The effect of High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) on characteristics of asphalt concrete with dry and wet mixing process

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The effect of High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) on characteristics of asphalt concrete with dry and wet mixing process

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Abstract. Plastic waste in Indonesia reaches 64 million tons per year which 3.2 million tons are disposed to the sea. Therefore, a solution is needed to solve plastic waste problem in Indonesia. The objectives of the study is to know the effect of using High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE) waste on characteristics of asphalt concrete AC - WC based on the Marshall Test, compare the characteristics produced based on dry and wet mixing process, and evaluate whether the test results fulfil Bina Marga Specification 2018. By the result of wet process, stability value of 7% HDPE increased up to 38.08% and 8% LDPE content increased up to 22.03% and for the dry process, 9% HDPE and 11% LDPE increase the stability value up to 24.61% and 19.30% respectively. The use of HDPE or LDPE can increase stability of asphalt concrete mixing both in dry and wet process. We can use up to 8.7 ton of plastic waste into 1 km of 7-meter-wide asphalt pavement road.

1. Introduction

Based on data from *Asosiasi Industri Plastik* Indonesia (INAPLAS) and Badan Pusat Statistik (BPS) 2018, plastic waste in Indonesia reaches 64 million tons per year which 3,2 million tons are disposed to the sea. Several studies have discussed about utilization of plastic waste in asphalt mixtures. Such pavements show enhanced properties and increased life spans, thus making the road construction economical and solving the environmental problem at the same time [1]. Plastic waste can be used as road construction material and is expected to be durable and more resistant to water [2]. The effect of polyethylene addition on flexible pavement resulted that 6% LDPE usage yield stability 11.7 kN which its value improved about 57.89% compared to conventional mixes of without plastic [3].

Daily, HDPE plastic type is usually found in detergent bottles, juice bottles, medicine packaging bottles, and some packaged milk products. Whereas the LDPE plastic type is widely used as food wrapping plastics, and supermarket plastic bags and have no economic value to be recycled.

2. Method and Materials

2.1. Sample preparation

2.1.1. Aggregates. The laboratory tests of aggregate refer to SNI 1969: 2008, SNI 1970:2008, and SNI 2417:2008.

2.1.2. Bituminous. Bitumen used in the experiment was 60/70 grade and the laboratory tests of bitumen refer to SNI 06-2456-1991, SNI 2441-2011, SNI 2432-2011, SNI 2434-2011, SNI 06-2433-1991, SNI 06-2433-1992.

2.1.3. Plastic. The laboratory test performed to evaluate the plastic waste property was specific gravity test.

2.2. Method

There are two processes for manufacturing bitumen mix for flexible pavement using plastic waste:

a) Dry Process

Plastic is mixed with the aggregates. The aggregate coated with plastics and this improved its quality with respect to voids, moisture absorption and soundness, and also decrease the porosity and helps to improve the quality of the aggregate and its performance in flexible pavement.

b) Wet Process

Plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and the ability of the bitumen to withstand high temperature [4]. The plastic waste is melted and mixed with bitumen in a particular ratio.

Marshall Test implemented to obtain the characteristic of asphalt mixture produced, namely stability, flow, VIM, VMA, VFA and MQ.

2.3. Specification

This study refers to Bina Marga Specification 2018. Characteristic required shown in Table 1.

Table 1. Bina Marga Specification 2018

Characteristic		**Asphalt Concrete Wearing Course**
Void in Mixture (VIM) (%)	Min.	3
	Max.	5
Void in Mineral Aggregate (VMA) (%)	Min.	15
Void Filled with Asphalt (VFA) (%)	Min.	65
Marshall Stability (kg)	Min.	1000
Flow (mm)	Min.	2
	Max.	4

3. Results and Discussion

3.1. Materials

3.1.1. Aggregates. The various tests are conducted in the laboratory and the results obtained are tabulated below in Table 2. It can be seen that the result of aggregates tests filled the requirements except absorption value of fine aggregate (≤ 3%), which is 3,62%.

Table 2. Result test of Aggregates

Tests	Standard	Coarse Aggregate	Fine Aggregate	Requirement
Bulk Specific Gravity (gr/cc)	SNI 1969: 2008 & SNI 1970:2008	2,5	2,58	≥ 2.5 gr/cc
Saturated Surface Dry (gr/cc)		2,535	2,93	
Apparent Specific Gravity (gr/cc)		2,605	2,83	
Absorption (%)		1,53	3,62	≤ 3%
Los Angeles Abrasion Value (%)	SNI 2417:2008	22,78		≤ 40%

3.1.2. Bituminous. Various tests conducted are penetration, specific gravity, ductility, softening, flash, and fire point. Tests are carried out to obtain the quality of bitumen used. Based on the result in Table 3, the bitumen used has filled the requirements or standard specifications.

Table 3. Result test of Bitumen

Tests	Standard	Result	Requirement
Penetration	SNI 06-2456-1991	66	60-70 mm
Specific Gravity	SNI 2441-2011	1,114	Min 1.0 gr/cc
Ductility	SNI 2432-2011	104,5	Min 100 cm
Softening Point	SNI 2434-2011	56	Min. 48° C
Flash Point	SNI 06-2433-1991	336	Min. 232° C
Fire Point	SNI 06-2433-1992	364	Min. 288° C

3.1.3. Plastic. Plastic is basically the polymer having long chain hydrocarbons and bitumen is a complex mixture of asphaltenes and maltenes which are also long chain hydrocarbon. The plastics used were low density polyethylene and high-density polyethylene which were cleaned and shredded.

Table 4. Result test of Plastic

Type of Plastics	Test	Value
HDPE	Gmm (Maximum Specific Gravity) (gr/cc)	0,92
LDPE	Gmm (Maximum Specific Gravity) (gr/cc)	0,88

3.2. Optimum Bitumen Content (OBC)

OBC test is conducted to obtain the optimum bitumen content that will be used for asphalt modifications. The value generated from each Marshall parameters is adjusted to the reference used, Bina Marga Specification 2018. The results of OBC test are shown in Table 5 below.

Table 5. Result test of OBC

Parameter	Bitumen Content					Requirements
	5%	5,5%	6%	6,5%	7%	
Stability (kg)	1135,76	1221,77	1235,32	1162,29	880,84	Min. 800
Flow (mm)	4,02	4,08	4,07	4,44	4,87	Min. 2 Max. 4
VIM (%)	3,95	3,64	3,44	3,20	2,13	Min. 3

						Max. 5
VMA (%)	18,19	17,82	15,77	16,19	18,90	Min. 15
VFA (%)	78,29	79,57	78,17	80,19	83,39	Min. 65
MQ (kg/mm)	291,17	296,78	304,75	261,27	181,08	Min. 250

Most of the characteristics have fulfilled the specification except flow. Based on the test that have been done, it can be concluded that 6% asphalt mixture has the highest stability value and filled the requirements except the flow.

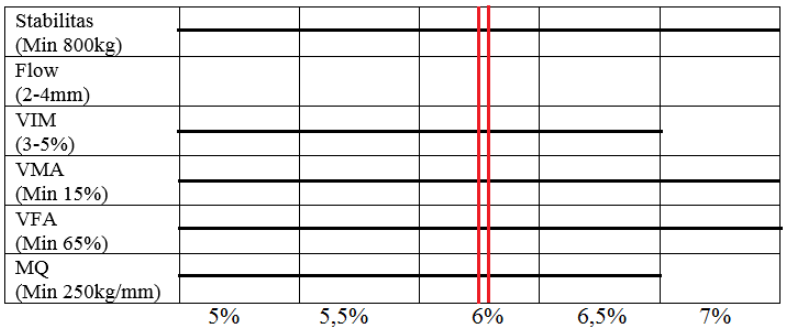

Figure 1. Optimum Bitumen Content (OBC)

3.2.1. Comparison Result. Based on the test that have been done, as the results that concluded and then compared are listed in Table 10. The value shown are the value with the highest stability of each type of plastic and certain plastic content.

Table 6. Comparison

Parameter	**KAO**	**Wet Process**				**Requirements**
	6%	LDPE 8%	HDPE 7%	LDPE 11%	HDPE 9%	
Stability (kg)	1235,32	1507,49	1705,76	1473,76	1539,31	
Flow(mm)	4,07	3,38	3,60	3,32	3,38	Max. 4
VIM (%)	3,44	3,34	3,44	3,32	3,42	Max. 5
VMA (%)	15,77	17,13	16,37	18,95	16,73	
VFA (%)	78,17	80,55	78,91	82,48	79,49	
MQ (kg/mm)	304,75	451,54	474,77	427,95	457,71	

In Table 10 shows the difference between the mixture without plastic and using both types of LDPE and HDPE by both mixing processes. Both dry and wet process, the quality and characteristic of asphalt mixes obtained are better than conventional mixes without plastic [2]. Hence, expected to be more durable. Based on research that have been done, mixing plastic using wet process has better result than dry process, and HDPE plastic mix has better stability value than LDPE. The improvement of stability in plastic modified asphalt mixes can be explained as a result of the better adhesion developed between bitumen and plastic coated aggregates due to intermolecular bonding, these intermolecular attractions enhanced strength of asphalt mix, which in turn help to enhance durability and stability of the asphalt mix [5].

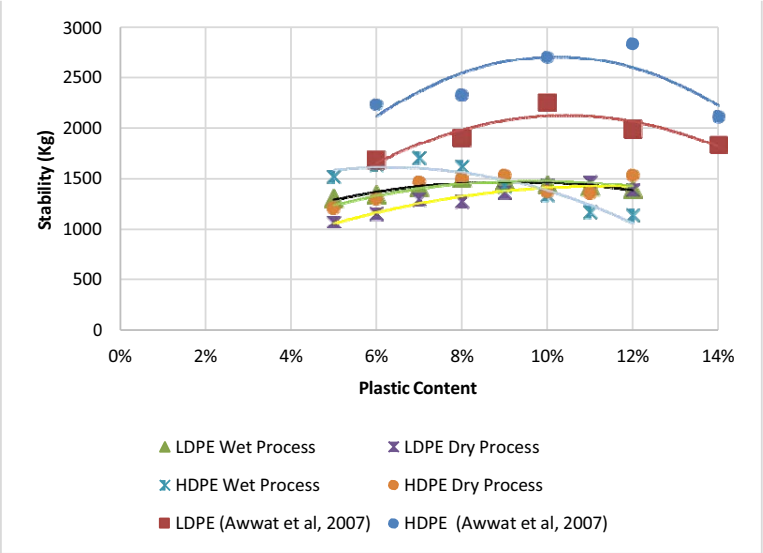

Figure 2. Stability comparison

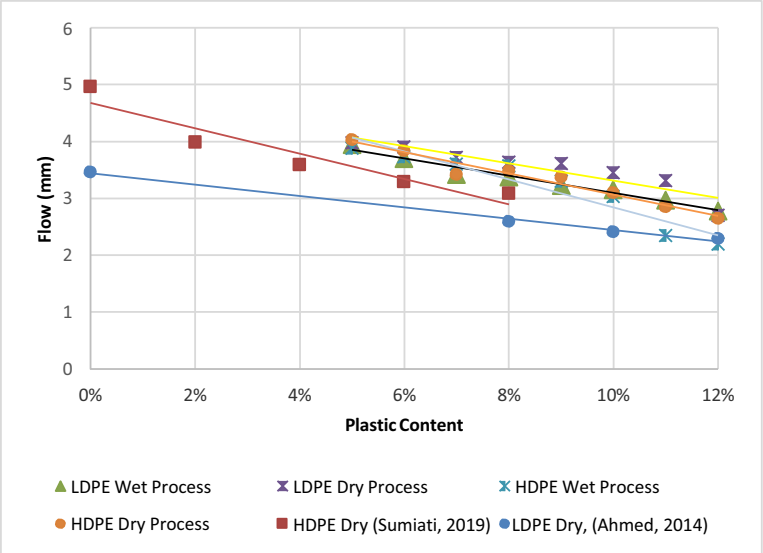

Figure 3. Flow comparison

The addition of plastic on asphalt mixture reduces flow value and produces stiffer mix. Addition of plastic causes the asphalt to become viscous and decreases its flexibility therefore flow of mixture decreases [6].

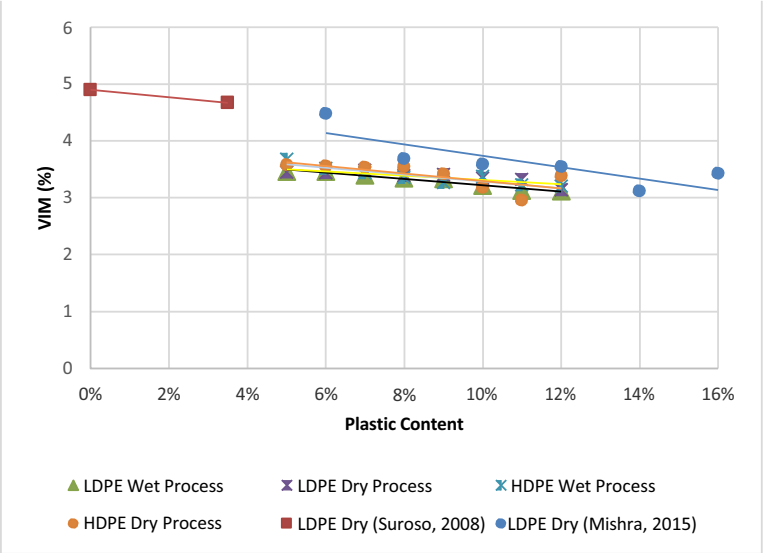

Figure 4. VIM comparison

VIM decreases due to increase in value of VFA due to addition of plastic [2]. The more plastic content fills the voids, the smaller voids left in the mixture which makes the VIM value decrease. VIM value decreased because of plastic addition on asphalt mixture increases the bonding ability to bind the aggregate minerals to make up the mixtures [7].

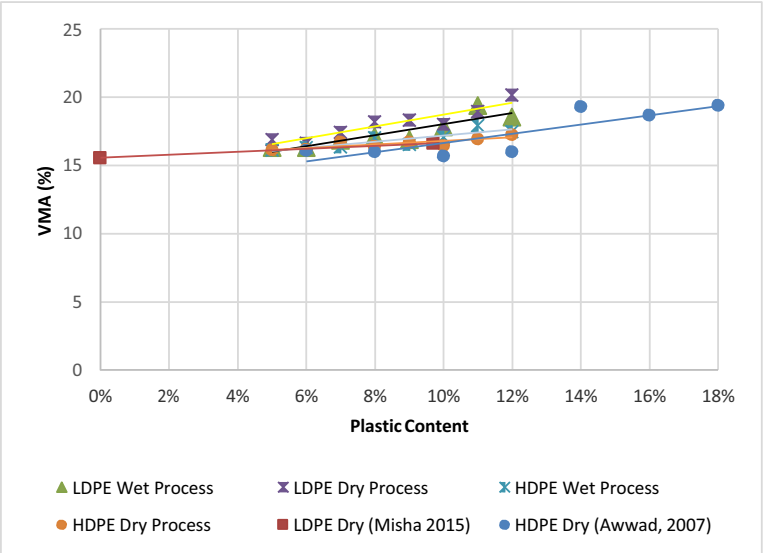

Figure 5. VMA comparison

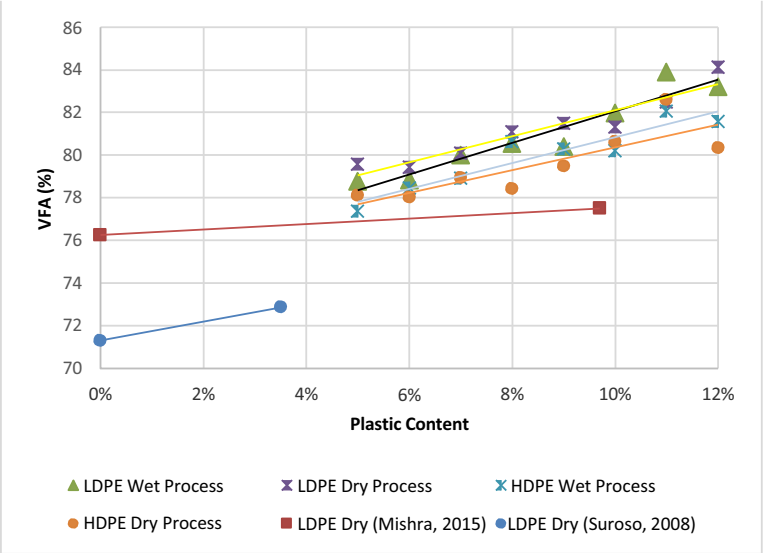

Figure 6. VFA comparison

VMA and VFA decreased due to addition of HDPE and LDPE. VMA increased due to plastic addition on asphalt mixes and became more viscos. One of the reasons the increase of VFA is due to the decrease in VIM, which a divisor in determining the value of VFA [6], [8].

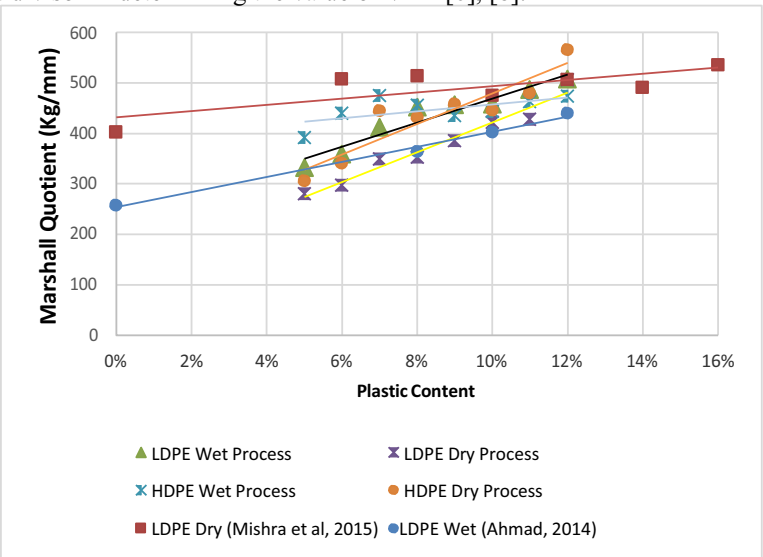

Figure 7. Marshall Quotient comparison

Marshall Quotient (MQ) also known as rigidity ratio. MQ is the ratio of stability to flow value of the mixture. MQ increases due to increment of stability while the flow value decreases compared to no plastic addition. The more plastic content added into the mixture, MQ value would increase because the increase of stability value while flow decreased. The higher MQ value, the stiffer the mixture is [6], [9]. If compared entirely, wet process shows have better results compared to conventional mix and dry process. It is because the mixing of plastic asphalt by wet process is more homogeneous so that all the added plastic is truly improve the performance of the asphalt mixture especially its stability. The plastics show adhesion property in their molten state. Plastics will increase the melting point of the bitumen.

Hence, the use of waste plastics for pavement is one of the best methods for easy disposal of waste plastics. Moreover, plastic is not recyclable and using them in road construction will help in the disposal of these plastic wastes in an eco-friendly manner [1], [2].
As mentioned, wet process shows better performance compared to dry process with optimum content of 9% HDPE. 1 km road with assumption of 7m wide, 10cm thickness, OBC 6% and maximum specific gravity 2.300 kg/m3, then the volume for asphalt mixture can be calculated by multiplying the length, width, and the thickness of the road = 1 km (1000) x 7 m x 10 m (0.01) = 700 m3. By obtaining the volume, multiply the maximum specific gravity to obtain the weight value of the mixture = 700m3 x 2.300 kg/m3= 1.610.000 kg.
For 6% OBC, the amount of asphalt requirements in the mixture is 1,610,000 kg x 6% = 96,600 kg for 1 km of road pavement. The need for HDPE plastic with 9% content of the weight of asphalt is 96,600 kg x 9% = 8,694 kg or 8.7 tons of waste plastic needed per 1 km.

4. Conclusion

Based on the study and experimental data for waste plastic modified bituminous concrete mix compared with conventional bituminous concrete mix, the following conclusions can be drawn:
a) The addition of HDPE and LDPE plastic affected the Marshall characteristics by increasing the stability value, decreasing the flow and VIM, and increasing the VMA, VFA and MQ;
b) Wet process showed higher stability value, it is likely because wet process produced more homogeneous result than dry process, which:

- The optimum addition of HDPE by wet process is 7% whereas the dry process was 9%;
- The optimum addition of LDPE by wet process is 8% whereas the dry process was 11%;

c) The Addition of HDPE produces higher stability value than LDPE, both wet and dry processes were 38% and 24,6%, whereas LDPE for both wet and dry processes were 22% and 19,3%;
d) Test result of characteristic of asphalt mixes for optimum plastic asphalt mixes (HDPE by wet process with 9% content) has filled Bina Marga 2018 Specifications, stability, flow, VIM, VMA, VFA, MQ.

References

[1] Shafiq H. & Hamid A. 2016. *Plastic Roads: A Recent Advancement in Waste Management, International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181, Vol. 5, Issue 9, September 2016.
[2] Suroso, Tjitjik Wasiah. 2008. *Pengaruh Penambahan Plastik LDPE (Low Density Polyehtylene) Cara Basah dan Cara Kering terhadap Kinerja Campuran Beraspal*. Media Komunikasi Teknik Sipil, Vol. 16, No. 3, 208-222, Oktober 2008.
[3] Al-Hadidy,A.I dan Qiu, T.Y. (2008), *Effect of Polyethylene on Life Flexible Pavements, Construction and Building Materials*. Vol. 23: 1456-1464, 2008.
[4] Sutar A. S., Awasare S.D, Kukalekar A.A. 2015. *Experimental Investigation on use of (Low Density Polyethylene) LDPE in Bituminous Road Construction, Journal of Information, Knowledge and Research in Civil Engineering*, ISSN: 0975-6744, Vol. 3 Issue 2, Oktober 2015.
[5] Mishra B. & Mishra R.S. 2015. *A Study on Use of Waste Plastic Materials in Flexible Pavements, International Journal of Innovative Research in Science*, Engineering and Technology, ISSN: 2319-8753, Vol. 4, Issue 3, Agustus 2015.
[6] Rahmawati, Anita. 2015. *Pengaruh Penggunaan Plastik Polyethylene (PE) dan High Density Polyethylene (HDPE) pada Campuran Lataston-WC terhadap Karakteristik Marshall*, Jurnal Ilmiah Semesta Teknika Vol. 18, No.2, 147-159, November 2015.
[7] Nasution, M. Fadil Natoras et al. 2017. *Pengaruh Penambahan Plastik PET (Polyethylene Terephthalate) terhadap Karakteristik Campuran Laston AC - WC di Laboratorium*. Skripsi. Departemen Teknik Sipil, Fakultas Teknik, Universitas Sumetera Utara.
[8] Iqbal, Buyung Muhammad. 2005. *Pengaruh Retona (P 6014 Powder) terhadap Karakteristik Campuran Marshall pada KAO dengan AC 60/70*. Jurusan Teknik Sipil, Fakultas Teknik Sipil dan

Perencanaan, Universitas Islam Indonesia, Jogjakarta
[9] Purnamasari, P. Eliza dan Suryaman, Fransiskus. 2010. *Pengaruh Penggunaan Limbah Botol Plastik Sebagai Bahan Tambah Terhadap Karakteristik Lapis Aspal Beton (LASTON)*. Skripsi. Program Studi Teknik Sipil, Universitas Atma Jaya Yogyakarta.