

# Experimental characteristic of PET plastic bottle waste addition on asphalt concrete wearing course compound

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**Abstract.** Optimization of bottle plastic waste with *Polyethylene Terephthalate* (PET) type as additional material for asphalt can be performed by running a test on modified plastic bottle waste for further usage as the asphalt compound. Besides, Indonesia is placed second in the world rank for producing plastic waste into the sea so that waste domestication becomes a necessity to reduce the increasing amount of waste. Moreover, inserting plastic bottle waste is to get the durability of pavement structure in case of deformation tolerance in the traffic load. The study is oriented to the plastic bottle waste called Polyethylene Terephthalate (PET). The study utilizes the wet process method as asphalt additional material. The present study is executed on the *Asphalt Concrete Wearing Course* compound by using 60/70 asphalt pen which is modified with PET plastic bottle waste by 0%, 3%, 6%, 9% and 12% levels. The study aims to investigate the Marshall parameter of asphalt concrete characteristics with various asphalt PET modifications. The result of the Marshall parameter shows that asphalt optimum level (AOL) for asphalt 0 % is about 5.9, PET asphalt of 3%, 6%, 9%, and 12% is about 5.95. Based on the analysis, the optimum level of asphalt concrete compounded with 9% PET has improved stability value of 33% between the usage of optimum modified asphalt and asphalt pen by 60/70.

## 1. Introduction

The optimization and usage of PET (*Polyethylene Terephthalate*) plastic bottle waste as asphalt additional material can be conducted by testing the usable plastic bottle waste. On the other hand, based on Juambeck data, it states that Indonesia is ranked second in the world as a plastic waste producer into the sea that reaches 187,2 million tons, following China that reaches 262.9 million tons [1]. A large amount of plastic can cause crucial harm to nature considering its materiality that is very difficult to decompose. Therefore, it is necessary to take an effective action on a big scale to solve this plastic waste that cannot be recycled or being utilized in the road pavement structure field. Polymer plastics of *Polyethylene Terephthalate* (PET) and *Polypropylene* (PP) mixed into asphalt with penetration of 80/100 and compound level of 0%, 3%, 6%, 9%, and 12% from asphalt mass level by exerting *wet process* [2]. The result from both plastics mixed in the asphalt indicates improvement stability up to 60-70% rather than conventional asphalt which is asphalt pen 80/100 with 9% polymer addition by utilizing PET modification. A study of plastic bottle usage by using a dry process method as means of additional material for AC-WC. It showed asphalt optimum level in 4% plastic addition and Marshall stability value increased by 19% with additional PET and cement as the compound [3]. Moreover, the study about the management method of plastic asphalt compound known as dry process and wet process. The effect of putting the plastic type of *Low-Density Poly Ethylene* (LDPE) into the asphalt compound has



higher stability value by 22.5% which is more tolerated towards the traffic load in contrast to the stability of asphalt pen 60. However, undertaking LDPE addition with dry process and wet process may affect the wet process method to have a higher Marshall stability value [4]. Therefore, the researcher will utilize asphalt pen 60/70 which is suitable for the weather in Indonesia. It is then compared further with an improvement in the results of these studies, namely the stability value that can be improved more than conventional asphalt and the asphalt compound characteristics that will be performed in this study.

## 2. Materials and method

### 2.1. Materials

The material used in this study is asphalt Pertamina pen 60/70. Then the other material, Polyethylene Terephthalate (PET), which is an added material that will be put into the asphalt. Before mixing pure asphalt with PET powder, the asphalt properties have been tested first, as well as the aggregates used and have met the 2010 revised 3 general specifications.

### 2.2. Mixture plan

In asphalt modification using Polyethylene Terephthalate (PET), the process cannot be mixed into a mixer. Because there is a separation or not homogeneous between Asphalt Pen 60/70 with PET. Therefore the process of softening PET with Ethylene Glycol (EG) added ingredients. After all the ingredients are fulfilled, pure asphalt is mixed with the reflux of PET waste or can be seen in Figure 1 (a), (b), (c) where the process of softening PET is carried out by reflux then mixing is carried out into asphalt. so the next step is to test the modified asphalt using PET. The results of testing the modified asphalt properties using PET can be seen in Table 1. which can be seen in the table below.

**Table 1.** PET modification asphalt testing result.

Test	Requirement	PET level (%)				
		0%	3%	6%	9%	12%
Penetration (0,1 mm)	Min .40	63	54	46	42	34
Soft point (°C)	≥54	48.5	54.1	55.2	56.4	58.5
Ductility (cm)	≥ 100	140	140	140	127	109
Weight	≥ 1.0	1.03	1.03	1.04	1.05	1.06
Bright point (°C)	≥ 232	330	318	306	294	275
Storage Stability (°C)	≤ 2.2	0.3	1.4	1.3	1.2	1.3
Kinematic Viscosity (°C)	≤ 3000	360	330	375	430	495

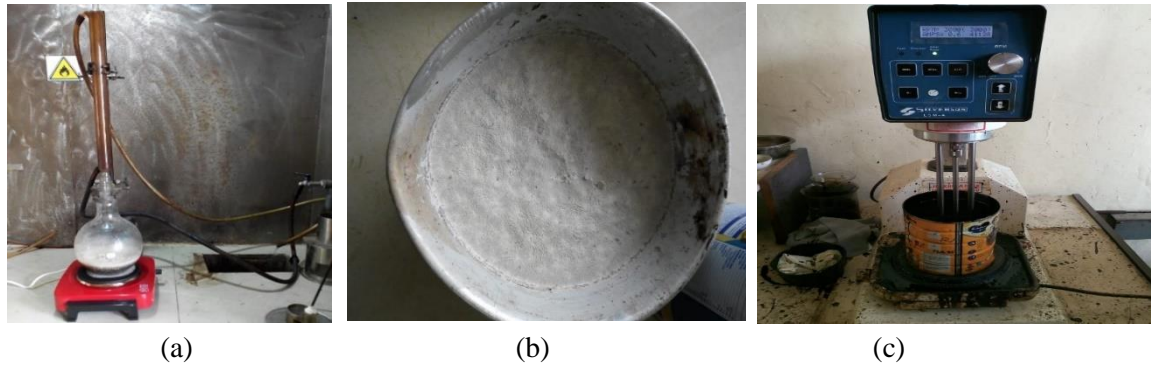
To determine asphalt optimum level can be measured by determining the asphalt optimum level empirically by applying the following formula:

$$Pb = 0.035(\%CA) + 0.045(\%FA) + 0.18(\%FF) + K \quad (1)$$

Description: Pb = Estimation of asphalt level towards compound  
 CA = Coarse Aggregate constrained by filter number 8  
 FA = Fine Aggregate slipped through the filter number 8  
 FF = Filler fabrics slipped through the filter number 200  
 K value = Constanta for *asphalt concrete wearing course*

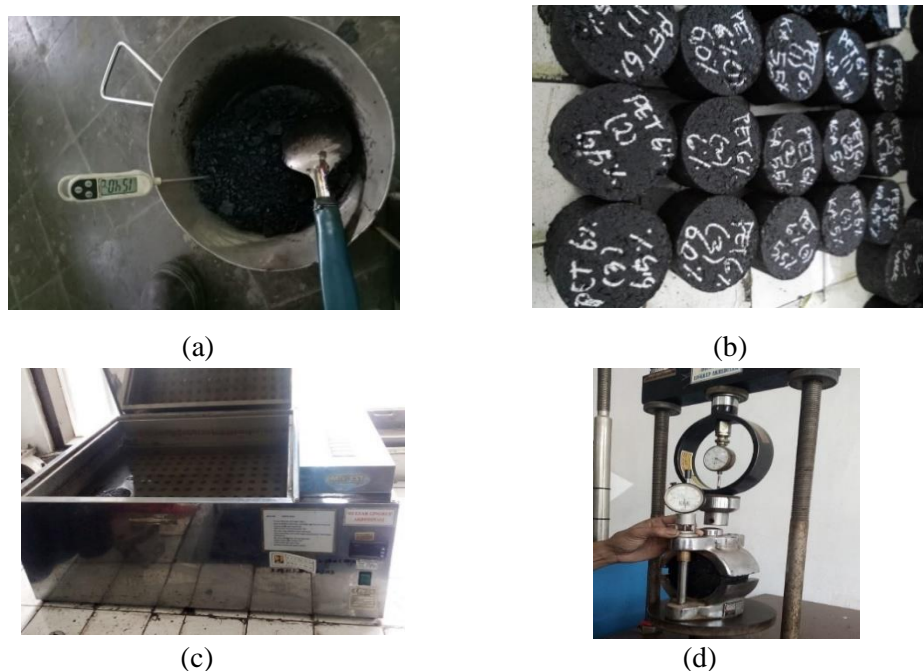
Pb value from the calculation result is rounded to 0,5% and defined by two upper asphalt level and two lower asphalt level where the initial estimated level of asphalt has been rounded to 0.5%. Furthermore, modified asphalt is compounded to the aggregate as described in Figure 2(a), by allocating different

initial asphalt levels, it will produce several samples of Marshall value that are ready to be tested as displayed in Figure 2(b).



**Figure 1.** (a) Reflux process of plastic bottle waste, (b) smelting of PET plastic bottle waste, (c) Asphalt and PET compound by using a mixer.

Equipment exerted in this study for the compound test Marshall method is the Marshall press tool shown in Figure 2 (d). The equipment consists of a press head in the form of a curve, test ring with a capacity of 3000 kg (6000 lbs) equipped with a plastic melt measurement watch (flow meter). Test object printing tool in the form of cylindrical shape with a diameter of 10.2 cm and height 7.5 cm for Marshall equipment standard featured with plate and tube connector. Manual pounder has a cylindrical flat surface with a diameter of 9.8 cm, weighs 4.5 kg, and a free fall height of 45.7 cm for Marshall standards. Water bath equipped with temperature control is used before testing Marshall standards and Marshall Immersion value as it is displayed in Figure 2 (c).



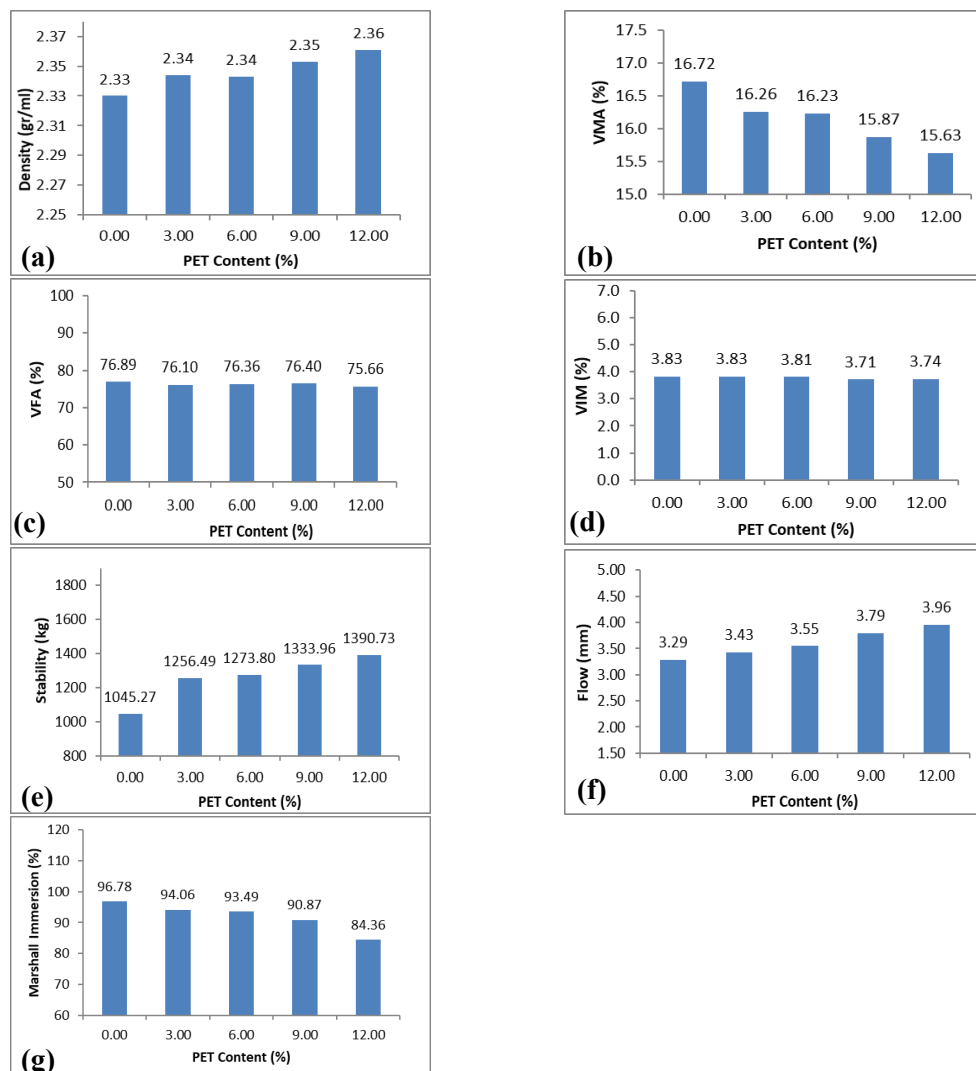
**Figure 2.** (a) Stirring Process (b) Ready-use test samples (c) water bath (d) Marshall Test.

### 3. Results and discussion

The result analysis of Laston AC-WC compound utilizes PET plastic bottle waste of 0%, 3%, 6%, 9%, and 12% towards the Marshall parameter. Parameter Marshall is required to identify consistency in the test result by drawing a relation graphic between percentage variations of PET with the Marshall parameter.

#### 3.1. Density value analysis

Based on the graphic in Figure 3(a), it shows that PET level of 0% has minimum density value by 2.33 gr/ml, while PET of 3% level has density value by 2.34 gr/ml and the highest value of density is experienced by PET of 12% level approximately 2.36 gr/ml. The greater the amount of PET added to asphalt compound, the more increase its density is. It is due to the effect of PET addition into asphalt that makes it denser.



**Figure 3.** Analysis of modified asphalt mixture; (a) density, (b) VMA, (c) VFA, (d) VIM, (e) Stability, (f) Flow, (g) Marshall Immersion.

### 3.2. Void in Mineral Aggregate (VMA) value analysis

VMA is cavity volume inside a compact asphalt concrete when the whole cover of asphalt is removed. VMA will decrease along with the increase of used PET percentage. Based on the graphic in Figure 3(b), VMA minimum value is acquired by amount of 15.63% in PET level of 12%. Overall, VMA value by using PET modification asphalt fulfills the general specification of third revision 2010 which sets a requirement of a minimum 15% value. VMA result is defined that the bigger PET given level is, the smaller VMA value will be. The maximum VMA value can be obtained from asphalt content without PET or modification for about 16.72%. It suggests that a compound without PET has a higher capability to cover the aggregate properly and has a sufficient cavity prior to the asphalt compound with PET modification. VMA percentage value enhancement utilizing PET is not significantly high so that when there is an addition of pavement by traffic load, the asphalt compound does not suffer *bleeding* (asphalt layers are melted out).

### 3.3. Void in Filled Asphalt (VFA) value analysis

Filled air cavity of asphalt is a cavity percentage between particles aggregate (VFA) with asphalt content and the VFA of unabsorbed asphalt by the aggregate. VFA is asphalt that is intended to cover the aggregate grains in the slid compound. Based on the graphic in Figure 3(c), VFA value tends to decrease along with the increase of PET level. Nevertheless, PET modification asphalt still can fill in the existed cavities. On a whole, VFA value still meets the requirement of the third revision general specification 2010.

### 3.4. Void in Mixture (VIM) value analysis

Based on the graphic in Figure 3(d), it can be seen that all the VIM values of PET variation which has different VIM value tends to decrease in fulfilling the requirement of third revision general specification 2010 that sets a prerequisite for the VIM value about 3-5%. Any compound that suffered a compaction where the VIM value is less than 3.5% will emerge plasticity traces. When the final cavity level is too higher or in the compaction process achieved more than 5.5% value, the cavity may suffer early fractures, grain detachment, and exfoliation. When PET level is getting higher, VIM value will be getting lower even it is not in a significant decrease.

### 3.5. Stability value analysis

Stability is asphalt concrete ability to receive traffic load without suffering modification such as waves, traces, and bleeding. The stability value can be seen in Figure 3(e), as long as all the components still meet the minimum requirement of AC-WC compound with a modification of 1000 kg. The existence of PET modification asphalt usage in AC-WC compound may increase stability value by 33% in the optimal PET level of 9%. It can be utilized in AC-WC compound and comply to the specification with asphalt optimum level of 5.95%. Similar to the previous study, the optimum AC-WC compound level occurred in PET asphalt level of 9% experienced an increase in stability value by 68% using the asphalt pen 80/100 [1]. Meanwhile, the present study stability value is improved by 33% from the comparison of PET modification asphalt by using asphalt pen 60/70. A high stability value will reduce durability due to a high stiffness. A higher stability of asphalt concrete is resistance towards rutting.

### 3.6. Flow value analysis

Based on the graphic in Figure 3(f), It can be examined that maximum melting value (*flow*) appeared in asphalt compound with PET level of 12% by amount of 3.96 mm. It is higher than the asphalt compound without PET which has a flow value of 3.29 mm and the lowest flow value existed in the asphalt compound without PET modification. It can be defined that the higher PET level is used, the higher flow value will be. In consideration, that PET is a plastic that has plasticity properties when if it is mixed into asphalt concrete compound, it will give stiffness or brittle properties. The study argues that a high flow value may influence a deformation on a deflection pavement. The whole flow value is expected to

meet the requirement of the second revision of the Public Works Department Specification 2010 by 3.0 mm.

### 3.7. Marshall immersion value analysis

The stability decline of certain compounds can be intertwined with the loss of adhesion or the knot between the asphalt and aggregate. Most of the aggregate materials own gravity force with water which is bigger than asphalt. When an asphalt compound is soaked in the water for a certain period of time, the water will try to permeate and fill in the cavities inside the compound and interact with building materials like aggregate and asphalt. Water that interacts with aggregate will be absorbed inside and encompass the aggregate's surface that has not been completely covered by asphalt. Thus, the asphalt will encounter difficulties to substitute the water which has created a film layer on the surface of aggregate. In addition, the water also exerted asphalt as the result of the stress force (*water pressure*) in all directions. It causes adhesion bond between asphalt and aggregate to become diminished. In Figure 3(g), it is elaborated that the higher PET level addition in asphalt concrete is, the lower Marshall Immersion value will be. On the level of 12%, asphalt has a value of less than 90% so that PET level of 12% did not meet based on the Indonesia Specification for Hot-mix Asphalt Department of Public Work 2010. Table 2 shows the results of the characteristics of the AC-WC mixture using PET plastic waste bottles.

**Table 2.** Asphalt optimum level characteristic with PET compound test result.

No.	Compound Characteristic	Type of PET Compound					Specification	
		0%	3%	6%	9%	12%	Min	Max
1.	Asphalt Optimum Level, (%)	5.90	5.95	5.95	5.95	5.95	-	-
2.	Density, (ton/m <sup>3</sup> )	2.33	2.34	2.34	2.35	2.36	-	-
3.	VMA (%)	16.72	16.26	16.23	15.87	15.63	15.00	-
4.	VIM-Marshall (%)	3.83	3.83	3.81	3.71	3.74	3.00	5.00
5.	VFB (%)	76.89	76.10	76.36	76.40	75.66	65.00	-
6.	Stability, (kg)	1045.27	1256.49	1273.80	1333.96	1390.73	1000	-
7.	Flow, (mm)	3.29	3.43	3.55	3.79	3.96	2.00	4.00
8.	Immersion Marshall, (%)	96.78	94.06	93.49	90.87	84.36	90.00	-

## 4. Conclusion

This research was conducted by adding PET to 60/70 pen asphalt as conventional asphalt and comparing it with the asphalt to form a modified asphalt mixture. In the study, stability value has increased by 33% from the comparison of 9% PET modified asphalt and pure asphalt. The improvement existed by the addition of PET plastic bottle waste in the compound of AC-WC is improving the flow value. The flow value of asphalt compound without PET plastic addition (0%) about 3,29 mm and keep increase up to the point of 12 % plastic level enhancement by value 3,96 mm which almost surpassing the flow standard of 4 mm. The impact of the flow increase is the plasticity nature of the AC-WC compound. Marshall Immersion value that complies with the specification of the third revision Bina Marga 2010 (Marshall Immersion >90%) is the test sample with PET level of 0-9%. Marshall immersion value that does not meet the Indonesia Specification for Hot-mix Asphalt Department of Public Work 2010 is the sample with PET level of 12 % and marshall immersion value by 84, 4%.

## References

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