, Hawinuti, Fauzi, & Setiadi, 2022). The results of these tests are presented in Table 1.

Table 1: Aggregate Physical Properties Check Results

Properties		Results			Unit
		(5-10 mm)	(10-15 mm)	Fine Agg.	
Oven-Dry Weight of the Specimen	(W ₁)	982.0	983.5	484.5	gram
Weight of the Specimen in Water	(W ₂)	616.5	616.7	310.7	gram

Properties		Results			Unit
		(5-10 mm)	(10-15 mm)	Fine Agg.	
Saturated Surface-Dry Weight of the Specimen	(W _s)	1,000	1,000	500	gram
Bulk Specific Gravity		2.56	2.57	2.56	gram/cm ³
Saturated Surface-Dry Specific Gravity		2.61	2.61	2.64	gram/cm ³
Apparent Specific Gravity		2.69	2.68	2.79	gram/cm ³
Absorption		1.83%	1.68%	3.20	%

The test results indicate that all aggregate types exhibit specific gravity values that fall within the acceptable range specified by the 2018 Bina Marga standards. However, the water absorption value of the fine aggregate does not meet the required criterion, as it exceeds the maximum permissible limit of 3%. Higher aggregate water absorption indicates increased residual moisture trapped within the pore structure, which can interfere with the proper development of the asphalt binder film and allow moisture to persist either on the aggregate surface or within its internal pores (Ji et al, 2021).

Prior to mixture preparation, all aggregate materials delivered to the laboratory were first sieved and separated into their respective size fractions. Each fraction was subsequently blended according to the AC-WC gradation limits established in the 2018 Bina Marga Standard Specifications. This procedure ensured uniformity of gradation across all mixtures, preventing any variation between test specimens and allowing for a more accurate evaluation of mixture performance. The resulting combined aggregate gradation used throughout the study is shown in Table 2 and Figure 1.

Table 2. Aggregate Physical Properties Check Results

Sieve	Retained Weight (grams)	Cumulative Retained Weight (grams)	Percent Passing (%)	Req. (AC-WC)
3/4"	0	0	100%	100%
1/2"	68	68	94%	90 - 100%
3/8"	102	170	86%	77 - 90%
No. 4	335	505	58%	53 - 69%
No. 8	215	720	40%	33 - 53%
No. 16	148	868	28%	21 - 40%
No. 30	100	968	19%	14 - 30%
No. 50	75	1,043	13%	9 - 22%
No. 100	66	1,109	8%	6 - 15%
No. 200	31	1,140	5%	4 - 9%
Pan	60	1,200	-	-

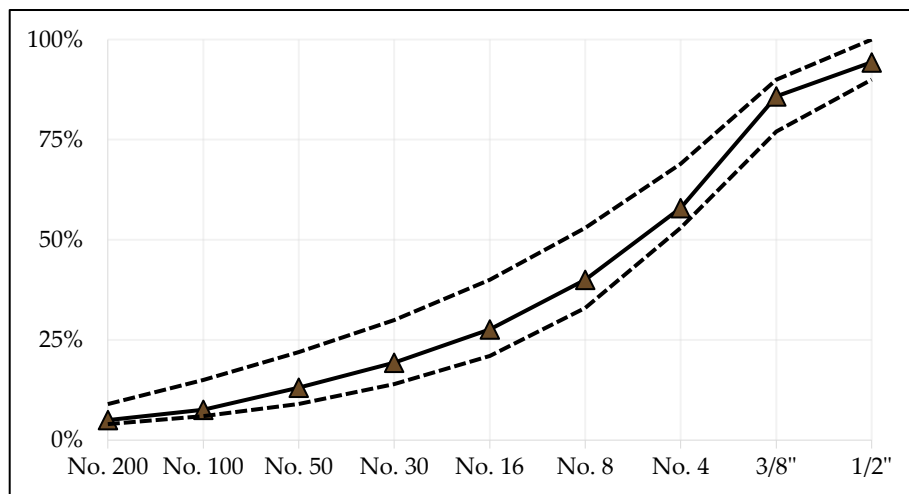


Figure 1. Gradation Curve of Combined Aggregate Sample.

• Asphalt Physical Testing Results

The physical characteristics of bitumen are important in determining the durability and performance of asphalt pavements. Therefore, prior to its use in asphalt concrete mixtures, the binder is subjected to several laboratory evaluations penetration, softening point, flash point, and ductility tests to ensure compliance with the 2018 Bina Marga specifications. The results of these evaluations are presented in Table 3.

Table 3. Results of Physical Properties of Asphalt Pen 60/70 Ex Pertamina

No	Properties	Specification		Results	Description
		Min	Max		
1	Penetration at 25°C (0.1 mm)	60	70	65.24 mm	OK
2	Soft Spots (°C)	48	58	49 °C	OK
3	Flash Point (°C)	232	-	>275 °C	OK
4	Ductility at 25 °C (cm)	100	-	114.5 cm	OK

The test results indicate that the 60/70 penetration asphalt satisfies all the requirements specified in the 2018 Bina Marga Specifications. The penetration value of 65.24 mm, softening point of 49°C, flash point of >275°C, and ductility of 114.5 cm all fall within the acceptable limits, confirming that the asphalt is suitable for use as a binder in asphalt mixtures.

b. Asphalt Content Determination

After the constituent materials for the asphalt mixture were evaluated, the mixing process was carried out using the predetermined asphalt contents. The asphalt binder was first heated until it transitioned from a solid to a fully fluid state. Prior to mixing, the aggregates were also heated, and once they reached the required mixing temperature, the liquefied asphalt was incorporated into the heated aggregates. The asphalt content

variations used to determine the optimum asphalt content were 5.0%, 6.0%, and 7.0% by weight of aggregate. The results of these tests are presented in Table 4.

Table 4. Results of Physical Properties of Asphalt Pen 60/70 Ex Pertamina

Properties	Unit	Req.	Asphalt Content		
			5%	6%	7%
Air Voids	%	3 – 5	3.67%	2.37%	1.02%
Voids in Mineral Aggregate	%	Min. 15	16.80%	22.69%	25.51%
Voids Filled with Asphalt	%	Min. 65	77.82%	89.61%	95.95%
Stability	kg	Min. 800	1,469.89	1,625.50	1,350.05
Flow	mm	2 – 4	3.17	3.47	3.93
Marshall Quotient	kg/mm	Min. 250	489.94	471.89	344.55

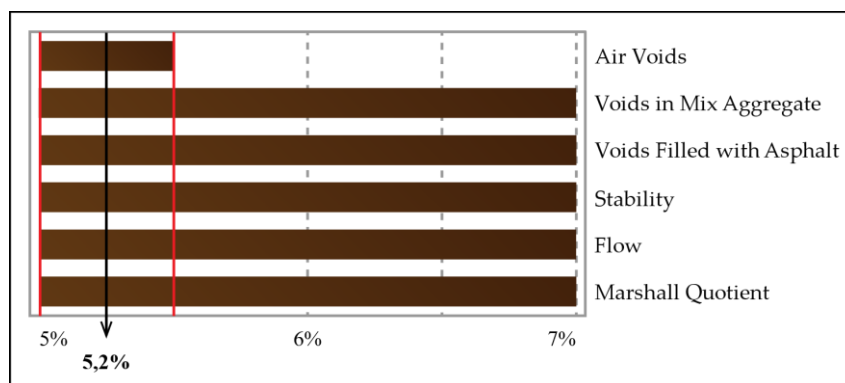


Figure 2. Determination of Optimum Asphalt Levels.

Based on the determination of the optimum asphalt content, the asphalt content used for comparing the mixtures with and without the anti-stripping agent was set at 5.2% of the aggregate weight, which is equivalent to approximately 4.9% of the total mixture weight.

c. Comparative Analysis of Mixtures With and Without Anti-Stripping Agent

The optimum asphalt content determined in the preceding stage served as the reference for comparing mixtures prepared with and without the Morlife 300 additive (0%). The additive was incorporated by introducing the liquid anti-stripping agent into the heated asphalt and mixing until a uniform blend was achieved. Three additive dosages 0.1%, 0.3%, and 0.5% by asphalt weight were employed. The preparation procedures and the corresponding test results for the additive-modified mixtures are presented in Table 5.

Table 5. Average Values of ACWC Marshall Testing with Antistripping Additives Morlife 300

Properties	Unit	Req	Anti-Stripping Dosage			
			0%	0.1%	0.3%	0.5%
Air Voids	%	3 - 5	3.65%	3.25%	3.14%	3.07%
Voids in Mineral Aggregate	%	Min. 15	18.43%	15.65%	15.42%	15.35%
Voids Filled with Asphalt	%	Min. 65	78.15%	79.25%	79.64%	80.13%
Stability	kg	Min. 800	1,536.85	1,842.21	2,006.86	1,688.71
Flow	mm	2 - 4	3.25	3.26	3.02	2.92
Marshall Quotient	kg/mm	Min. 250	527.127	588.57	682.02	606.54

The test results indicate that all anti-stripping agent dosage variations (0.1%, 0.3%, and 0.5%) meet the 2018 Bina Marga specifications. The Air Voids and Voids in Mineral Aggregate values tend to decrease with increasing additive content, while the VFA shows an upward trend, indicating a denser mixture. The highest stability is achieved at a dosage of 0.3%, reaching 2006.86 kg with a flow value of 3.02 mm and an MQ of 682.02 kg/mm, demonstrating the best balance between mixture strength and plasticity.

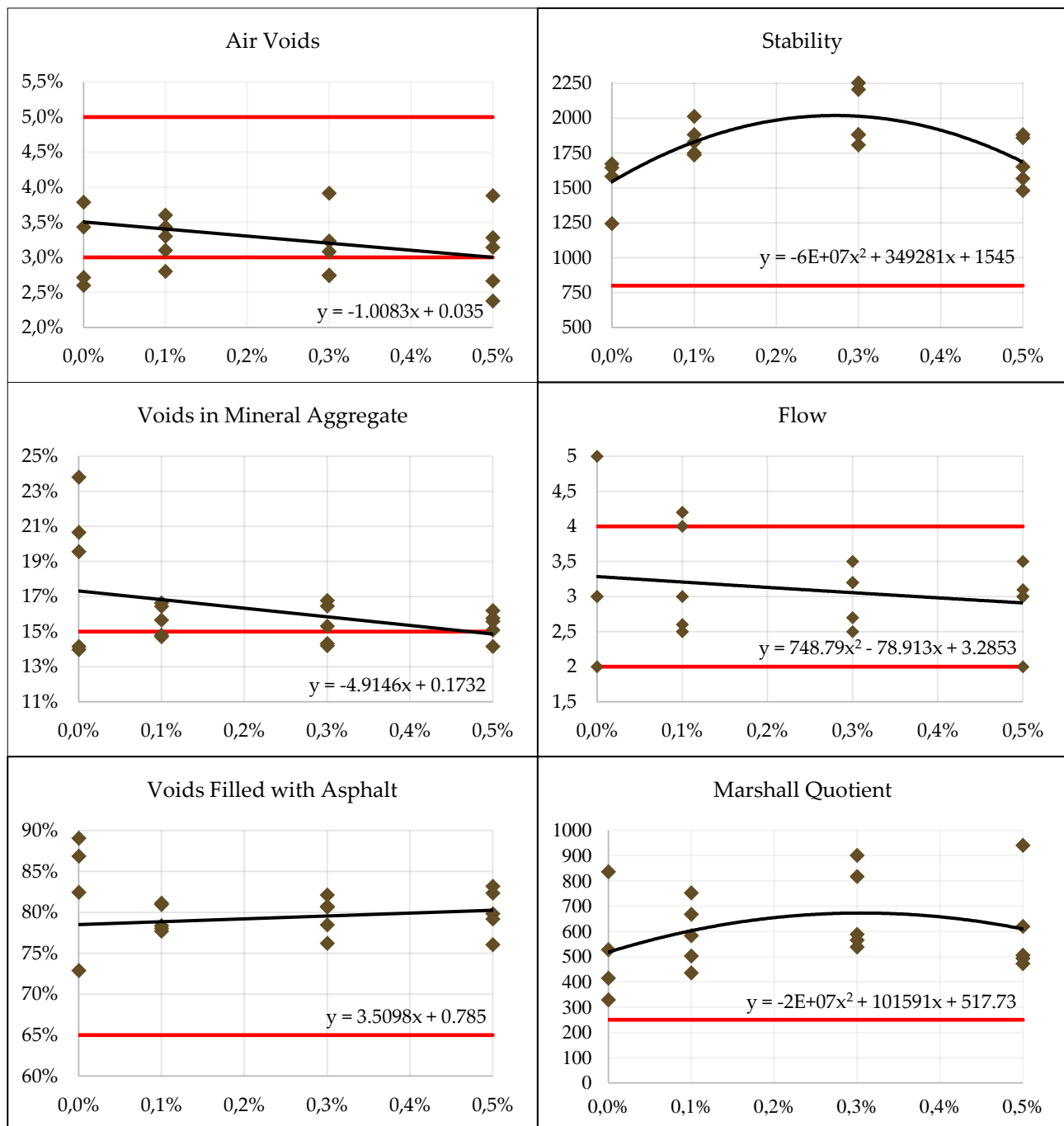


Figure 3. Marshall Testing with Antistripping Additives Morlife 300 Result

The graphical trends of the Marshall parameters across the anti-stripping dosages (0–0.5%) reveal distinct behavioral patterns. Air Voids exhibit a consistent decline, indicating reduced internal voids and improved compactness with increasing additive content, while the Voids in Mineral Aggregate similarly decrease, reflecting a progressively denser aggregate structure. In contrast, the Voids Filled with Asphalt increase steadily, showing that a larger portion of the available void space becomes filled with binder. The stability curve displays a characteristic peak, where stability rises sharply with additive addition before declining beyond the optimum dosage, suggesting that excess additive offers no

further structural benefit. Flow values decrease with additional additive, indicating greater mixture stiffness. The Marshall Quotient follows a trend similar to stability, increasing up to the 0.3% dosage and then falling, which identifies this point as the dosage providing the most favorable balance between strength and deformation resistance.

d. The Optimum Morlife 300 Anti-Stripping Agent Dosage

Since all Marshall parameters required by the 2018 Bina Marga specifications were satisfied, the determination of the optimum anti-stripping dosage was focused on comparing the stability and Marshall quotient values. This approach was adopted because one of the primary functions of an anti-stripping agent is to enhance the stability of the asphalt mixture. To determine the optimum dosage, the relationship between additive content and mixture performance was modeled using quadratic equations. The first equation, which describes the change in stability with respect to additive content, is given by $y = -6 \times 10^7 x^2 + 349,281x + 1,545$, while the second equation, representing the trend for the Marshall quotient, is expressed as $y = -2 \times 10^7 x^2 + 101,591x + 517.73$. In practical terms, both equations form curves that rise and then fall, allowing the highest point of each curve to indicate the most effective dosage of the additive. The peaks of both curves occurred at an additive content of approximately 0.3% of the asphalt weight, demonstrating that this dosage provides the best overall improvement in stability and Marshall quotient. Therefore, the optimal Morlife 300 content for this asphalt mixture is concluded to be 0.3%.

A comparison between the mixture without additive (0%) and the mixture containing the optimum dosage (0.3%) demonstrates substantial improvements in both volumetric and mechanical characteristics. The Air Voids values decrease from 3.65% to 3.14%, the Voids in Mineral Aggregate values decrease from 18.43% to 15.42%, and the Voids Filled with Asphalt values increase from 78.15% to 79.64%, indicating a denser and more effectively bound mixture. The flow values also decrease from 3.25 mm to 3.02 mm, suggesting increased mixture stiffness. More importantly, stability improves from 1,536.85 kg to 2,006.86 kg, representing a 30.57% increase, while the Marshall Quotient rises from 527.13 kg/mm to 682.02 kg/mm, equivalent to a 29.38% increase.

Conclusion

The Marshall test results confirm that the AC–WC mixture using Madura aggregates meets all requirements of the 2018 Bina Marga Specifications. The trends observed across the anti-stripping dosages show that increasing Morlife 300 content reduces Air Voids and VMA while increasing VFA, indicating a progressively denser and better bonded mixture. Stability and Marshall Quotient both exhibit a clear optimum at the 0.3% dosage, where the mixture achieves its highest structural resistance and stiffness. At this optimum level, the Air Voids decrease from 3.65% to 3.14%, VMA decreases from 18.43% to 15.42%, and VFA increases from 78.15% to 79.64%. The flow value also slightly decreases, reflecting increased mixture rigidity. Most notably, the 0.3% dosage increases stability from 1,536.85 kg to 2,006.86 kg a 30.57% improvement and raises the Marshall Quotient from 527.13 to 682.02 kg/mm, equivalent to a 29.38% increase. These findings demonstrate that the addition of

0.3% Morlife 300 provides the most effective enhancement of both volumetric and mechanical performance of the AC–WC mixture.

Based on the results, future research is recommended to examine long-term durability characteristics such as Indirect Tensile Strength (ITS), moisture susceptibility tests like TSR, and field performance evaluations. Additional studies involving different types of anti-stripping agents or the combination of additives may also provide broader insights into strategies for improving the utilization of local aggregates in pavement construction.

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