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Original Article

Stability Marshall of Porous Asphalt Mixed with Waste Polyethylene Terephthalate (PET) and Modified Asbuton

D. S. Mabui[1*], M. Tumpu[2], M. W. Tjaronge[3], Irianto[1], Sri Gusty[4], Mansyur[5]

[1]*Department of Civil Engineering, Faculty of Engineering, Yapis University, Jayapura, Indonesia.*
[2]*Disaster Management Study Program, The Graduate School, Hasanuddin University, Makassar, Indonesia.*
[3]*Department of Civil Engineering, Faculty of Engineering, Hasanuddin University, Makassar, Indonesia.*
[4]*Environmental Infrastructure Engineering Study Program, Graduate Faculty, Fajar University, Makassar, Indonesia.*
[5]*Department of Civil Engineering, Faculty of Engineering, SembilanBelas November University, Kolaka, Indonesia.*

[*]*Corresponding Author : mabuididik80@gmail.com*

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Abstract *- The stability of a porous asphalt mixture, including plastic waste, will be investigated in this study. In this study, plastic waste is used as an addition to improve the performance of the porous asphalt mixture. In the lab, this research is experimental. The test object without plastic waste was used as a comparison, and the variables of this study were the porous asphalt mixture utilizing plastic waste in amounts as much as 0.5%, 1.0%, 1.5%, 2.0%, and 2.5%. The results showed that the porous asphalt mixture's stability value containing plastic waste increased by 0.5%, 1.0%, 1.5%, and 2.0% compared to the porous asphalt mixture's stability value without plastic waste, which was 25.50%, 13.84%, 22.42%, and 27.40%, respectively. However, the stability value decreased from 2.0% plastic waste to 2.5% or 26.57%. Therefore, according to the study's findings and the resulting stability value, the ideal level of plastic trash is 2.0%.*

Keywords *- Stability marshall, Porous asphalt, PET, Modified asbuton.*

1. Introduction

When there is no form change, and the surface layer of road pavement is still within its service life, it can function as a wear layer [1,2]. One of the reasons roads are damaged or do not last as long as they should is increased traffic congestion [3,4]. The repeated traffic loads brought on by high traffic density contribute to the accumulation of permanent deformation in the asphalt-concrete combination, claim Tayfur et al. in 2005 [5] and Birgisson et al. in 2007 [6], which reduces road performance over the course of the road's service life. Adding chemicals to the mixture is one technique to address this issue. Porous asphalt is one kind of road paving that can lessen the effects of several pavement issues, including aquaplaning or standing water on the road surface, as well as road safety and noise levels [7-10].

Since polymers do not biodegrade on their own, it can take hundreds or even thousands of years for plastic to break down and decompose. In every hemisphere, plastic garbage has turned into a dangerous phenomenon not just in poor nations but also in developed nations like the United States, Great Britain, and Japan [11–14].

According to the Indonesia Solid Waste Association (2013), Indonesia is the second-largest generator of marine plastic garbage worldwide, after China, with an annual production rate of 5.4 million tons. Packaging materials like beverage bottles and plastic bags account for the majority of plastic trash. This plastic trash is composed of LDPE (Low-Density Polyethylene), a thermoplastic plastic that can be recycled easily and has a density of between 0.910 and 0.940 gr/cm^3. Additionally, this kind of plastic is exceedingly flexible and resistant to water vapor but less so to other gases like oxygen [15]. Furthermore, scientists are still urged to discover additional substitutes for traditional plastics or the utilization of plastic waste in buildings, particularly road construction. Numerous research has been conducted both domestically and internationally that look at the usage of plastic trash in the asphalt mixture.

When plastic bottle recycling (PET) was used to modify asphalt concrete, Sojobi et al. (2016) [16] discovered that marshall's properties improved. In their investigation of plastic waste in asphalt mixes, Rajput & Yadav (2016) [40] found that adding 12% plastic trash to the mixture resulted in the highest marshall stability value. Fernandes et al. (2015) [18] assembled a bitumen invention utilizing plastic waste materials and motor oil that demonstrated how plastic waste can enhance various crucial asphalt mixed properties. By Angelone et al. (2015) [19], an environmentally acceptable method for examining the effects of plastic waste asphalt mixture was developed. It demonstrates how using plastic trash might enhance the mixture's properties. Mohammed et al. (2014) [20] conducted a study on the addition of several types of polymers to asphalt concrete, and it was discovered that the addition of polymers in an ideal state enhanced kinematic viscosity, stability, indirect tensile strength, and decreased the value of penetration. According to Musa & Haron (2014) [21], when LDPE plastic waste is added, the characteristics of the asphalt mixture improve especially the stability, which exhibits a noticeable increase. Soltani et al. (2015) [41] examined the addition of plastic as an ingredient to the asphalt mixture as well, who discovered that it is one of the factors influencing the asphalt mixture's fatigue life.

The ideal bitumen content and its properties in asphalt concrete mixtures with or without incorporating PET plastic waste were studied in Indonesia by Arianti & Balaka (2015) [23]. The findings of this study suggest that if PET content is increased, stability, VMA, VFA, flow, and MQ will increase, but VIM will decrease. According to Amiruddin et al. (2012) [24], adding polymer to an asphalt mixture raises the stability value, which shows that the interlocking between the particles is getting better. Israil et al. (2012) [25] looked into how adding plastic flakes affected the qualities of the concrete asphalt mixture and found that there was an improvement in stability and other marshall characteristics.

Numerous locations in the southern part of Indonesia's Buton Island include sedimentary rock that contains hydrocarbon compounds in its native state. There are approximately 60,991,554,382 tons (equal to 24,352,833,071 barrels of oil) of natural rock asphalt, also known as Buton natural asphalt (BRA). Bitumen makes up between 15% and 35% of the overall weight of the rocks. About 600.000 tons of bituminous asphalt are imported annually to build and maintain flexible pavements in the United States. The import requirement for petroleum bitumen can be decreased by effectively using BRA because it is abundant. In order to create Buton granular asphalt (BGA) in the form of grains with specification-compliant water, bitumen, and penetration values, BRA has recently been put through a mechanical technique [26–33,42]. This study's goal is to assess the stability of a porous asphalt mixture that also contains plastic trash as an additive.

2. Materials and Method

2.1. Physical Properties of Aggregate

The parameters of the fine aggregate (stone dust), stone dust used as filler, and coarse aggregate are all presented in Tables 1 to 3. The results of evaluating the properties of coarse aggregate, stone dust, and filler [35] demonstrate that the used coarse aggregate conforms with the General Specification of Indonesia 2018 and the Indonesia requirement (in Indonesian) for the required road materials.

Table 1. The results of the characteristic examination of fine aggregate (stone dust)

No.	Material Characteristics	Test results	Unit
1	Water soaking up	2.69	%
2	Specific gravity of the bulk	2.38	-
	Specific gravity saturated surface dry	2.69	-
	Specific gravity of apparent	2.74	-
3	Equal to sand	89.66	%

Table 2. The results of the inspection of filler characteristics (stone dust)

No.	Material Characteristics	Test results	Unit
1	Water soaking up	2.31	%
2	Specific gravity of the bulk	2.69	-
	Specific gravity saturated surface dry	2.59	-
	Specific gravity of apparent	2.67	-
3	Equal to sand	70.64	%

Table 3. The results of the inspection of coarse aggregates

No.	Material Characteristics	Test results	Unit
1	**Water soaking up**		
	Shattered stone 0.5 – 1.0 cm	2.11	%
	Shattered stone 1.0 – 2.0 cm	2.12	%
2	**Specific gravity**		
	Shattered stone 0.5 – 1.0 cm		
	Specific gravity of the bulk	2.70	-
	Specific gravity saturated surface dry	2.71	-
	Specific gravity of apparent	2.87	-
	Shattered stone 1.0 – 2.0 cm		
	Specific gravity of the bulk	2.72	-
	Specific gravity saturated surface dry	2.78	-
	Specific gravity of apparent	2.89	-
3	**Index of flakiness**		
	Shattered stone 0.5 – 1.0 cm	22.15	%
	Shattered stone 1.0 – 2.0 cm	9.84	%
4	**Abrasion of the substance**		
	Shattered stone 0.5 – 1.0 cm	27.62	%
	Shattered stone 1.0 – 2.0 cm	25.66	%

2.2. Physical Properties of Modified Asbuton

Table 4 presents the results of the modified asbuton test. The information in Table 4 shows that the modified asphalt utilized in this study conformed with the General Specification of Indonesia 2018 (in Indonesian) for the required road materials [35] on asphalt pavement. Table 4's inspection results for the modified asbuton features show that the asphalt used in this study conformed with Indonesia Specifications 2010 standards for asphalt pavement.

Table 4. Characteristics of modified asbuton

No.	Kind of testing	Results
1	Before weight loss, penetration (mm)	79.59
2	Softening Point (°C)	51.99
3	At 25°C, ductility is 5 cm per minute (cm)	113.99
4	Flashing Point (°C)	279.99
5	Specific Gravity	1.11
6	Loss of weight (%)	0.29
7	penetration after a decrease in weight (mm)	85.99

2.3. Mix Design of Porous Asphalt Mixture

The combination used in this study is in compliance with the requirements of the Malaysian grading porous asphalt mixture (REAM, 2008) [36] and uses an open-graded system. The used aggregate is a fine aggregate that passes through sieve number 4, is stopped by filter number 8, and passes through filter number 8 while stopping filter number 200. Additionally, it cleans the filters 3/4, which was "stuck 1/2", and 1/2, which was "with the filter 3/8." Based on the criteria of the Malaysian porous asphalt mixture (REAM, 2008) [36], Table 5 shows the gradations of Malaysian porous asphalt.

Table 5. Malaysia porous asphalt gradation (REAM-SP 5/2008) [36]

Sieve size (mm)	Percentage of passes (weight)	
	Gradation A	Gradation B
20.0	-	100
14.0	100	85 - 100
10.0	95 - 100	55 - 75
5.0	30 - 50	10 - 25
2.36	5 - 15	5 - 10
0.075	2 - 5	2 - 4

2.4. Stability Marshall Test

The paragraph above makes reference to the SNI 06-2489-1991 [37] on the testing method for the asphalt mixture utilizing the marshall equipment. Stability and flow are measured during this test to ascertain how resistant a test object is to take on the applied stress. Stability demonstrates a test object's resilience to bearing a load. There are two types of stability: dry stability and wet stability. The resistance of the test object to taking loads in dry air circumstances is measured by the object's dry stability. Wet stability is a method for determining an object's capacity to withstand a load in saturated conditions. The Marshall Quotient measures stability and flow, indicating a material's vulnerability to breaking. Equation 1 can be used to get the Marshall Quotient value. In order to determine the test object's resistance to loads, stability and flow can be measured using the marshall test equipment shown in Figure 1.

$$MQ = \frac{S}{F} \tag{1}$$

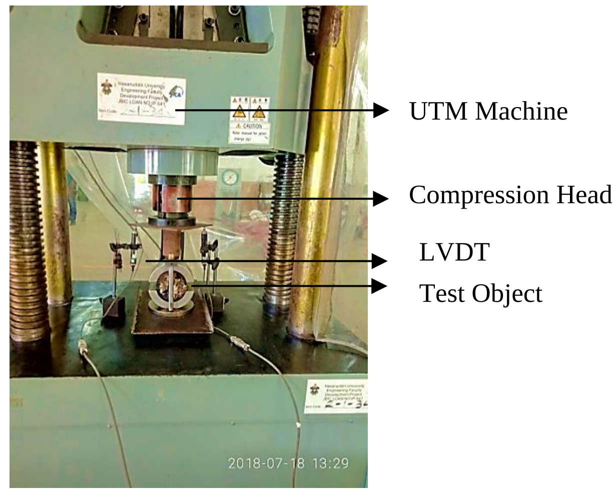

Fig. 1 Marshall stability test

Where:
MQ = Marshall Quotient (kg/mm)
S = stability (kg)
F = Flow value (mm)

2.5. Optimum Asphalt Content in Porous Asphalt Mixture

The REAM 2008 specification states that three different forms of testing—cantabro testing, binder drain down, and porosity—are used to identify the ideal asphalt composition. The abrasion value, the drain-down binder value, and the porosity value (void in the mix) are necessary criteria. In porous asphalt mixtures employing modified asbuton, the ideal asphalt content is 6.0%. The results of the three different experiments used to establish the ideal asphalt content show that the ideal modified asbuton content is between 5.5% and 6.5%.

3. Results and Discussion

3.1. Combined Aggregate Gradation

Figure 1 shows the aggregate gradation of the mixed porous asphalt mixture obtained for this experiment, according to REAM, 2008 [36]. Since the combined aggregate design created and achieved in this investigation is within the REAM-required specification interval, it is anticipated that the ideal combination will be obtained (see Figure 2).

3.2. Design and Composition of Porous Asphalt Mixture Based on Estimated Asphalt Content

The ideal asphalt concentration of a porous asphalt mixture is attained at a modified asbuton level of 6.0%, in accordance with the REAM specification (2008) [36]. Therefore, plastic waste was added to the optimal bitumen content at rates of 0%, 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% of the aggregate's total weight. Table 6 shows the composition of the porous asphalt mixture made from plastic trash based on the aggregate gradation or the total aggregate retained in each filter.

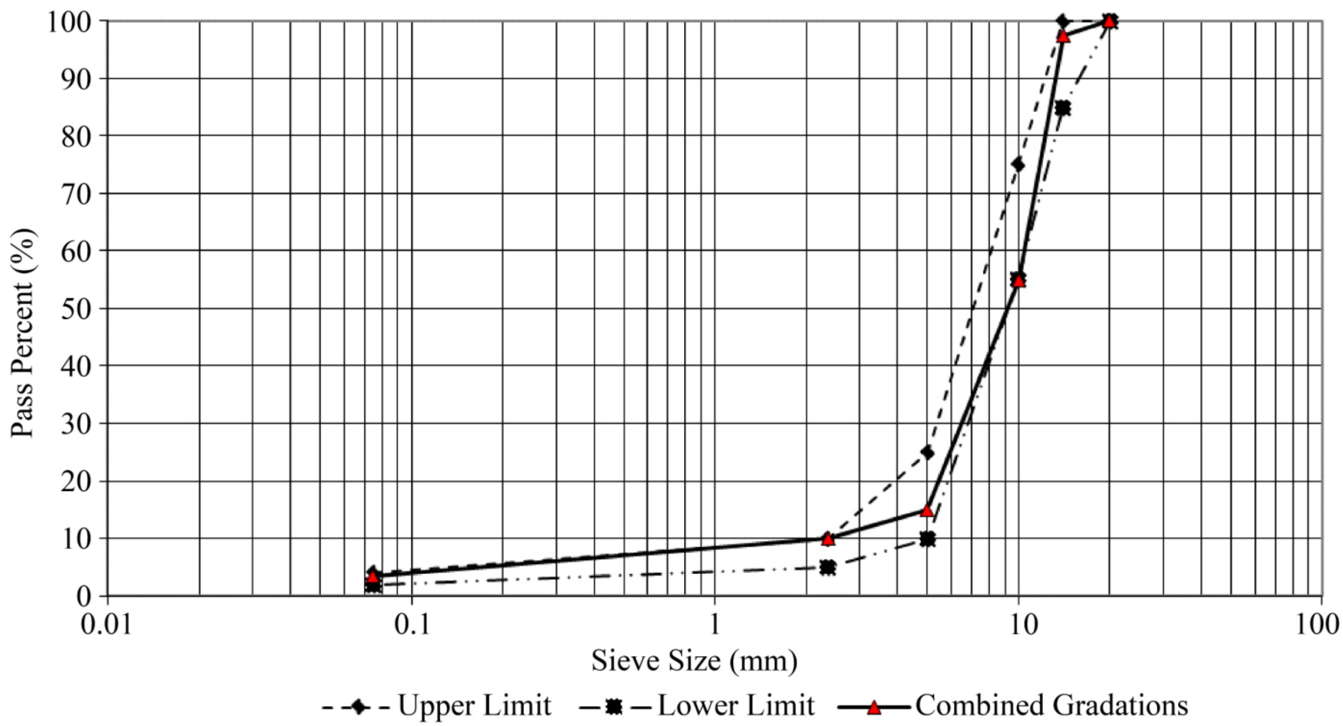

Fig. 2 Combined aggregate gradation in porous asphalt

Table 6. Material composition in weight for 1200 grams of specimen

No.	**Description**	**Unit**	**Content of plastic waste (%)**					
			0.0	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**
A	Weight of Plastic Waste	gr	0.00	5.64	11.28	16.92	22.56	28.20
B	Weight of Modified Asbuton (6.0%)	gr	72					
C	Gradient Combined Aggregate Sieve		Aggregate weight according to sieve size					
1	3/4"	gr	-	-	-	-	-	-
2	1/2"	gr	28.70	27.76	26.82	25.88	24.94	24.00
3	3/8"	gr	478.95	478.01	477.07	476.13	475.19	474.25
4	No. 4	gr	451.15	450.21	449.27	448.33	447.39	446.45
5	No. 8	gr	56.40	55.46	54.52	53.58	52.64	51.70
6	No. 200	gr	73.66	72.72	71.78	70.84	69.90	68.96
7	PAN	gr	39.14	38.20	37.26	36.32	35.38	34.44
Total		gr	1128.00	1128.00	1128.00	1128.00	1128.00	1128.00
C	**Test object weight**	gr	1200.00	1200.00	1200.00	1200.00	1200.00	1200.00

3.3. Marshall Stability of Porous Asphalt

The results of a test to determine the stability of a porous asphalt mixture that included plastic trash as an additional material are displayed in Table 7. The stability value of the porous asphalt combination is shown in Table 7, obtained at 0%, 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% plastic waste contents is 741.8 kg, 931.0 kg, 1059.9 kg, 1297.58 kg, 1653.2 kg, and 1213.8 kg. 6.54 mm, 6.49 mm, 6.98 mm, 6.49 mm, 6.40 mm, and 6.63 mm, respectively, were the different flow values that were found.

The corresponding values for the Marshall Quotient (MQ) value, which indicates how flexible the asphalt mixture is, are 113.42 kg/mm, 143.45 kg/mm, 151.85 kg/mm, 199.93 kg/mm, 258.31 kg/mm, and 183.08 kg/mm. The reason test specimens containing plastic waste as an added material have a low MQ value is due to the process or phenomenon of the added plastic waste hardening and embrittling [38]. Figure 3 depicts the size of the stability value increase for each level of plastic waste in the porous asphalt mixture.

Table 7. Stability of the porous asphalt mixture using plastic waste

No.	Plastic waste content (%)	Stability (kg)	Flow (mm)	MQ (kg/mm)
1	0.0	741.80	6.54	113.42
2	0.5	931.00	6.49	143.45
3	1.0	1059.90	6.98	151.85
4	1.5	1297.58	6.49	199.93
5	2.0	1653.20	6.40	258.31
6	2.5	1213.80	6.63	183.08

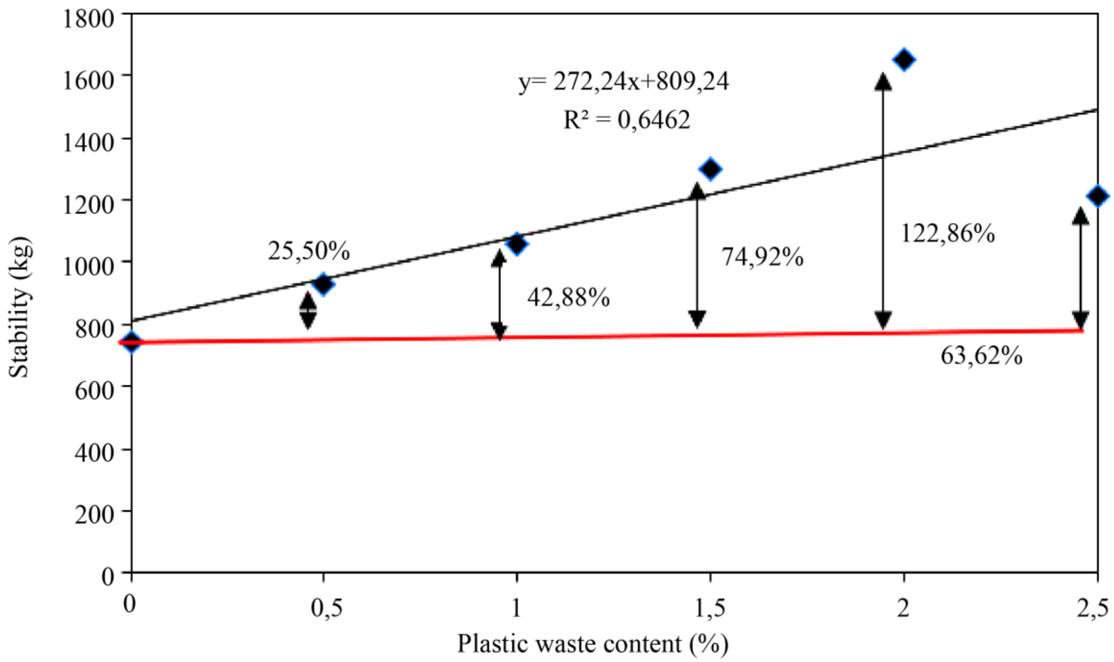

Fig. 3 Increased stability value

Figure 3 depicts the increase in stability value when plastic waste is added, with the corresponding values for the test objects employing plastic trash being 25.50%, 42.88%, 74.92%, 122.86%, and 63.62%. Additionally, it can be shown that the 2.0% plastic waste content has the highest stability value. Equation 2 can therefore be used to approximate the link between the amount of plastic garbage present and the stability value.

$$Y = 272.24X + 809.24 \quad (2)$$

Where :
Y = Stability value (kg)
X = Plastic waste content (%)

4. Conclusion

According to the results of the porous asphalt mixture's stability test, the plastic waste content has the highest stability value, or 1653.20 kg, at a plastic waste percentage of 2.0%. According to the study's findings, adding plastic waste up to a level of 2.0% improved the performance of porous asphalt mixtures under normal conditions (in accordance with the requirements and guidelines of Highways and REAM, 2008), which suggests that PET-type plastic waste can combine as an ingredient. Polymer and petroleum bitumen, as well as asbuton extraction bitumen, increase the bond strength of the binder materials. However, at a content of 2.5%, the strength decreases due to polymers of the PET type weakening the binding bonds of oil-asphalt bitumen and bitumen from asbuton extraction. The findings of this study can promote the construction of a national infrastructure made of waste materials, particularly PET-type plastic waste and natural materials like Buton asphalt. This is projected to increase the usage of environmentally friendly development.

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