Impact Of Fly Ash And Plastic Pellets Addition On The Performance Of Asphalt Mixture (AC-WC) For Sustainable Roads

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Abstract. Roads need to possess the proper combination of thickness and design to safeguard the subgrade from damage and to support the load pressure on the road. This study investigates the impact of incorporating fly ash and plastic granules on the performance of asphalt mixtures (AC-WC) for sustainable road construction. The experimental design involved setting the asphalt content according to standard specifications while maintaining a constant fly ash content of 6%. Performance evaluation was conducted using the Marshall test to assess key parameters such as stability, flow, and Marshall Quotient (MQ), which reflect the mixture's strength and flexibility. The results indicated that at a plastic granule content of 6%, the values for Voids in Mixture (VIM), Voids in Mineral Aggregate (VMA), and Void Fill Index (VFA) were 5%, 15%, and 66.28%, respectively, meeting the required standards. At higher plastic content levels (6.5% and 7%), these values slightly increased, indicating a denser mixture that could potentially reduce stability. Specifically, AC WC asphalt with a 6% LDPE plastic mixture achieved average stability of 1594.7 kg, with increased plastic content correlating with improved stability, though also presenting a higher risk of cracking. Among the various tested mixtures, the optimal plastic content for the AC-WC asphalt mixture was identified as 6%. This research highlights the potential for utilizing fly ash and recycled plastic to enhance the performance of asphalt mixtures, contributing to more sustainable road materials and construction practices.

Keywords: fly ash, plastic pellets, sustainable asphalt mixtures.

1 Introduction

The construction of sustainable road infrastructure necessitates innovative approaches that not only enhance road performance but also promote environmental friendliness. Asphalt pavements must provide a high level of

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service to withstand heavy traffic and extreme environmental conditions. Hot mix asphalt (HMA) or asphalt concrete- wearing course (AC-WC) is a commonly used surface layer due to its strength and durability.

Traditional materials such as aggregates and pure asphalt significantly impact the environment, often contributing to road deterioration. To mitigate these issues, industrial waste and recycled materials like fly ash and recycled plastic pellets can be utilized as alternative components in asphalt mixtures. Fly ash, a byproduct of coal combustion can effectively serve as a filler in asphalt mixtures, while plastic granules enhance the mechanical properties of the asphalt. Incorporating plastic waste as an additive in hot mix asphalt for road pavements offers a viable solution to both road deterioration and the reduction of plastic waste [1].

Research on the utilization of fly ash in concrete has yielded significant findings, but similar studies for asphalt mixtures are relatively scarce. The cementitious properties of fly ash, activated by water, have the potential to enhance the strength and durability of asphalt mixtures [2], [3].

The addition of plastic waste to AC-WC mixtures results in increased Marshall stability, higher flow values, increased density, decreased VIM, decreased VMA, and increased VFA [4], [5]. Types of plastic waste that can be used as additives in hot mix asphalt include HDPE, PET, and LDPE.

The use of PET plastic waste as a partial replacement for asphalt in AC-WC mixtures increases the mixture's stiffness, as evidenced by a decrease in asphalt penetration values, improved high-temperature resistance, and increased resistance of the pavement to permanent deformation such as cracking and rutting [6]. The optimal range for HDPE content is 4-6%, as it can improve stability while providing a more flexible mixture and optimal bitumen absorption [7]

This study aims to evaluate the effects of using fly ash and plastic granules on the performance of asphalt mixtures (AC-WC) by setting the asphalt content according to the design asphalt content and maintaining a constant fly ash content of 6%. The Marshall test will be used to measure mixture performance based on stability, flow, and Marshall Quotient (MQ), which indicates the strength and flexibility of the mixture. This approach is expected to produce a more sustainable road material with optimal performance.

2 Methodology

This research was conducted experimentally at the Civil Engineering Laboratory of Politeknik Negeri Sriwijaya. Generally, the research was carried out in several stages as follows:

2.1 Material preparation

LDPE 812 was used as the plastic add, and fly ash was employed as a filler at a 6% content. The asphalt used in this study was a Shell product with a penetration grade of 60-70, categorized as low penetration asphalt..

2.2 Aggregate testing

Filler, fine aggregate, and coarse aggregate were among the aggregates utilized. These aggregates had a constant gradation and were utilized in the asphalt concrete-wearing course (AC-WC) composition. SNI criteria were followed when testing aggregate characteristics.

Sieve analysis, specific gravity and absorption measurements, and abrasion tests were performed on coarse aggregate. Water absorption, specific gravity, and sieve analysis were measured for fine aggregate. Tests for specific gravity and sieve analysis were conducted on the fly ash filler. [8].

2.3 Homogeneous Asphalt and Plastic Pellet Mixture

The asphalt mixture was prepared in the laboratory using a wet mix method, ensuring a homogeneous blend of asphalt and plastic pellets [6].

2.4 AC-WC Specimens

The AC-WC specimens were cylindrical, with a diameter of 10 cm and a height of 64 cm. To determine the optimal value, at least 3 specimens were prepared for each variation of aggregate and asphalt proportions, as well as for varying substitution rates of LDPE plastic (6%, 6.5%, and 7%).

2.5 Marshall Testing

Marshall testing was conducted to determine the optimum asphalt content (OAC), following SNI 06-2489-1991. This resulted in a pavement mixture with optimal performance. The specimens were removed from the molds, measured, and weighed in dry, submerged, and saturated surface-dry (SSD) conditions.

These data were used to compute the percentage values of VIM (voids in mineral aggregate), VMA (voids in mineral aggregate), and VFA (voids filled with asphalt). To ascertain stability and flow values, the specimens were subsequently examined using a Marshall apparatus with a continuous loading rate after being submerged in a water bath at 60°C for 30 minutes.

3 Result and Discussion

3.1 Aggregate test results

The results of the tests conducted on coarse and fine aggregates are summarized in Table 1, which details their physical properties. The sieve analysis results for these aggregates are tabulated in Table 2.

Table 1. Characteristics of Coarse and Fine Aggregates.

No	Measurement	Value			Specification
		Ag. 1/2	Ag. 1/1	sand	
1.	Abration *Los Angeles* 500	18,27%			Max 40%
2.	Specific gravity				The difference between the tests is 0.2
	Bulk	2,508	2,215	2,516	
	SSD	2,570	2,230	2,582	
	Apparent	2,671	2,250	2,695	
3.	Water absorption	2,420	1,817	2,630	Max 3%

Table 2. result of sieve analysis

Sieve size		% cumulative passing		
ASTM	mm	sand	Ag. 1/1	Ag. 1/2
3/4"	19	100.00	100.00	97.96
1/2"	12.5	100.00	96.74	76.69
3/8"	9.5	100.00	82.25	54.61
# 4	4.75	99.96	52.33	36.49
# 8	2,36	99.62	20.03	25.94
# 16	1,18	79.88	9.27	11.91
# 30	0,6	50.78	5.97	11.72
#50	0,3	17.72	4.66	8.94
#100	0,15	11.60	3.99	3.42
# 200	0,075	5.56	3.57	2.77

Based on the aggregate gradation results, the percentage of the constituent components for the AC-WC mixture can be determined. The composition results that meet Bina Marga specifications, with composition values falling within the required range, are shown in Figure 1.

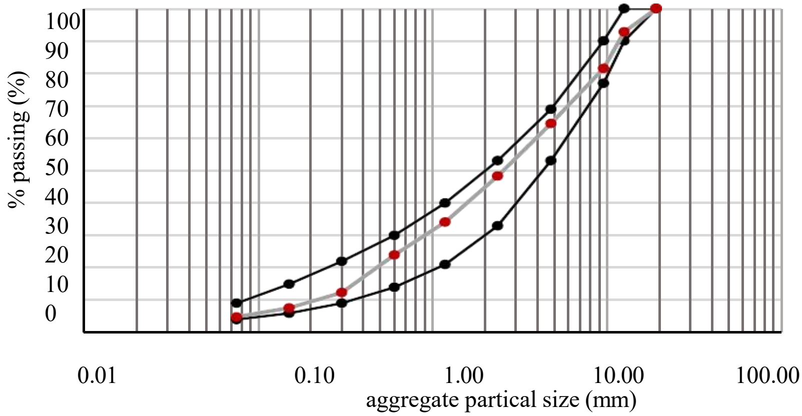

Fig. 1. mixed gradatiob of aggregate for AC-WC.

The optimal asphalt content (Pb) can be determined by analyzing the aggregate gradation. The following formula is used to calculate Pb:

$$Pb = 0,035\ (\%CA) + 0,045\ (\%FA) + 0,18\ (\%F) + K$$
$$= 0,035\ (43) + 0,045\ (67) + 0,18\ (4) + 1$$
$$\approx 6\ \%$$

3.2 Asphalt testing result

The asphalt used is Pen 60/70 asphalt produced by Shell. The results of the asphalt characteristic tests conducted in the laboratory can be seen in Table 3.

Table 3. Asphalt characteristic

No	Measurement	Value	Specification
1.	Penetration 25°C (0,1 mm)	68,2	60 - 70
2.	Softning point (°C)	48,8 - 49	> 48
3.	Ductility 25°C, (cm)	131,6	> 100
4.	Flash poin (°C)	298	> 232
5.	Specific gravity	1,025	> 1,0

3.3 Additive Material Testing

Fly Ash. The test conducted on fly ash filler was specific gravity. The research results indicate that the specific gravity of fly ash is 2.71 g/cm³.

Plastic Pellets. The plastic pellets used in this study are LDPE 812 type plastic pellets with a specific gravity of 0.917 g/cm³. LDPE 812 plastic pellets can be derived from plastic waste, such as plastic bottle packaging waste, plastic bags, plastic toys, cable protective layers, and flexible hose pipes.

3.4 Marshall Test Results

Based on the calculation of the plan and the results of the Marshall test, the density values are obtained as follows table 4.

Table 4. Specific Gravity Values of Test Samples at 6% Asphalt Content

Plastic pellets content	Sample Weight (Grams)			bulk Vol (cm^3)	Bulk spec. grav, G_{mb}
	Dry	In water	SSD		
C6	1203,4	658,5	1215,8	557,3	2,159
C6	1207,8	662,0	1220,2	558,2	2,164
C6	1219,0	667,0	1232,0	565,0	2,158
					2,160
C6.5	1180,0	642,0	1198,0	556,0	2,122
C6.5	1199,4	638,5	1203,2	564,7	2,124
C6.5	1190,6	659,0	1199,6	540,6	2,202
					2,150
C7	1187,8	634,2	1198,2	564,0	2,106
C7	1177,4	638,3	1186,2	547,9	2,149

C7	1136,7	616,2	1143,8	527,6	2,155
					2,136

VIM (Voids in Mixture). Figure 2 shows the relationship between VIM and asphalt content, indicating that an increase in asphalt content results in a decrease in VIM values. A VIM value that is too low can cause the mixture to become too dense, less flexible, and prone to cracking.

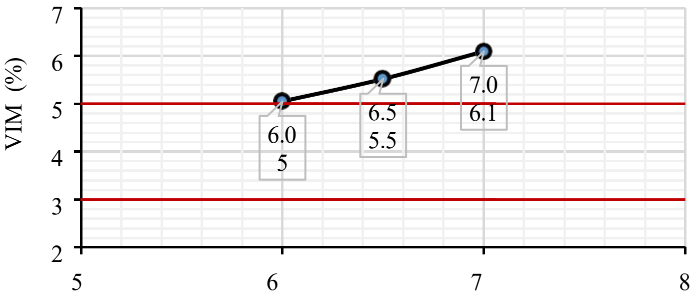

Fig. 2. Impact of LDPE plastic content on VIM.

VMA (Void in Mineral Aggregate). Based on Figure 3, it is observed that as the content of LDPE plastic increases, the VMA (Voids in Mineral Aggregate) value also increases.

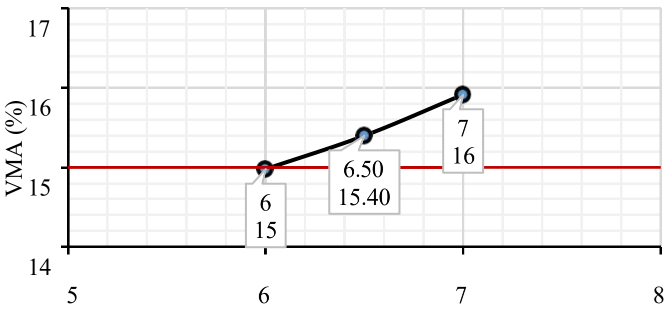

Fig. 3. Impact of LDPE plastic content on VMA.

VFA (Voids Filled with Asphalt). The results of the VFA (Void Fill Index) testing can be seen in Figure 4. A high VFA value can lead to damage in the pavement layer, such as bleeding, which can reduce the service life of the road [9].

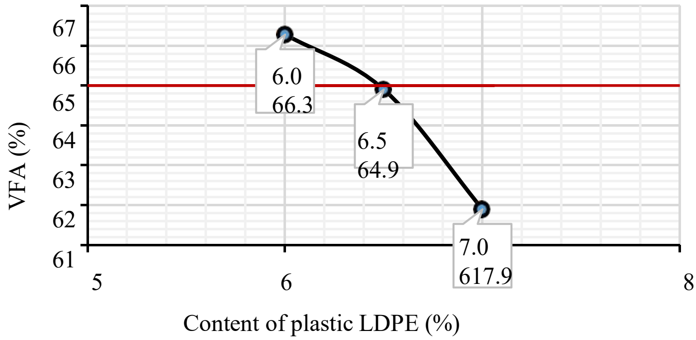

Fig. 4. Impact of LDPE plastic content on VFA.

Stability and Flow. Based on the results of the Marshall test, there is a tendency for the MQ (Marshall Quotient) value to increase alongside the stability value. The results for stability and flow are shown in Figures 5 and 6, respectively, while the MQ values are illustrated in Figure 7.

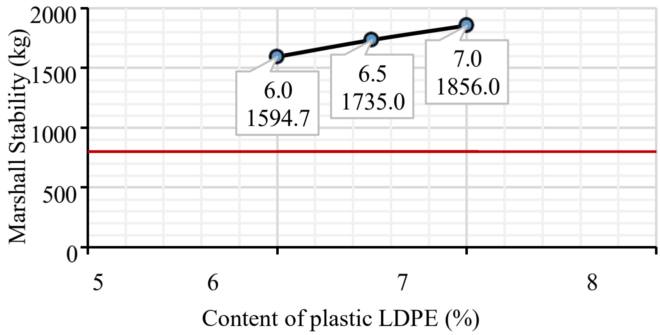

Fig. 5. Impact of LDPE plastic content on Marshall stability.

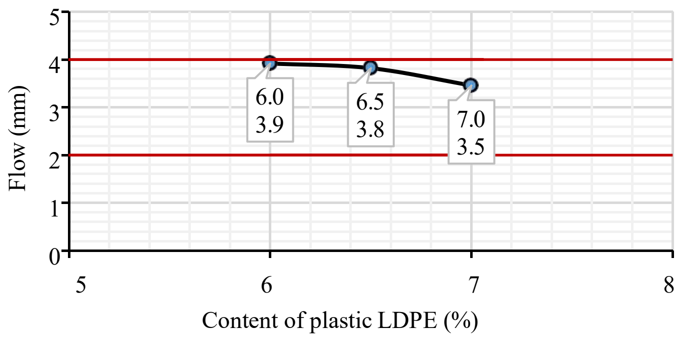

Fig. 6. Impact of LDPE plastic content on Flow.

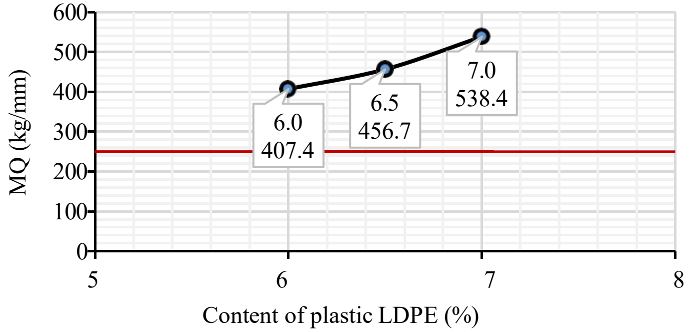

Fig. 7. Impact of LDPE plastic content on Marshall Quotient.

Data analysis from Figures 5 and 7 indicates a positive correlation between stability and MQ (Marshall Quotient) values. Sample 1, with an average stability of 1595 kg, and Sample 3, with a stability of 1856 kg, have MQ values of 407.43 kg/mm and 538.39 kg/mm, respectively. These values exceed the minimum MQ threshold established in the Bina Marga Specification Revision II of 2018, which is set at 250 kg/mm.

Figure 8 shows that the optimum plastic pellet content used is 6%, demonstrating that the test results for VIM, VMA, VFA, stability, flow, and MQ meet Bina Marga specifications.

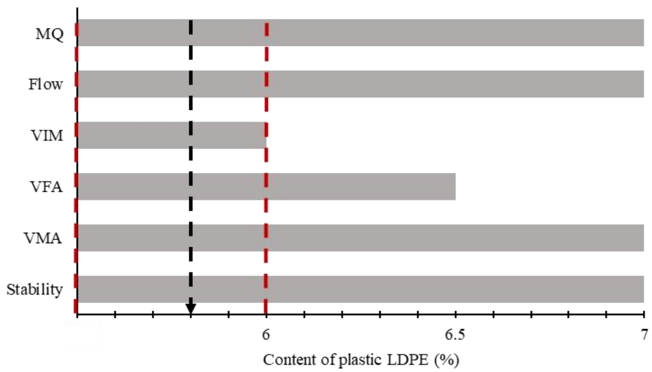

Fig. 8. Impact of LDPE plastic content on Marshall Quotient.

4 Conclusion

The test results on asphalt mixture performance (AC-WC) with the addition of fly ash and plastic granules LDPE, with a fixed asphalt content of 6%, showed the following;

1. At a plastic granule content of 6%, the VIM, VMA, and VFA values were 5%, 15%, and 66.28%, respectively. These values meet the specified requirements. At a plastic granule content of 6.5%, the VIM, VMA, and VFA values were 5.52%, 15.40%, and 64.90%, respectively. At a plastic granule content of 7%, the VIM, VMA, and VFA values were 6.10%, 15.91%, and 61.90%, respectively. Several factors can influence the Marshall characteristics of an asphalt mixture, including mixing temperature, mixture composition, mixing method, soaking time, and human error. High mixing temperatures can impact flow and density values. The percentage of mixture content affects VIM, VMA, and VFA, with denser mixtures having more filled cavities. However, increasing mixture content can also reduce Marshall stability, leading to a harder and more brittle mixture.
2. AC WC asphalt with a 6% LDPE plastic mixture produces an average stability of 1594.7 kg. Increasing LDPE content is directly proportional to increasing stability, but also increases the risk of cracking.
3. Among the variations of hot mix asphalt AC-WC (with 6% asphalt content) + 6% fly ash + 6%, 6.5%, and 7% LDPE plastic, the optimal content of plastic for the AC-WC asphalt mixture was found to be 6%.

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