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Utilization of LDPE Plastic Waste for Mixed AC-WC Asphalt

E. Sutandar, F. Juniardy, A. Supriyadi, G. Setyabudi
H. Azwansyah and Aryanto

Faculty of Civil Engineering, University of Tanjungpura
Prof. Dr. Hadari Nawawi Pontianak street, West Kalimantan, Indonesia

*Corresponding author details: Erwin Sutandar; Erwin_sutandar@yahoo.com

ABSTRACT
Road infrastructure development in Kabupaten Ketapang necessitates asphalt as a building material to support the acceleration of growth. Innovations are required to reduce the consumption of materials derived from nature to conserve diminishing natural resources. Plastic is an element that requires between 500 billion and one trillion years to decompose. With the addition of plastic to asphalt, the permanent deformation value of the mixture decreased and its dynamic stability increased, as determined by the wheel track test. Marshall tests on asphalt mixtures containing plastic revealed that the addition of up to 3% plastic increased the HRA mixture's stability, bulk density, compacted aggregate density (CAD), and Marshall Quotient. This study evaluated the Marshall value of the modified AC-WC asphalt layer by adding a mixture of Low-Density Polyethylene (LDPE) plastic waste with a variety of mixed properties. Each of the four variations of the AC- WC mixture (0%, 2%, 4%, and 6% LDPE) that met the specifications yielded stability values. LDPE at 6% has the highest stability value, while LDPE at 0% has the lowest stability value.

Keywords: low density polyethylene (LDPE) plastic; AC-WC mixture; ketapang regency plastic waste; plastic waste asphalt

INTRODUCTION
Considering the significance and strategic function of roads to promote the distribution of goods and services as well as the mobility of the population, roads are the basic and primary infrastructure that drives the national and regional economy. The availability of roads is an absolute requirement for investment to enter a region. All communities have access to education, health, and employment services because of roads. Therefore, it is necessary to design a pavement structure that is robust, long-lasting, and resistant to plastic deformation.

In addition to infrastructure development in Ketapang Regency, roads and land transportation infrastructure are indispensable for infrastructure accessibility development in Ketapang Regency.

To reduce the use of materials derived from nature, such as sand, natural stone, and asphalt, the most recent innovations are required. This innovation intends to reduce the consumption of diminishing natural resources. The processing of waste for use as raw materials or as raw materials for the production of asphalt mixtures is one of the innovations found in the construction industry. Plastic is an element that cannot or takes a long time to decompose. It is estimated that between 500 billion and 1 trillion plastics are used annually in the world, where it is known that the amount of plastic is growing. It is estimated that each individual uses 170 plastic bags annually. Each year, more than 17 billion plastic bags are given away for free by supermarkets around the world. Plastic has numerous advantages, but also disadvantages, particularly plastic waste. However, plastic waste presents opportunities for use in road infrastructure construction.

Asphalt mixtures have a number of disadvantages, including permanent deformation (change in shape) due to excessive pressure due to excessive truck loads, cracking due to heat, and damage due to moisture concluded in his thesis that the addition of plastic to asphalt will improve the asphalt's properties. Marshall tests on asphalt mixtures containing plastic revealed that the addition of up to 3 percent plastic increased the HRA mixture's stability, bulk density, compacted aggregate density, and Marshall Quotient. In proportion to the amount of plastic added to asphalt, the permanent deformation value of the mixture decreases in wheel track tests, resulting in an increase in dynamic stability. Referring to this, the author wishes to test the Marshall value of the modified AC – WC asphalt layer by incorporating a mixture of Low-Density Polyethylene (LDPE) plastic waste with a variety of mixed properties.

METHODS
1. Implementation Method
1.1 Preparatory Stage
This study utilized the following materials:
(1) Ex. Buil Stone-produced coarse aggregate
(2) Fine aggregate, derived from Ex. Buil Stone
(3) TPS is an asphalt additive derived from plastic (LDPE).
(4) The asphalt shell 60/70 comes from the Tanjungpura University Highway Laboratory.

This study employs the following tools:
(1) Marshall test apparatus comprised of a curved press head, a test ring with a capacity of 3,000 kg (6,000 lb) equipped with a plastic melt gauge, and a test ring with a capacity of 3,000 kg (6,000 lb) (flowmeter).

(2) Marshall test object compactor in the form of a manual masher with a flat cylindrical surface measuring 9.8 cm (3.86 inches) in diameter, weight 4.5 kg (10 lbs), and having a free fall height of 45.7 cm (18 inches). for the conventional Marshall.

(3) The cylindrical test specimen (mold) for the standard Marshall has a diameter of 10.2 cm (4 inches) and a height of 7.5 cm (3 inches).

(4) Ejector to extract the test object following solidification.

(5) A soaking tub (water bath) equipped with a temperature regulator.

(6) Scales with a test object hanger and a precision of 1 gram.

(7) A set of sieves (sieves)

(8) Equipment for marking the test object, including a heater (oven), mixing pan, heating stove, thermometer, stirring spoon, heat-resistant gloves, rag, and tip-ex.

1.2 Implementation Phase

In this study, the following tests will be implemented:

• LDPE Plastic Waste Disposal

In this research, the waste used as an asphalt additive is LDPE plastic waste that must be processed before it can be used. LDPE plastic waste must first be washed before being chopped. Following that, it was washed and then sun-dried. Prior to use, LDPE must be sieved with a mesh size of 9.5 mm.

• Material Test

Asphalt, coarse aggregate, fine aggregate, and filler are examined to determine if they are suitable for use in the mixture through testing.

(1) Asphalt Test

Although only a small amount of asphalt is used, it has a significant impact on the cohesiveness of a mixture. This study utilized a 60/70 asphalt shell pen. Included in the tests conducted are softening point, flash point, burning point, asphalt penetration, ductility, asphalt density, and weight loss.

(2) Coarse Aggregate Test

Specifications for the coarse aggregate test are as follows:

a) The coarse aggregate fraction for the design is the material retained on a No. 4 sieve (4.75 mm) and must be clean, hard, durable, free of clay or other undesirable materials, and meet the specifications.

b) The coarse aggregate fraction must consist of crushed stone or crushed gravel with nominal particle sizes. The maximum size (maximum size) of aggregate exceeds the nominal maximum size by one sieve. The maximum nominal size is one sieve smaller than the first sieve that retains less than 10% of the material.

c) The cement blocks passed the No. 200 (0.075 mm) < 1% dry sieve because the coarse aggregate attached to the mud could not be separated during drying, preventing it from bonding with the asphalt.

The standards for coarse aggregate testing are:
a) Aggregate grading
b) Specific gravity
c) Abrasion caused by the Los Angeles machine

(3) Fine Aggregate Test

Specifications for the fine aggregate test are as follows:

a) According to SNI 03-6819-2002, fine aggregate from any source material must pass a No. 4 (4.75 mm) sieve and be composed of sand or crushed stone screenings.

b) Fine aggregate must be a clean, abrasive material free of clay and other impurities. Fine aggregate must be sourced from stone that meets the required quality standards. To meet the quality standards, finely crushed stone must be made from clean stone.

c) Fine aggregate requirements must be met.

The coarse aggregate test standards are:
a) Aggregate grading
b) Specific gravity
c) Sand equivalent

• Mixing Plan for AC-WC (Asphalt Concrete – Wearing Course) Asphalt

The combined aggregate grading envelope for asphalt mixtures according to revision 2 of the 2018 Highways Specification is as follows:

TABLE 1: Envelopes of Gradient for Paved Mixtures

Sieve Size		% Additional Weight to the Total Aggregate							
		Stone Matrix Asphalt (SMA)			Hot Rolled Sheet (HRS)		Asphalt Concrete (AC)		
ASTM	(mm)	Thin	Fine	Coarse	WC	*Base*	WC	BC	*Base*
1 1/2"	37,5								100
1"	25			100				100	90 - 100
3/4"	19		100	90 - 100	100	100	100	90 - 100	76 - 90
1/2"	12,5	100	90 - 100	50 - 88	90 - 100	90 - 100	90 - 100	75 - 90	60 - 78
3/8"	9,5	70 - 95	50 - 80	25 - 60	75 - 85	65 - 90	77 - 90	66 - 82	52 - 71
No.4	4,75	30 - 50	20 - 35	20 - 28			53 - 69	46 - 64	35 - 54
No.8	2,36	20 - 30	16 - 24	16 - 24	50 - 72	35 - 55	33 - 53	30 - 49	23 - 41
No.16	1,18	14 - 21					21 - 40	18 - 38	13 - 30
No.30	0,600	20 - 30			35 - 60	15 - 35	14 - 30	12 - 28	10 -22
No.50	0,300	10 - 15					9 - 22	7 - 20	6 - 15
No.100	0,150						6 - 15	5 - 13	4 - 10
No.200	0,075	8 - 12	8 - 11	8 - 11	6 - 10	2 - 9	4 - 9	4 - 8	3 - 7

TABLE 2: Planned Aggregate Gradation

Sieve Size		% Additional Weight to the Total Aggregate	%Gradation Plan
Inch / No	(mm)	Asphalt Concrete (AC-WC)	
1 1/2 "	37,500	100	100
1"	25,400	100	100
3/4 "	19,050	100	100
1/2 "	12,700	90 - 100	98,94
3/8"	9,525	77 - 90	87,64
# 4	4,750	53 - 69	66,01
# 8	2,360	33 - 53	40,40
# 16	1,200	21 - 40	22,43
# 30	0,600	14-30	14,78
# 50	0,300	9-22	10,52
# 100	0,150	6-15	6,68
# 200	0,075	4-9	4,94

• ***Calculation of Planned Asphalt Content***

The amount of coarse aggregate, fine aggregate, filler, and asphalt in the mixture used to create a test object must equal 100% of the total amount of materials used. In planning the AC-WC asphalt mixture (Asphalt Concrete Wearing Course), the optimal asphalt content percentage has not been determined; therefore, it is necessary to calculate the planned asphalt content to determine the asphalt content percentage. In the calculation of the optimal asphalt content, analysis, graphics, or trial-and-error methods may be utilized.

Based on the Construction and Building Guidelines, the following formula is used to determine the asphalt content of a plan: Pd T-04-2005-B:

PB = 0.035 (% CA) + 0.045 (% FA) + K (% FF) + C

Where:
PB= Initial estimate of the optimal asphalt content value to the weight of the mixture.
CA= % of from the coarsest aggregate to that retained by the No. 4 sieve (stone).
FA= % of aggregate passing No. 4 sieve and retained No. 200 filter.
FF= % of aggregate passing No. 200. sieve
K= 0.15 for 11-15% passing the 200. sieve
0.18 for 6-10% to pass the 200. sieve
0.15 for < 5% to pass the 200. sieve
C= Coefficient for Laston = 0.5 to 1.

There are no instructions or guidelines for determining the initial asphalt content %. However, implicitly, given the minimum effective asphalt content, it is expected that the initial asphalt content of the plan will exceed the minimum asphalt block. So that the optimal asphalt content produced has an asphalt content value greater than the minimum number of concrete blocks.

PB = 0.035 (% CA) + 0.045 (% FA) + K (% FF) + C
PB = 0.035 (59.60) + 0.045 (35.47) + 0.18 (4.94) + 1
PB = 6.0%

In order to determine the optimum asphalt content, 15 specimens with five distinct asphalt content variations, each differing by 0.5%, are typically created.

If the median asphalt content is a%, the test object is constructed with asphalt contents of (a-1) %, (a-0.5) %, a%, (a+0.5) %, and (a+1) %.

For each asphalt content, three samples were created. The table below displays the planning table for the number of samples with asphalt content and the planning table for the number of samples with different filler variations.

2. Method of Data Collection

Several laboratory-tested test objects subjected to a variety of treatment conditions were subjected to the experimental technique for data collection. This study groups its data types into two categories: primary and secondary.

(1) Primary Data
Primary data are data collected directly through a series of experimental activities conducted independently, such as research or direct testing, with reference to existing manuals. Laboratory Marshall tests (VMA, VIM, VFA, stability, melting, and MQ) generated the primary data for this study.

(2) Secondary Data
Secondary data are data obtained indirectly (from other studies) for the same material or type that is still relevant to research.

3. Data Analysis Method

Marshall Testing included void analysis consisting of VMA (Void Material Aggregate), VIM (Void in the Mix), VFB (Void Filled with Bitumen), and MQ (Moisture Quantification) (Marshall Quotient). The analysis of data derived from the recording and calculation of tests conducted using the Marshall Test Method, followed by the development of recommendations based on the findings.

THE RESULTS AND DISCUSSION

In this study, asphalt with penetration of 60/70 was utilized. The examination results at the Highway Laboratory of the Faculty of Engineering at Tanjungpura University, Pontianak, yielded data that satisfies the U Specifications General Bina Marga 2018 revision 2 requirements. Table 3 displays the outcomes of an examination of the physical properties of asphalt.

TABLE 3: Asphalt Inspections

No	Test Variant	Specifications for Highways 2018	Test Result	Information
1	Penetration on 25°C (0,1 mm)	60-70	64,80	FULFILL
2	Asphalt Specific Gravity	≥1,0	1,029	FULFILL
3	Softening Point (°C)	≥48	51,23 °C	FULFILL
4	Flashpoint (°C)	≥232	285 °C	FULFILL
5	Ductility at 25°C, (cm)	≥100	132 cm	FULFILL
6	Losing Weight	≤0,8	0,751	FULFILL

The following is a summary of the Marshall test parameter values for asphalt mixtures with different LDPE additions at each optimal asphalt content value:

TABLE 4: Asphalt Inspections for LDPE variations

No.	Description	Test Results				AC-WC Specifications
		LDPE 0%	LDPE 2%	LDPE 4%	LDPE 6%	
1	Marshall Test					
	- Optimum Asphalt Level (%)	6,2	6,2	6,2	6,2	
	- Stability (kg)	912,91	972,90	1071,27	1231,35	min. 800
	- Flow (mm)	2,97	3,03	2,80	2,60	2 - 4
	- VIM (%)	4,57	54,56	54,58	54,63	3 - 5
	- VFB (%)	78,81	46,25	46,10	45,80	min. 65
	- VMA (%)	17,64	30,09	30,25	30,48	min. 15
	- MQ (kg/mm)	308,37	321,19	382,66	476,62	

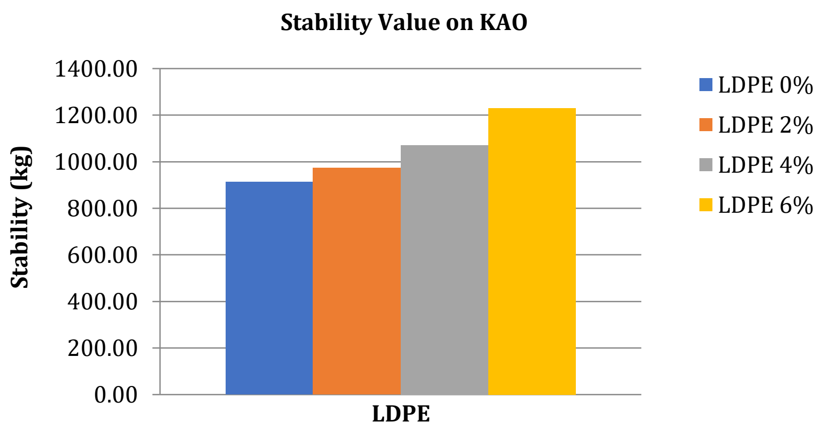

FIGURE 1: Bar Chart Stability Values on KAO Values of Each LDPE

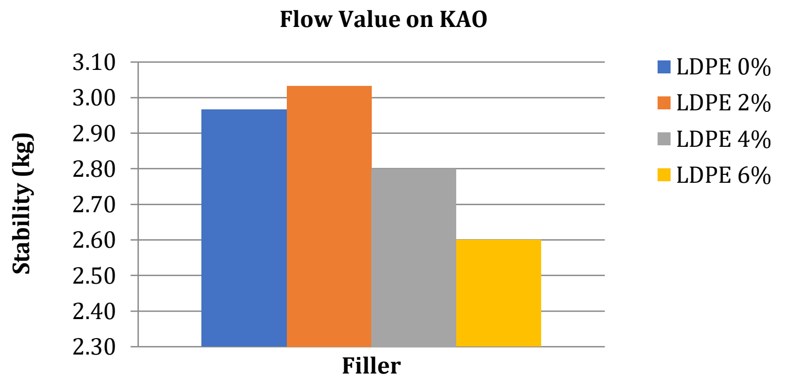

FIGURE 2: Bar Chart of Flow Values on KAO Values of Each LDPE

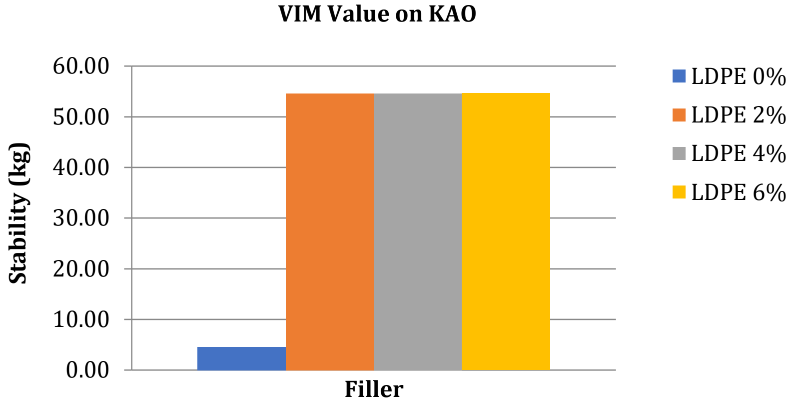

FIGURE 3: Bar Chart of Void in The Mixture (VIM) Values on KAO Values of Each LDPE

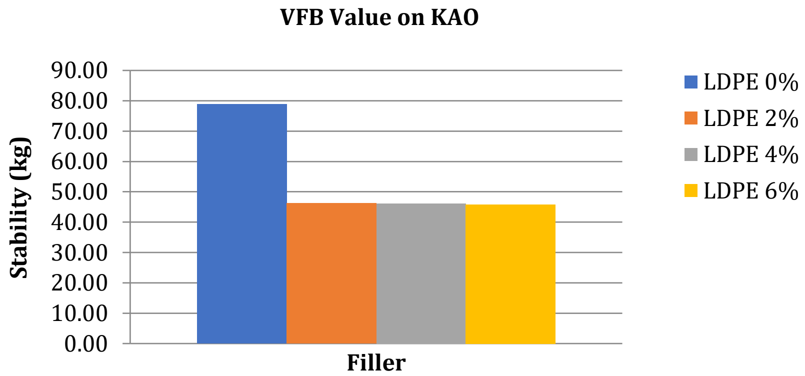

FIGURE 4: Bar Chart Value of Void Filled with Bitumen (VFB) on KAO Value of Each LDPE

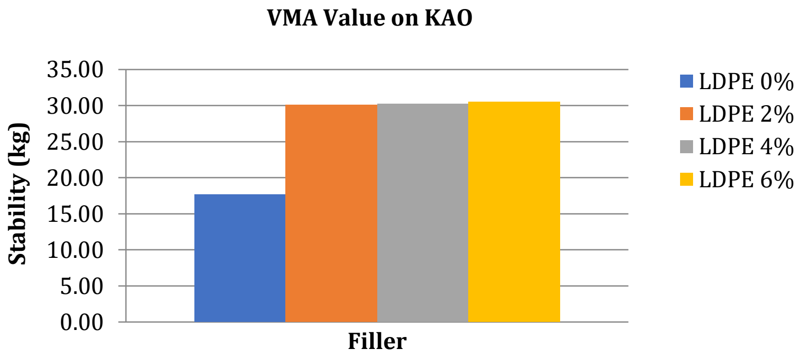

FIGURE 5: Bar Diagram of Void in The Mineral Aggregate (VMA) Values on KAO Values of Each LDPE

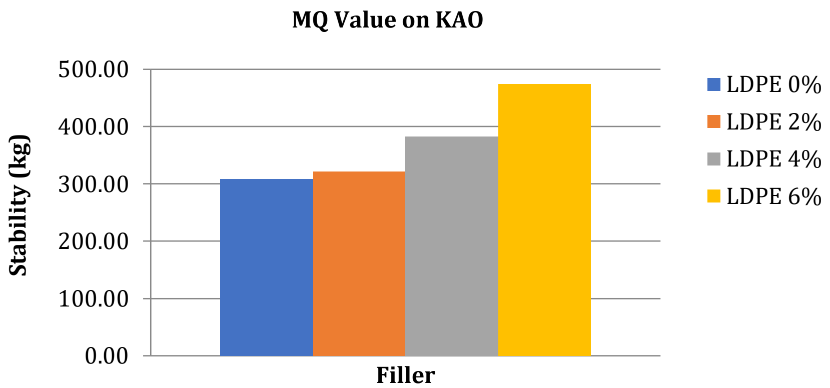

FIGURE 6: Bar Chart Marshall Quotient (MQ) Value on KAO Value of Each LDPE

From the Marshall Quotient (MQ) data above on asphalt mixtures with various LDPEs, different results are obtained. In asphalt mixture with LDPE 0% the MQ value is 308.37 kg/mm, at LDPE 2% is 321.19 kg/mm, at LDPE 4% is 382.66 kg/mm, and at LDPE 6% is 474.62 %.

CONCLUSION

Processing Based on the data and analysis conducted previously, the conclusions obtained are:

(1) Stability values obtained from the four variations of the AC-WC mixture (0%, 2%, 4%, and 6% LDPE) where each variation has met the specifications. For LDPE 6% has the highest value and LDPE 0% has the lowest value.

(2) Flow values generated from the four variations of the AC-WC mixture (0%, 2%, 4%, and 6% LDPE) where each variation has met the specifications. In the variation of LDPE 2%, 4%, and 6%, the flow value decreases, this shows that the more LDPE on the asphalt, the flow value will decrease.

(3) The VIM value produced from the four mixtures of AC-WC mixtures (0%, 2%, 4%, and 6% LDPE) only 0% LDPE met the specifications. In other variations, it has a value that exceeds the maximum limit of the specification.

(4) The VFB value produced from the four variations of the AC-WC mixture (0%, 2%, 4%, and 6% LDPE) only 0% LDPE met the specifications. In other variations have values that do not reach the minimum value of the specification.

(5) The VMA value generated from the four variations of the AC-WC mixture (0%, 2%, 4%, and 6% LDPE) where each variation has met the specifications. In the 2%, 4%, and 6% LDPE variations, the VMA value has a very increasing value.

(6) The MQ value generated from the four variations of the AC-WC mixture (0%, 2%, 4%, and 6% LDPE) where each variation has met the specifications. The increasing value of LDPE on asphalt, the MQ value increases.

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