The Effect of Low Density Polyethylene Asphalt Additives on the Properties of Asphalt Concrete Wearing Course (AC-WC)

Wafa Natasya Nurfadhillah[1] and Rangga Adiprima Sudisman[2*]

{ wafanatasyaa@gmail.com[1], rangga.as@universitaspertamina.ac.id[2] }

Faculty of Infrastructure Planning, Universitas Pertamina, Kebayoran Lama, South Jakarta 12220, Indonesia[1,2]

Abstract. Using plastic waste in asphalt mixtures may increase the service life of the asphalt pavement surface while also reducing waste. The purpose of this study is to see how Low-Density Polyethylene (LDPE) asphalt additives affect the Marshall properties of asphalt concrete wearing course (AC-WC). 42 AC-WC pavement samples were created using the Bina Marga 2018 specification and the Indonesian National Standard for Asphalt Testing. Using the wet process, 5-8% LDPE with 0.5% intervals of the optimum asphalt content were added to the samples. Marshall tests were performed to determine the optimum asphalt and LDPE content. The optimal asphalt content was 6.5%, and the optimal plastic content was 7.5%. The results show that adding 7.5% LDPE can improve Marshall stability by two times, from 977.18 kg to 2103.44 kg, and reduce asphalt content consumption by up to 7.05% compared to the mixture without the addition of LDPE.

Keywords: Flexible pavement, asphalt mixture, AC-WC, Marshall test, LDPE.

1 Introduction

Indonesia's annual need for raw road materials, mainly asphalt, continues to grow. According to the statistics for the year 2020, as shown in **Figure 1**, 58.32% of all road length is made up of paved roads, while 41.68% is still made up of unpaved roads. Bina Marga, the Department of Public Highways, Ministry of Public Works and Housing, establishes rules for the quality of asphalt mixing materials and specifies that the quality of the materials will impact the pavement's quality. According to statistics, 44.27% of Indonesian roads are in excellent condition, 22.33% are in good condition, and 33.41% are in poor condition. Low-quality asphalt is one source of road deterioration. The growth of the number of vehicles in terms of quantity, weight, and speed, as well as changing weather conditions are the primary causes of road damage [1].

ICO-SEID 2022, November 23-24, Jakarta, Indonesia

DOI 10.4108/eai.23-11-2022.2338875

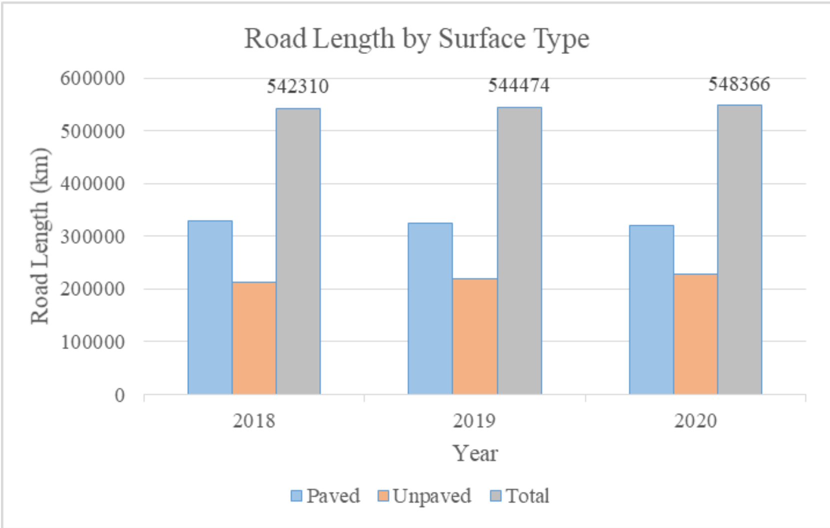

Fig. 1. Indonesia's Road Pavement growth 2018-2020

On the other hand, there is a significant issue in the field of environmental protection in Indonesia, which is pollution brought on by plastic waste or plastic bags. According to information made public by the Indonesian Plastic Industry Association (INAPLAS), Indonesia is believed to be responsible for as much as 64 million tons of plastic waste produced each year globally. The Indonesian government has implemented a variety of actions in an attempt to cut down on the amount of waste produced from plastic in the country. One of these initiatives is the restriction of the use of plastic bags in certain parts of the country. However, these solutions have not significantly reduced the amount of plastic waste produced in the community [2].
To solve the rising demand for road materials, frequent road damage, and environmental issues caused by plastic waste, one thing that can be done is to use plastic waste as an additive to hot asphalt mixtures in the pavement field. The laboratory experiment results conducted by the Ministry of Public Works and Housing indicate that hot asphalt mixes that include plastic waste are much more durable than standard hot asphalt mixtures [3]. Also, many researchers have investigated the possibility of using discarded plastic items as a component of paving materials [1, 4, 5, 6], which has proven to improve the quality of the Asphalt Concrete Wearing Course (AC-WC) mixture. According to the findings of those studies, the optimal plastic content for AC-WC mixtures ranges between 5% and 6%. It depends on the type of plastic, optimum asphalt content, and type of mixture used. This research was carried out to examine whether adding LDPE to asphalt might change the AC-WC properties. In order to improve the precision of AC-WC, this study used a variation of LDPE between 5% and 8% (with 0.5% intervals) of the optimal asphalt content.

2 Methodology

Marshall testing experiments were used in this research using the Bina Marga 2018 Specification. The materials that must be tested are fine aggregates, coarse aggregates, and asphalt. The asphalt used in this research is Shell Bitumen with Pen 60/70. This research consists of aggregate testing that includes specific gravity, absorption tests, and sieve analysis. Four types of aggregates are tested for their quality: the rubbled stone that passes through a ¾” sieve, the rubbled stone that passes through a ½” sieve, sand, and stone ash. In addition, the characteristics of asphalt are investigated through tests such as specific gravity, ductility, flash point, softening point, and penetration. The physical properties of both aggregates and asphalt can be seen in Table 1. The optimal asphalt content is calculated when all of the tests have been completed successfully. It is necessary to determine the asphalt content first before proceeding with the mixing with LDPE. The purpose of determining asphalt content is to establish the optimal asphalt content, which will be used as a reference for creating AC-WC samples with the addition of LDPE. If all the standards are met, the next step is to add LDPE to the pavement sample by using a wet process. The LDPE variation used is 5% to 8% (with an interval of 0.5%) of the optimal asphalt content. The AC-WC mixture was then subjected to Marshall tests to determine its stability and flow rates, while other factors were determined based on the sample weight and the calculation results. Marshall testing generally consists of bulk-specific gravity testing, volumetric properties, stability, and flow testing.

Table 1. Physical Properties of Aggregate and Asphalt

Material	Properties	Value	Unit	Standard
Aggregate < ¾”	Bulk Specific Gravity	2.80	-	>2.5 (SNI 03-1969-1990)
	Absorption	2.97	%	<3.0 (SNI 03-1969-1990)
	Mix Portion	20	%	ASTM C136-2012
Aggregate < ½”	Bulk Specific Gravity	2.53	-	>2.5 (SNI 03-1969-1990)
	Absorption	1.74	%	<3.0 (SNI 03-1969-1990)
	Mix Portion	25		ASTM C136-2012
Fines	Bulk Specific Gravity	2.54	-	>2.5 (SNI 03-1970-1990)
	Absorption	2.46	%	<3.0 (SNI 03-1970-1990)
	Mix Portion	40		ASTM C136-2012
Ash	Bulk Specific Gravity	2.53	-	>2.5 (SNI 03-1970-1990)
	Absorption	2.04	%	<3.0 (SNI 03-1970-1990)
	Mix Portion	15		ASTM C136-2012
Asphalt	Penetration	64.73	mm	60-70 (SNI 2456:2011)
	Softening Point	53	°C	48-58 (SNI 2434:2011)
	Flash Point	337	°C	>232 (SNI 2433:2011)
	Ductility	127.7	cm	>100 (SNI 2432:2011)
	Specific Gravity	1.0	-	1.0 (SNI 2434:2011)

3 Results and Discussion

3.1 Analysis of the characteristics of AC-WC with LDPE

The optimal asphalt content of the AC-WC mixture used in this research is 6.5%. LDPE plastic was then added to the mixture to create samples. LDPE plastic composition varies between 5%, 5.5%, 6%, 6.5%, 7%, 7.5%, and 8%. The Marshall test was used on the samples to obtain the results shown in **Figures 6**, **Figures 7**, **Figures 8**, showing the connection between plastic content and the estimated parameters.

1. Density

The correlation between plastic content and density can be seen in **Figure 2**. With a minimum density of 1.95 gram/cm^3, this test's plastic mixture samples fulfilled the needed standards. As seen in **Figure 2**, the density value of the plastic mixture has a trend toward increasing. It is because more plasticized asphalt mixture envelops the spaces between the particles, which results in the asphalt concrete mixture being denser.

2. Void in mix (VIM)

Figure 3 depicts the relationship between plastic content and density. Because the plastic asphalt lumps fill the spaces between the aggregates, the VIM value decreases. As a result, the voids in the mixture become smaller and tighter, lowering the VIM value. However, once the plastic content reaches the minimum VIM limit, the plastic asphalt lumps will continue to grow, making it difficult for the lumps to fill the voids between the aggregates. As a result, the mixture will not be filled with plastic, which will cause the VIM value to rise again. As a result, incorporating 5% to 8% LDPE into the asphalt mixture may have an effect on the VIM value.

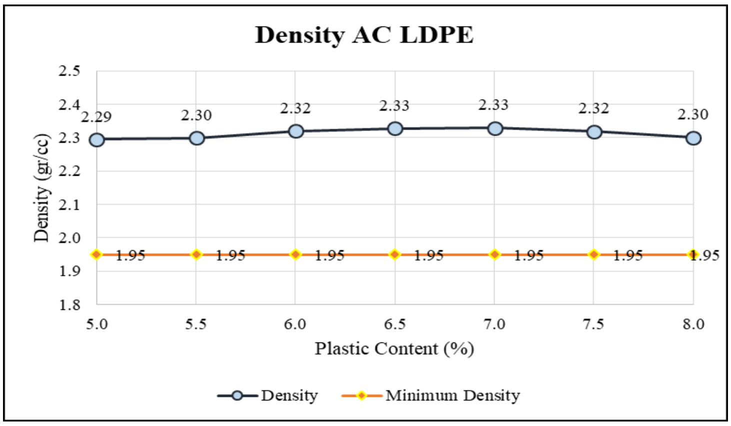

Fig. 2 Correlation between plastic content (%) and density (gr/cc)

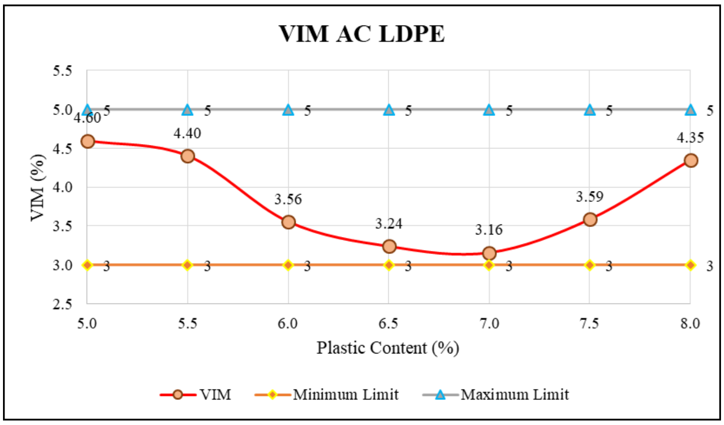

Fig. 3 Correlation between plastic content (%) and VIM (%)

3. Void in mineral aggregate (VMA)

The value of the VMA is affected when asphalt concrete mixes are added with LDPE, as seen in **Figure 4**. The change in VMA value is due to the plastic enveloping the aggregate and covering most of the voids between grains. Therefore, well-graded or tightly-graded aggregates affect the size of the VMA value.

4. Void in filled with asphalt (VFA)

In this test, the amount of plastic tends to make the VFA value go up. It means that the plastic bitumen is filling more spaces. However, when the VFA reaches its maximum, the value goes down. It means that there are fewer voids to fill with plastic bitumen and that the plastic bitumen covering the aggregate is thin. In this study, **Figure 5** shows the link between the amount of plastic and the VFA value. A high VFA value makes the asphalt-concrete mixture last longer by making it more durable, flexible, and resistant to cracking. When the amount of plastic in the AC-WC mixture increases, more holes fill with asphalt and plastic.

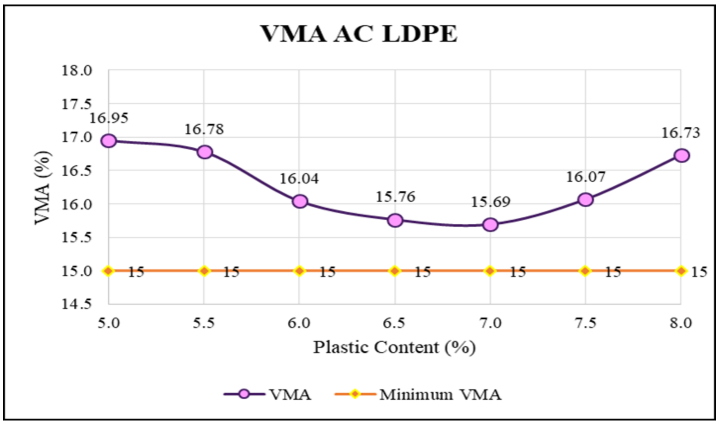

Fig. 4 Correlation between plastic content (%) and VMA (%)

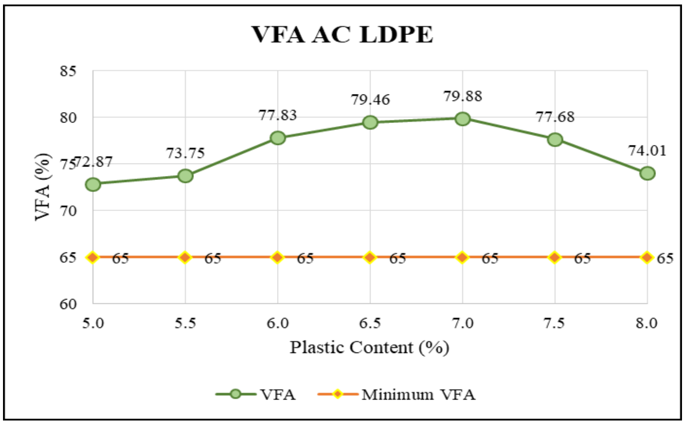

Fig. 5 Correlation between plastic content (%) and VFA (%)

5. Stability

The stability values for all different variations of plastic content fulfill the 2018 Bina Marga standards of a minimum of 800 kg since the correlation between plastic content and stability value in this research is shown in **Figure 6**. With the addition of LDPE, the most significant stability value achieved is 2103.44 kg with a plastic content of 7.5%. Because the plastic fills the gaps between the aggregates, the voids between the aggregates become much smaller and more compact, which contributes to the improvement in stability value. In addition to this, the particles that have been wrapped in plastic asphalt work well together. Because it is difficult to move the aggregate from its location before loading. The aggregate gradation, the quantity of asphalt present, the level of compaction, the temperature, and the amount of plastic present all have a significant impact on the stability value of this combination. AC-WC that have high values for their stability will be able to handle significant amounts of traffic load [2]. According to the findings, the ideal amount of plastic achieved in the AC-WC combination is 7.5%.

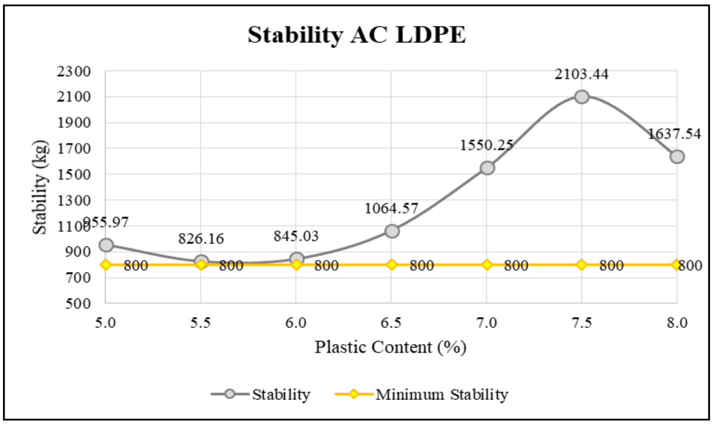

Fig. 6 Correlation between plastic content (%) and stability (kg)

6. Flow

Figure 7 shows the relationship between the plastic content and the flow value in this study. From this, the flow value for all the different plastic content meets the 2018 Bina Marga specifications, which are between 2 and 4 mm. With the addition of plastic, the flow value of the mixture changes. It depends on how much plastic is in the mixture, how good the asphalt is, and the compaction process. The increase in flow value at 5.0% to 6.5% plastic content makes the mixture more elastic. The plastic in the asphalt mixture is increasing and can fill the spaces in the mixture. **Figure 7** also shows that the plastic content of 5.5% has a flow value close to the required minimum limit. It makes it possible that the mixture will become stiff, making the pavement more likely to crack.

7. Marshall Quotient (MQ)

Figure 8 shows that the MQ value of the LDPE fluctuates due to changes in the flow value. Samples with a plastic content of 6.5% to 7.5% tend to raise the MQ value. It is because the higher plastic asphalt mixture causes an increase in the binding of asphalt with aggregate, which in turn, makes the mixture more rigid. **Figure 8** also demonstrates that when the amount of plastic in a mixture grows, it is more likely to have a lower MQ value. It means that the mixture is more likely to become plastic and possibly deformed as the number of plastic increases.

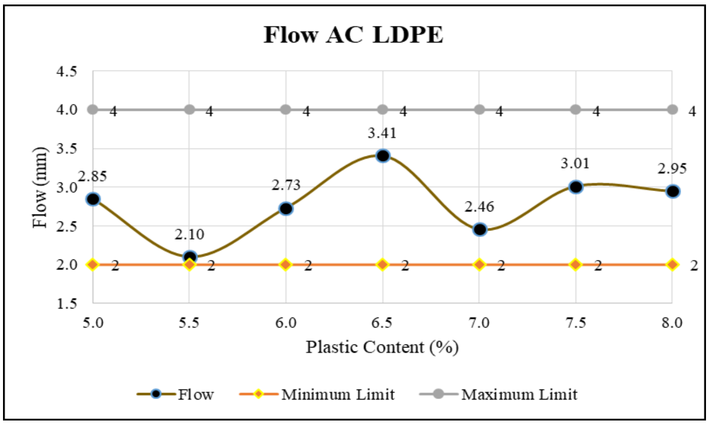

Fig. 7 Correlation between plastic content (%) and flow (mm)

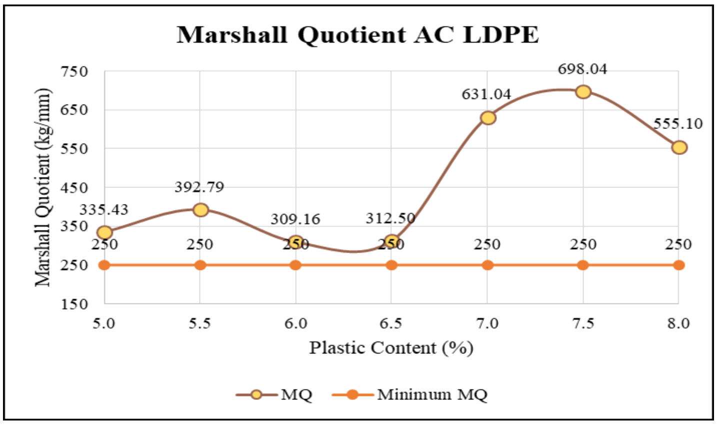

Fig. 8 Correlation between plastic content (%) and MQ (mm)

3.2 Optimum plastic content

Table 2 summarizes the main parameter findings for asphalt concrete mixes using LDPE. According to the results in Table 2, the ideal amount of plastic in this experiment is 7.5%. The asphalt mixture was then subjected to further testing with plastic at several percentages, which are 7.25% and 7.75%. It was done to substantiate and enhance the findings of the tests that were acquired earlier. Table 2 provides a side-by-side comparison of the mixture properties created with LDPE concentrations of 7.25%, 7.50%, and 7.75%.

According to the analyses shown in Table 2 and Table 3, all of the different variations of the plastic content found in the AC-WC combination met the parameters established by Bina Marga. Because the AC-WC mixture with 7.5% plastic content has the best stability value compared to the usage of other plastic content, the value of 7.5% plastic content has been determined to be the optimal value for this study's investigation into the optimal plastic content value. Compared to the previous findings [7], the optimum plastic content value of 7.5% shows a difference that is 0.05% higher. According to the findings of the various tests carried out, the incorporation of 7.5% optimum plastic content into the asphalt not only successfully enhances the quality of the AC-WC mixture but also boosts the mixture's stability value.

Table 2. Recapitulation of AC LDPE Marshall Parameter Results

Testing	Specification	Plastic Content						
		5%	5.5%	6%	6.5%	7%	7.5%	8%
Stability	> 800 kg	955.97	826.16	845.03	1064.57	1550.25	2103.44	1637.54
Flow	(2 - 4) mm	2.850	2.103	2.733	3.407	2.457	3.01	2.95
VIM	(3 - 5) %	4.60	4.40	3.56	3.24	3.16	3.59	4.35
VMA	> 15 %	16.95	16.78	16.04	15.76	15.69	16.07	16.73
VFA	> 65 %	72.87	73.75	77.83	79.46	79.88	77.68	74.01
QM	> 250 kg/mm	335.43	392.79	309.16	312.50	631.04	698.04	555.10

Table 3. Comparison of Characteristics of AC-WC Mixtures with LDPE 7.25%, 7.50%, and 7.75%

No	Characteristics	LDPE 7.25%	LDPE 7.5%	LDPE 7.75%
1	Density (gr/cc)	2.32	2.32	2.31
2	VIM (%)	3.44	3.59	4.04
3	VMA (%)	15.94	16.07	16.46
4	VFA (%)	78.41	77.68	75.46
5	Stability (kg)	1598.48	2103.44	1926.83
6	Flow (mm)	3.55	3.01	3.15
7	Marshall Quotient (kg/mm)	450.70	698.04	611.69

3.3 Analysis of the relationship between the optimal asphalt content and the optimum plastic content

According to the findings of previous and current research, the AC-WC containing LDPE has a variety of optimal asphalt and plastic contents. The discrepancy might be attributed to the quality of the materials used until the compaction stage. The optimal asphalt and plastic content values, respectively, have been determined to be 6.5% and 7.5% for this study. These results are more significant than the values obtained in previous studies. Based on the findings of the Marshall tests, we'd like to see if there was a possibility that the the optimal plastic content was related to the optimal asphalt content or not. So, we're using the regression analysis as determined by both the present study and this research. The correlation between asphalt and plastic content, as determined by both the present study and earlier studies, is shown in **Figure 9**. We can observed that the data obtained is really scattered.

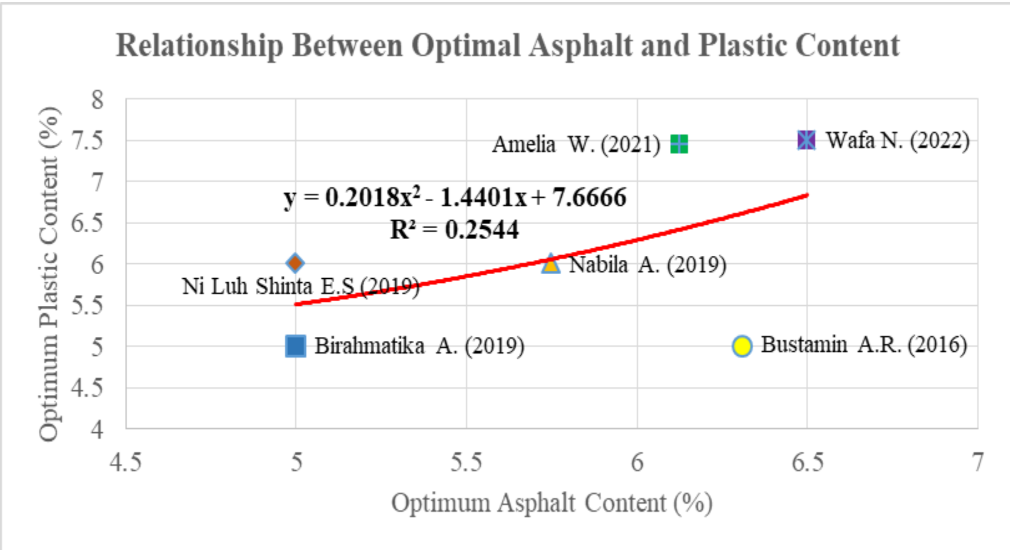

Fig. 9 Correlation between optimal asphalt content (%) and optimal plastic content (%)

Based on the collected data, it is difficult to determine the correlation between optimum asphalt content and optimum plastic content due to the extremely scattered data. Regression yielded the equation $y = 0{,}2018\,x^2 - 1{,}4401x + 7{,}6666$ and an R^2 value of 0.2544 The R^2 value produced is very low, this equation is not representative and cannot serve as a reference for further investigation. As a result, estimating the optimum plastic content only based on the optimum asphalt content is not suggested, as there are numerous other deciding elements such as asphalt type, aggregate gradation, material physical properties, and the compaction method.

4 Conclusion

Based on the laboratory analysis of test data findings, the utilization of LDPE (Low Density Polyethylene) as an additive of AC-WC can be conclude that:

1. The optimal asphalt content value for using LDPE on AC-WC properties is 6.5%, and the optimal plastic content value is 7.5%.
2. The addition of 7.5% LDPE has produced stability and flow values of 2,103.44 kg and 3.01 mm, respectively. Based on the results, the AC-WC combination with 7.5% LDPE has superior stability and MQ values than AC-WC without LDPE.
3. Adding 7.5% LDPE may raise the stability value by a factor of two and lower the asphalt content by up to 7.05% compared to the mixture without LDPE.
4. According to the evaluation of curernt and previous study, estimating the optimum plastic content only based on the optimum asphalt content is not suggested, as there are numerous other determining factors.

References

[1] I. Susanto dan N. Suaryana, "Evaluasi Kinerja Campuran Beraspal AC-WC dengan Bahan Tambah Limbah Plastik Kresek [Performance Evaluation of AC-WC Asphalt Mixture Added with Plastic Bags Waste]," *Jurnal Aplikasi Teknik Sipil,* vol. Vol. 17 No. 2, Agustus 2019.

[2] A. e. a. Gaus, "Karakteristik Marshall Campuran Aspal Beton Menggunakan Limbah Plastik [Characteristics of Asphalt Concrete Mixtures Containing Plastic Waste]," *Journal of Science and Engineering,* vol. Vol. 3 No. 2, Oktober 2020.

[3] B. K. PUPR, "Kementerian PUPR Lanjutkan Ujicoba Penggunaan Aspal Campuran Limbah Plastik [PUPR Ministry Continues Trials on the Use of Plastic Waste Mix Asphalt]," Jakarta, 2017.

[4] N. L. S. E. Setyarini, A. N. Tajudin dan J. Pratama, "Karakteristik Marshall Lapisan Aus Aspal Beton Menggunakan Agregat Terselimuti Limbah Plastik LDPE [Marshall Properties of Asphalt Concrete Using Aggregates Covered with LDPE]," *Jurnal Muara Sains, Teknologi, Kedokteran, dan Ilmu Kesehatan,* vol. Vol. 3 No. 1, no. ISSN 2579-6402, pp. pp. 123-136, April 2019.

[5] S. Fitri, S. M. Saleh dan M. Isya, “Pengaruh Penambahan Limbah Plastik Kresek Sebagai Substitusi Aspal Pen 60/70 Terhadap Karakteristik Campuran Laston AC-BC [The Effect of Adding Plastic Waste as a Substitute for Pen 60/70 Asphalt on the AC-BC Mixture],” *Jurnal Teknik Sipil*, vol. Vol. 1 No. 3, no. ISSN 2088-9321, pp. pp. 737-748, Januari 2018.

[6] A. F. Muqoddam, “Pemanfaatan Limbah Plastik PET (Polyethylene Terephthalate) Pada Campuran AC-BC Sebagai Inovasi Eco Material [Utilization of PET (Polyethylene Terephthalate) in AC-BC Mixture as an Eco Material Innovation],” Surabaya, 2018.

[7] A. Wijayanti dan I. F. Radam, “Pengaruh Penambahan Limbah Plastik Terhadap Karakteristik Campuran Aspal AC-WC [Effect of Plastic Waste Addition on AC-WC Asphalt Mixture Characteristics],” *Jurnal Rivet,* 2021.