

Analysis of the influence of additional plastic waste (HDPE) as Mixed Asphalt AC-WC on Marshall Parameters

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ABSTRACT

Flexible pavement structures that use asphalt as a binder are currently the mainstay of the Indonesian people because of their large load-bearing capacity and economical construction costs. One type of flexible pavement used is asphalt concrete with the top surface layer or Asphalt Concrete Wearing Course (AC-WC). The use of asphalt from the petroleum refining process is one of the problems because its availability is decreasing. However, the condition of the road pavement which has a limited life requires periodic repairs to maintain the condition of the road. In addition, there are also problems regarding the processing of plastic waste which is still not optimal. Based on data published by the National Waste Management Information System in 2020 as much as 18.3% of the total waste generated. This figure increased by 2.3% from the previous year. Sukoharjo Regency also experienced an increase in sales of plastic waste by 1.16% from 14.04% (in 2019) and now to 15.20% (in 2020). Plastic is one type of polymer in the thermoplastic polymer group which is processed by organic chemical compounds. One type of plastic that is often used is High Density Polyethylene (HDPE) which has strong, light and flexible properties that can soften at a temperature of 130-137°C and harden again if. In this study, HDPE plastic bag waste was used as a pure asphalt substitute with variations in the proportion of substitution of 2%, 4%, 6%, 8%, 10%. Where this study aims to analyze the effect of adding HDPE plastic waste as a mixture of AC-WC asphalt on asphalt parameters. From the research conducted, the use of asphalt content of choice is 5.7%. With the results of the mixture with HDPE asphalt mixture HDPE has increased with the addition of variations of HDPE. The flexibility of HDPE asphalt mixture decreased according to the flow meter reading. At a content of 2% HDPE has the largest percentage of VIM, flow, and proportion of VMA, but has the lowest value and percentage of VFB. The best range of HDPE content is in the percentage of 4%-6% because it can increase the value of a more flexible mixture and optimal asphalt absorption. The use of HDPE plastic waste is an alternative in waste treatment and can reduce the use of asphalt. It can be concluded that HDPE plastic bags can be used as an alternative to bitumen substitutes that meet the requirements of Bina Marga 2018 Revised 2nd Edition.

Keyword: asphalt concrete wearing course (ac-wc); high density polyethylene (HDPE); marshall parameters.

INTRODUCTION

Flexible pavement structure is a type of highway pavement commonly used in Indonesia which is formed from a mixture of aggregate with asphalt as a binder. The flexible pavement structure has several layers with different mixtures and functions of each layer lining the road. (Bonner, 2001). Asphalt concrete layer (laston) or commonly referred to as asphalt concrete is one of the commonly used types of asphalt concrete which has three kinds of mixtures with the top mixture in the form of Asphalt Concrete Wearing Course (AC-WC) with a maximum aggregate size of 19 mm and a minimum nominal thickness. 4 cm with bitumen adhesive. The type of asphalt commonly used in Indonesia is asphalt pen 60/70 (Sukirman, 2016). The large load carrying capacity and economical construction and maintenance costs make this type of pavement a mainstay in road construction.

The pavement structure is designed using materials that can produce high stability values to prevent damage to the road. With a high stability value, the service value both in terms of strength and attractiveness between aggregates can be increased. However, the increasing burden of motorized vehicles, repeated weather changes and the lack of maintenance funds can accelerate road damage. It is necessary to improve the quality of the road pavement with efforts to increase the stability value of the asphalt mixture (Hadid, 2020). Based on data published by the Central Bureau of Statistics of Central Java Province in 2015 along 696 km of roads in Sukoharjo Regency using paved roads, with 172 km of paved roads in good condition, 209 km of moderate conditions, 167 km of damaged, and 57 km of heavily damaged. When compared with the existing road conditions in the surrounding districts, Sukoharjo district needs to improve the quality of the road pavement. Besides that, there are also problems regarding the accumulation of waste in Indonesia. Based on data published by the National Waste Management Information System, the presence of plastic waste reaches 17.8% of the total waste generated per year 2020. In Central Java alone, the total pile of plastic waste generated in 2020 is 18.3% of the total waste generated. This figure increased by 2.3% from the previous year. Sukoharjo Regency also experienced an increase in the accumulation of plastic waste by 1.16% from 14.04% (in 2019) and now to 15.20% (in 2020). The Sukoharjo Regency Regional Research and Development Planning Agency in 2017 stated that as much as 30.62% of the total waste was plastic waste. Where plastic is a processed product of organic chemical compounds such as carbon, oxygen and non-metallic elements (O, N, Si) which can melt when heated at a certain temperature and harden again when cooled. Thermoplastic polymers can be PE (Polyethylene), PP (Polystyrene), PVC (Poly Vinyl Chloride) and others. HDPE (High Density Polyethylene) is a type of PE thermoplastic polymer which has light, strong and flexible properties and is easily soluble in suitable solvents and can soften at a temperature of 130-137°C but can harden when cooled (Bambang Admadi, 2015). The characteristics of HDPE can be seen in the table below:

Table 1. Characteristics of High Density Polyethylene (HDPE) Plastic

Parameter	Value
Density	0,958 gr/cm ³
Viscosity	380 ml/gr
Softening Point	67°C
Melting Temperature	127°C

Source: Bambang Admadi, 2015.

Tabel 2. Previous Research

Researcher Name	Research Title	Research result
Anita Rahmawati	The Effect of Using Polyethylene (PE) and High Density Polyethylene (HDPE) Plastics on Lataston-WC Mixtures on Marshall Characteristics (2015)	The use of polymer types of PE and HDPE with levels of 0%, 2%, 4% and 6% as a partial replacement for bitumen with the conclusion that the use of HDPE in asphalt mixtures gives better results of marshall characteristics than the use of PE.
Okky Hendra H, Nurdiana Yusuf, Isradias Mirajhusnita, Teguh Haris, Weimintoro	Effect of HDPE (High Density Polyethyleme) Type Waste on AC-WC Asphalt Layer	The type of polymer used is HDPE with levels of 5%, 7.5% and 10%. Asphalt concrete with HDPE added can improve the quality of the mixture. The best AC-WC asphalt stability value was obtained with the addition of 5% plastic

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Alternative to Polymer
Modified Asphalt by Using
Food Packaging Plastic Waste

The use of food packaging plastic waste at the optimum asphalt content with variations of 0%,1%,2%,3%,4% shows the optimum polymer content at 0.5% and a maximum of 1% and has a higher stability value than the asphalt mixture without added material.

Concrete with additional mixed forms will affect the compressive strength of the concrete. The influential concrete compressive strength is a mixture with mixing levels according to standard calculations. Concrete standards must be designed according to good requirements. The need for normal concrete and the need for concrete with additional additives will affect the compressive strength (Bachtiar E et.al, 2022; Rulhendri R et.al, 2013; Sutarno S et.al, 2021; Nugroho SA et.al, 2021; Priastiwati YA et.al, 2021).

RESEARCH METHODS

The research conducted by the author uses an experimental method by analyzing the utilization of HDPE (High Density Polyethylene) plastic waste in the AC-WC asphalt mixture using the Marshall Test method based on the 2018 General Specifications for Road and Bridge Construction Works Revised Edition 2, with a variation ratio of 2%, 4 %, 6%, 8% and 10%. The number of samples to be made is 3 samples of test objects for each variation. The type of asphalt used is the type of asphalt Pertamina pen 60/70. This research method can be seen in full in the flow chart in Figure 1.



Figure 1. Flowchart of Research Methods

RESULTS AND DISCUSSION

The first step is to test the physical properties of the aggregate that will be used in the study. This is intended to determine the characteristics of the aggregate that will be used to determine the percentage of aggregate fraction. The weight of the saturated surface test object (SSD) is 500 grams, the dry weight of the test object is 491.2 grams, the weight of the pycnometer and water is 1291.1 grams, the weight of the pycnometer is filled with water and the test object is 1601.3 grams. Performed calculations with the following formula:

$$\text{Specific gravity SSD} = \frac{a}{c+a-d} \quad (1)$$

$$= \frac{500}{1291.1+500-1601.3}$$

a = Weight of saturated surface test object (SSD)

c = Weight of pycnometer + water

d = Weight of pycnometer + water + test object

The results of physical properties testing for coarse aggregate and fine aggregate are shown in Table 3 below.

Table 3. Results of Aggregate Physical Properties Testing

No	Test Type	Results (%)	Standard
1) Fine aggregate			
1	Bulk Density	2.588	SNI 1970:2008
2	Saturated Surface Dry Specific Gravity (SSD)	2.634	
3	Apparent Density (Apparent)	2.714	
4	Absorption	1.792	
2) Coarse aggregate			
1	Bulk Density	2.606	SNI 1969:2008
2	Saturated Surface Dry Specific Gravity (SSD)	2.645	
3	Apparent Density (Apparent)	2.711	
4	Absorption	1.499	
5	Abrasion	26.85	SNI 2417:2008

The aggregate sieve analysis test based on SNI ASTM C136:2012 resulted in an analysis of the percentage distribution of aggregate grains which can be seen in Table 4. Combined Gradation is the sum of the percentages of each sieve in each fraction.

Table 4. Combined gradation table

No Filter	Size Filter (mm)	Original Gradation				Gradation Combined	Specification	
		F1 stone ash	F2 0-5	F3 1-2	F Cement		Min.	Max.
1"	25	100,00	100,00	100,00	100,00	100,00	100	100
3/4"	19	100,00	100,00	100,00	100,00	100,00	100	100
1/2"	12,7	100,00	100,00	59,32	100,00	92,27	90	100
3/8"	9,5	100,00	100,00	6,29	100,00	82,19	77	90
#4	4,75	98,36	39,88	0,67	100,00	58,76	53	69
#8	2,36	83,65	9,74	0,53	100,00	41,41	33	53
#16	1,18	54,89	4,66	0,47	100,00	26,92	21	40

#30	0,6	36,28	3,57	0,44	100,00	18,34	14	30
#50	0,3	25,87	3,16	0,42	100,00	13,60	9	22
#100	0,15	15,34	2,64	0,38	100,00	8,77	6	15
#200	0,075	9,87	2,13	0,34	99,86	6,18	4	9
A. F1						44,0%	CA :	41,24
Proportion B. F2						36,0%	FA :	52,59
Asphalt total C. F3						19,0%	FF :	6,18

The calculation of the gradation combination gets results that can be used to determine the percentage of aggregate content. With the results of the combination of aggregates must be in accordance with the standards and displayed in the aggregate graph for AC-WC asphalt. The use of coarse aggregate (CA) is 41.24% and Fine Aggregate (FA) is 52.59%. The aggregate gradation graph can be seen in Figure 2.

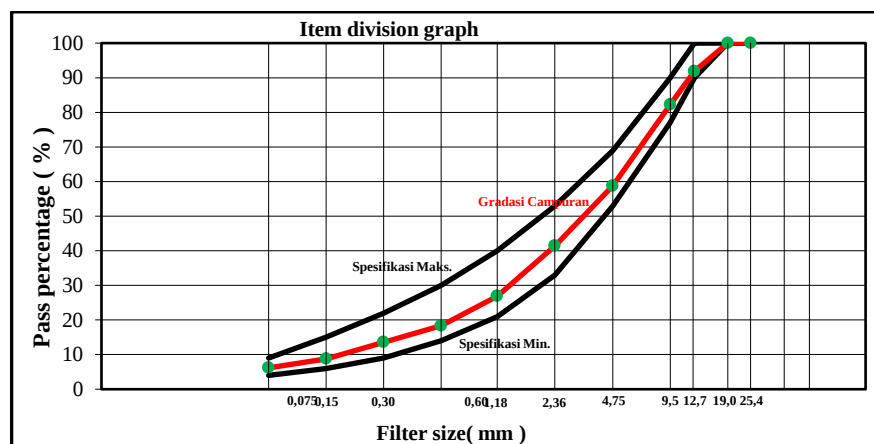


Figure 2. Graph of the division of aggregate grains

Based on the aggregate grain distribution test, the theoretical optimum asphalt content (Pb) was calculated based on the Bina Marga regulations with the following formula.

$$\begin{aligned}
 Pb &= (0.035 \times \%CA) + (0.045 \times \%FA) + (0.18 \times \%FF) + K \quad (2) \\
 &= (0.035 \times 41.24) + (0.045 \times 52.59) + (0.18 \times 6.18) + 0.5 \\
 &= 5.422\%
 \end{aligned}$$

$$K = \text{Constant AC-WC } 0.5 - 1$$

So it can be concluded to estimate the optimum asphalt content of 5%; 5.5%; 6%; 6.5%; and 7%. The test specimens were made with three briquettes for each variation to obtain the optimum asphalt content to be used in the innovation asphalt mixture.

Research conducted on 5 variations of asphalt content obtained stability values, VIM (Void in Mix) or the value of voids in the aggregate and asphalt mixture, VFA (Void Filled with Asphalt) or the value of voids filled with asphalt, and VMA (Void in Mineal Aggregate) or the value of the voids contained in the aggregate of each test object made. The test results can be shown in Table 4.

Table 4. Calculation of briquettes of asphalt content variations

No	% Asphalt content	BJ	BJ.	%	%	%	Kadar	stability		Flow
		Max.	Bulk	cavity	cavity	cavity	Asphalt	needle	burden	
		combined	Camp.	air	Between Aggregate	Asphalt	Effective	reading	(Kg)	
1	5,00	2,442	2,316	5,16	15,19	66,02		101	1356,43	2,60
2			2,307	5,53	15,52	64,39		96	1289,28	3,30

3			2,320	5,02	15,07	66,67		104	1396,72	3,00
			2,315	5,24	15,26	65,69	4,49		1347,48	2,97
1	5,50	2,425	2,328	3,98	15,20	73,79		96	1289,28	3,00
2			2,323	4,18	15,38	72,80		93	1248,99	3,20
3			2,321	4,30	15,48	72,25		90	1208,70	3,40
			2,324	4,15	15,35	72,94	4,99		1248,99	3,20
1	6,00	2,408	2,337	2,93	15,33	80,90		90	1208,70	3,90
2			2,330	3,21	15,57	79,41		89	1195,27	4,20
3			2,338	2,88	15,28	81,18		86	1154,98	4,40
			2,335	3,00	15,40	80,50	5,50		1186,32	4,17
1	6,50	2,391	2,336	2,30	15,83	85,47		86	1154,98	4,30
2			2,332	2,47	15,98	84,54		80	1074,40	4,80
3			2,333	2,41	15,93	84,89		84	1128,12	4,60
			2,333	2,39	15,91	84,97	6,00		1119,17	4,57
1	7,00	2,374	2,320	2,27	16,85	86,50		82	1101,26	4,30
2			2,317	2,38	16,94	85,96		79	1060,97	5,00
3			2,324	2,10	16,70	87,42		85	1141,55	4,50
			2,320	2,25	16,83	86,63	6,51		1101,26	4,60
Limitation			3,0 - 5,0	min 15	min 65				min 800	2,0 - 4,0

The conversion value from the stability dial reading to the load calculation can be found from the following formula

$$\text{Load (Kg)} = \text{Dial reading} \times \text{Unit conversion rate} \quad (3)$$

$$= 101 \times 13.43$$

From the research and calculation of briquettes of 5 variations in asphalt content, it can be seen that the mixture is in accordance with the Specifications of Highways 2018 Revised Edition 2 which can be seen in Figure 2.

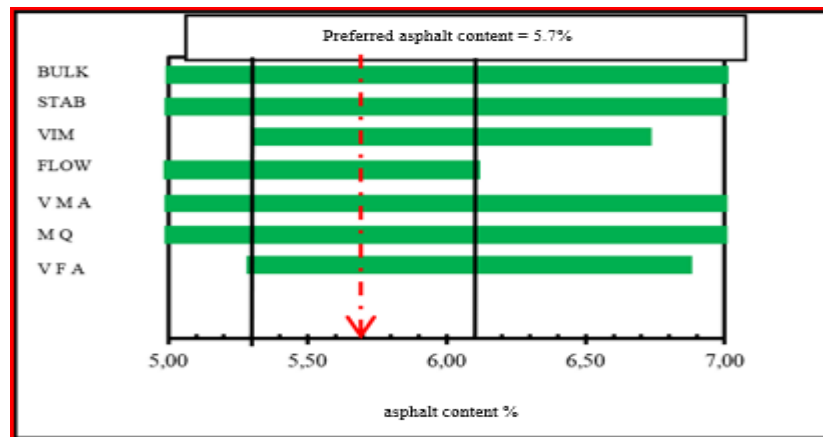


Figure 3. Graph of asphalt content determination

In Figure 3 it is shown that the preferred asphalt content for the manufacture of asphalt mixtures with HDPE added is 5.7%.

In the manufacture of asphalt mixture test specimens with variations in the addition of HDPE materials of 2%, 4%, 6%, 8%, 10% as many as 3 briquettes in each variation, the results can be seen in the table below.

Table 5. Calculation Results of Asphalt with HDPE added material

No	% Contentr mix.. Total	% Content HDPE	BJ Max. mix	BJ. Bulk mix	% VIM	% VMA	% VFB	Stability		Flow
								Needle reading	Burden (Kg)	
1	5,70	2,00	2,430	2,344	3,53	15,13	76,70	88	1181,84	3,40
2				2,340	3,70	15,28	75,81	80	1074,40	3,90
3				2,343	3,58	15,18	76,42	85	1141,55	3,60
				2,343	3,60	15,20	76,31		1132,60	3,63
1	5,70	4,00	2,430	2,343	3,58	15,18	76,39	89	1195,27	3,40
2				2,342	3,63	15,22	76,17	85	1141,55	3,60
3				2,349	3,32	14,95	77,78	96	1289,28	3,20
				2,345	3,51	15,12	76,78		1208,70	3,40
1	5,70	6,00	2,430	2,345	3,51	15,12	76,76	87	1168,41	3,60
2				2,350	3,31	14,94	77,84	101	1356,43	3,20
3				2,347	3,40	15,02	77,35	90	1208,70	3,30
				2,347	3,41	15,03	77,32		1244,51	3,37
1	5,70	8,00	2,430	2,352	3,22	14,86	78,35	98	1316,14	3,30
2				2,349	3,33	14,96	77,74	82	1101,26	3,50
3				2,352	3,23	14,87	78,28	101	1356,43	3,20
				2,351	3,26	14,90	78,12		1257,94	3,33
1	5,70	10,00	2,430	2,354	3,12	14,77	78,89	102	1369,86	3,40
2				2,351	3,26	14,89	78,12	90	1208,70	3,60
3				2,356	3,05	14,71	79,28	104	1396,72	2,90
				2,354	3,14	14,79	78,76		1325,09	3,30
Limitation					3,0 - 5,0	min 15	min 65		min 800	2,0 - 4,0

The calculation of the HDPE variants contained in Table 5 shows that the stability value increased by 6.7% at the addition of 4% when compared to the addition of 2% HDPE as well as the largest increase in stability compared to other percentage variations. with the addition of 6% HDPE, the stability value increased by 2% to the smallest percentage increase in stability in the variation of the mixture. The flow value obtained decreases with the addition of increasing variations of HDPE. The value of air voids and voids between the aggregates has decreased and the voids filled with asphalt have increased. The relationship between HDPE content and the parameters of the properties of the mixture is described as follows

1) HDPE Asphalt Specific Gravity

In Table 4. It is shown that the 2% plastic substitution produces an average density of 2,343, the 4% plastic substitution has an average of 2,345, the 6% substitution has 2,347, with 8% substitution has an average density of 2,351, and at 10% substitution of 2,354.

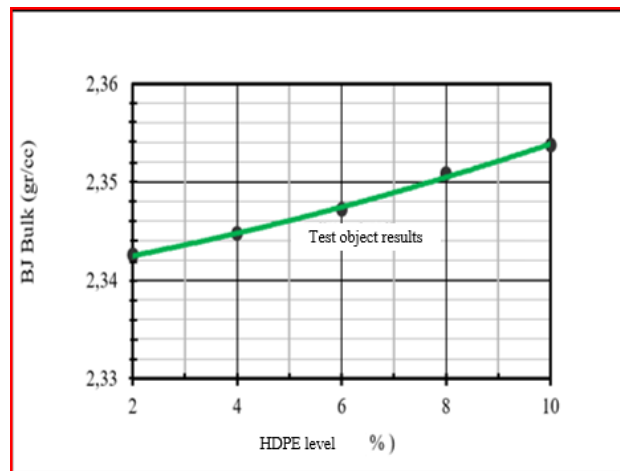


Figure 4. Graph of the relationship between asphalt content and bulk density

From the graph of the specific gravity shown in Figure 3, it can be seen that the HDPE asphalt mixture increases the value of the specific gravity of the mixture.

1) Void in Mix (VIM)

HDPE substitution has a VIM effect on asphalt mixtures with an average of 3.60 for 2% HDPE substitution, 3.51 for 6% HDPE substitution, resulting in an average VIM of 3.26 for 8% HDPE substitution, and 3.14 for 10% HDPE.

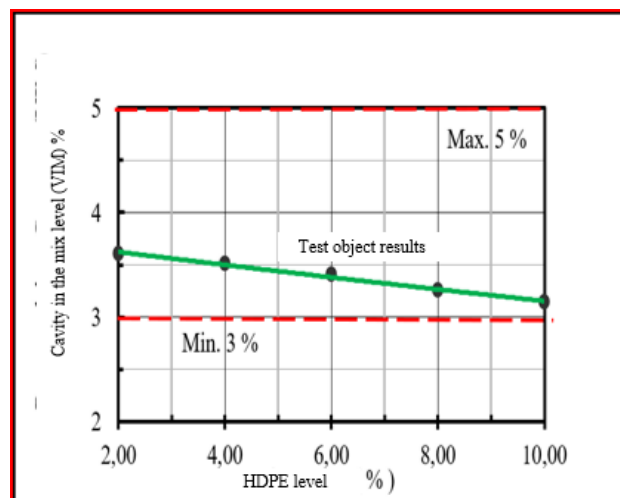


Figure 5. Graph of the relationship between VIM and HDPE variations

From Figure 4, it can be seen that the highest VIM value is found in 2% HDPE substitution, which is 3.6 and continues to decrease with each variation of the addition of HDPE. The lowest VIM value was obtained at 10% HDPE substitution of 3.14. Based on the General Bina Marga Specifications, the resulting VIM value is in accordance with the specifications.

1) Cavity in Aggregate/Void Mineral Aggregate (VMA)

The results of the VMA calculation in table 4 show that the largest VMA value is found in the 2% substitution of 15.20%, and the smallest VMA value is in the 10% HDPE substitution, which is 14.79%.

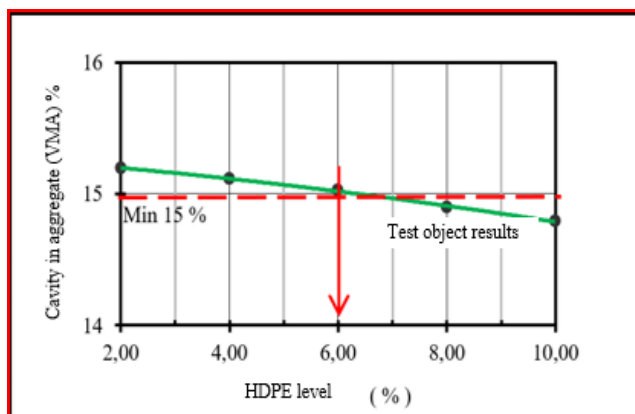


Figure 6. Graph of the relationship between VMA and HDPE variations

The requirements in the General Bina Specifications show that the minimum VMA value for laston is 15%. The optimum variation of HDPE substitution was obtained at a value of 6%. The more the number of HPDE substitutions, the lower the value of VMA

1) Cavity Filled Asphalt/Void Filled Bitumen (VFB)

The effect of HDPE substitution on AC-WC VFB can be seen in Table 4. 2% HDPE substitution produces an average VFB value of 76.31%, 4% substitution is 76.78%, 6% HDPE substitution is 77.32%, and HDPE substitution is 8% and 10% resulted in 78.12% and 78.76% VFB values, respectively.

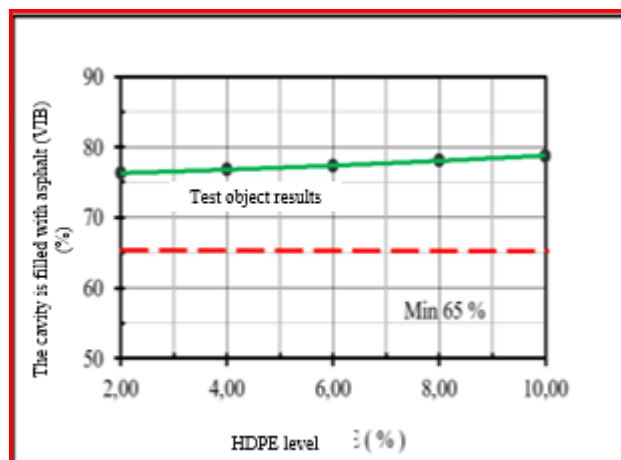


Figure 7. Graph of the relationship between VFB and HDPE variations

According to the requirements of the General Specification of Highways the VFB value must be >65%. So it can be concluded that the addition of HDPE plastic meets the applicable requirements.

1) HDPE Asphalt Stability

The results of stability testing for HDPE asphalt mixture with variations of 2% of 1132.60 Kg, 4% substitution of 1208.70 Kg, and for substitution of 6%, 8%, and 10% of 1244.51 Kg, 1257.94 Kg, and 1325.09 Kg.

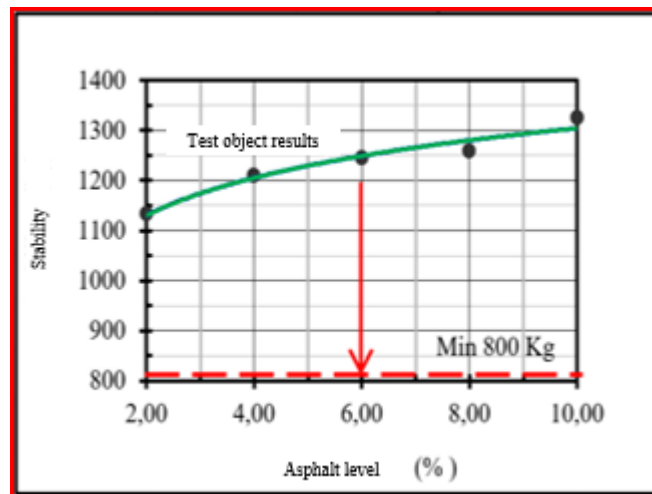


Figure 3. Graph of the relationship between asphalt stability values and variations in HDPE

From the test results and calculations obtained, the stability value of HDPE asphalt increases with the increase in HDPE content. Based on the General Specifications of Highways, the required stability value is at least 800kg for heavy traffic. So that all levels of HDPE variations used have met the requirements.

1) Flow

It can be seen in Table 4 that the flow value in the 2% asphalt variation has an average of 3.63 where this variation is the highest flow value. The value of flow decreased with the increase in HDPE content as in the 4% variation with a 6.3% decrease, the 6% variation decreased by 0.8%, and the 8% to 10% variation was 1%.

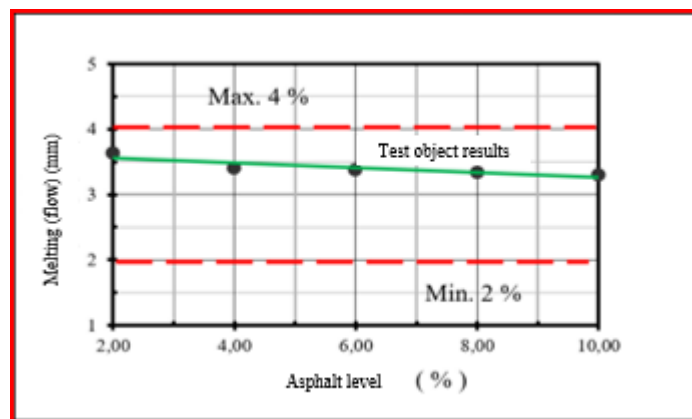


Figure 4. Graph of flow value relationship with variations in HDPE

Based on the General Specifications of Highways, the required flow value is at least 2 mm and the maximum value is 4 mm. The flow value shown from the graph above has met the requirements.

CONCLUSION

The increasing use of plastic bags as packaging containers causes the accumulation of garbage. This condition still requires good utilization. This study conducted an experiment in the utilization of HDPE plastic bag waste as bitumen substituent or pure asphalt in asphalt mixtures of Asphalt Concrete-Wearing Course (AC-WC) with variations in HDPE content of 2%, 4%, 6%, 8%, 10%. Based on the research conducted, it can be concluded that the selected asphalt content used in this study was 5.7%. The stability value of HDPE asphalt mixture increased with the addition of HDPE

variations. The flexibility of HDPE asphalt mixture decreased according to the flow meter reading. At a content of 2% HDPE has the largest VIM, flow, and VMA percentage, but has the lowest stability value and VFB percentage. The best range of HDPE content is in the percentage of 4%-6% because it can increase the stability value with a more flexible mixture and optimum bitumen absorption. The use of HDPE plastic waste is an alternative in waste treatment and can reduce the use of asphalt. It can be concluded that HDPE plastic bag waste can be used as an alternative to bitumen substitution that meets the requirements of Bina Marga 2018 Revised Edition 2.

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