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Utilization of PET Plastic Waste in Concrete Asphalt Mixture (AC-BC) to Improve the Stability and Sustainability of Road Infrastructure

Andri Dwi Cahyono[1*], Zendy Bima Mahardana[2], Evita Fitrianis Hidiyati[3], M. Faisol Firmansyah[4], Erwindsyah Putra W[5]

[1,2,3,4,5] Department Civil Engineering, Faculty of Engineering, Universitas Kadiri, Indonesia
*Corresponding Author, e-mail: adcahyono@unik-kediri.ac.id

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ABSTRACT

Plastic waste, especially Polyethylene Terephthalate (PET), is one of the biggest environmental issues in Kediri City, with a volume of 140 tons per month. This research aims to utilize PET plastic waste as an additional material in the Asphalt Concrete-Binder Course (AC-BC) mixture. The study was conducted using an experimental method with variations in PET levels of 0%, 6%, 8%, and 14% of the total weight of the mixture. The test was carried out using Marshall standards to evaluate performance parameters such as stability, flow, VIM (Void in Mix), VMA (Void in Mineral Aggregate), and VFB (Void Filled with Bitumen). The results showed that the addition of PET to 6% increased the stability of the mixture to 6300 kg, higher than the mixture without PET (6200 kg). The flow value increased with the addition of PET, reaching 3.8 mm at a rate of 14%. In addition, VMA and VIM tend to decrease, indicating an increase in the density of the mixture, while VFB achieves an optimal value at a PET level of 6%. This study concluded that PET waste can be used effectively to improve the performance of AC-BC mixtures, with an optimal level of 6%. The utilization of PET plastic waste not only improves the performance of road infrastructure but also contributes to the reduction of plastic waste, thus supporting environmentally friendly and sustainable construction solutions.

Keywords: *AC-BC; Road Pavement; Volumetric; Waste PET.*

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INTRODUCTION

The city of Kediri in East Java, Indonesia, is famous as the center of the cigarette industry with excise revenue reaching Rp 20.68 trillion/year (Kediri, 2019). The funds are used to improve facilities and infrastructure in order to support the Kediri city government's program in realizing the Kediri city brand "Harmoni Kediri, The Service City" (Kediri, 2020). By carrying this brand, the city of Kediri is committed to improving the quality of life of its residents. As a city of service, it places it in focus areas such as education, health, law, finance, technology, arts and culture and entertainment. With all the facilities presented, the city is a place of tourism and education [1].

The effect of this development has a negative impact that appears, one of which is the large amount of organic and inorganic waste. This problem is an important study by the Kediri city government because it can have an impact on beauty, comfort and health. One of the important problems is plastic waste, especially PET (Polyethylene Terephthalate)[2]. The high consumption of plastic packaging beverages is the main factor in the increase in the amount of PET waste. The amount of PET waste in the city of Kediri has reached an alarming level, with an estimated 140 tons every month (Official Website of the Kediri City Government, 2022). Plastic waste that is difficult to decompose naturally and takes centuries to decompose causes environmental damage, damaging water and soil quality[3]. In overcoming the problem of PET plastic waste and finding sustainable solutions in road pavement construction, this research was conducted to utilize PET plastic waste as an alternative material in the road pavement mix [4]. By adding PET plastic waste to the asphalt mixture, the pavement can have better strength, reduce plastic waste and reduce the use of asphalt [5].

The use of PET of 8% of the weight of 60 grams of asphalt on the AC pavement layer (Asphalt Concrete) is known to have a sample stability value with 75 collision treatments of 19.78 Kn, this value is greater than the pure mixture of 13.2 Kn, and has an effect on the ruts depth as deep as 2.08 mm. In another case, it is known that the use of AC pavement (Asphalt Concrete) with a PET content of 14% has a stability value of 20 Kn and a resilient modulus value with a temperature difference of 10°C and 22°C, respectively of 10000 Mpa and 4000 Mpa at 75 collisions. In addition, in the application of Type SMA (Stone Mastic Asphalt) road layer with the use of a combination of PET and nanosilica waste of 6%PET+8%NS, a stability value of 20 Kn, resilient modulus with a temperature of 60°C 75 times of collision of 6100 Mpa which affects the depth of the Rut as deep as 1.2 mm.

The purpose of this study is to determine the stability and deformation value of the use of PET (Polyethylene Terephthalate) plastic bottle waste in road pavement. By expanding the understanding of road pavement samples with the addition of PET waste, it can provide more comprehensive insights into considering the sustainability and effectiveness of the use of plastic waste in the road construction industry, with the aim of creating environmentally friendly and sustainable solutions.

PET waste will be treated and mixed into the asphalt mixture to form a pavement sample. In this study, several variables can be considered, such as the percentage of PET waste added to the asphalt mixture and the mixing method used. The Marshall test standard test method will be conducted to measure the performance of road pavement samples with the addition of PET waste.

The results of this study can be used as a basis for the development of road pavement mixtures that use PET waste as a substitute material. With a deeper understanding of the physical and mechanical characteristics of road pavement samples with PET waste, it will be possible to design an optimal mixture with good performance and effective use of plastic waste.

METHOD

This research was carried out using an experimental approach at the Civil Engineering Laboratory, Kadiri University. The main focus of this study is to examine the effect of the addition of Polyethylene Terephthalate (PET) plastic waste in the asphalt concrete - Binder Course (AC-BC) type of road pavement mixture[6][7]. PET plastic waste is used after going through the processing process into small flakes less than 2 mm in size. It is then mixed into asphalt with variations in content of 0%, 6%, 8%, and 14% of the total weight of the mixture.

The use of PET plastic waste aims to increase the stability and flexibility of the asphalt mixture while utilizing plastic waste in a sustainable manner[8]. As an additional material, Portland

Type I cement is used to strengthen the adhesion between materials in the mixture. All stages of the research, from basic material testing to final mixture testing, are carried out based on applicable standard procedures, such as SNI 8470:2017 for concrete asphalt mixtures.

Materials Used

The main materials used in this study include coarse aggregate, fine aggregate, asphalt, PET plastic waste, and cement[9][10]. All materials are selected and prepared to conform to the technical specifications required in the design of AC-BC pavement mixtures.

Table 1. Types of Materials Used

Material Type	Specifications	Information
Coarse Aggregate	Maximum size: 19 mm	According to the AC-BC gradation according to SNI/Bina Marga standards
Fine Aggregate	Good graded sand with particle size: < 4.75 mm	According to the AC-BC gradation according to SNI/Bina Marga standards
Asphalt	Asphalt Penetration 60/70	According to SNI/Bina Marga standards
Semen	Type: Portland Cement Type I	Used as a filler to improve stability.
PET Plastic Waste	Shape: Small flakes or powder	Washed, dried and crushed to a size of < 2 mm.

Basic Materials Testing

Before the mixing process is carried out, all materials are tested to ensure that their characteristics meet quality standards. Testing involves the analysis of key parameters on aggregates, asphalt, and additives. The results of the test are summarized in the following table:

Table 2. Basic Material Test Results

Types of Testing	Test Results	Specification Limits	Information
Abrasion Test	25,84%	Maks. 30%	Meet
Sieve Gradation Test	According to Specifications	As per AC-BC specifications	Meet
Specific Gravity & Water Absorption Test	1. BJ Bulk = 2,895 2. Water Absorption = 1,004%	Based on SNI standards	Meet
Asphalt Penetration Test	65	60 - 70	Meet
Asphalt Soft Point Test	50°C	Min. 48°C	Meet
Asphalt Ductility Test	105 cm	Min. 100 cm	Meet

Material Mixing

The material mixing process is carried out based on a procedure that refers to the SNI 8470:2017 standard for concrete asphalt mixtures. The mixing stages are carried out as follows:

1) Material Preparation

   Coarse aggregates, fine aggregates, and fillers (cement) are weighed according to the planned proportions for the AC-BC mixture. PET plastic waste that has been processed into small flakes (< 2 mm) is added with content variations of 0%, 6%, 8%, and 14% of the total

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weight of the mixture. 60/70 Penetration Asphalt is heated to a temperature of 150°C – 160°C to ensure homogeneous mixing.

2) Material Stirring
Coarse aggregate, fine aggregate, and filler are pre-mixed in a dry condition for 30 seconds. The PET waste is then added to the dry mixture and stirred for 1 minute until evenly distributed. The heated asphalt is slowly poured into the mixture and stirred for 2–3 minutes until the entire material is homogeneously mixed.

3) Sample Printing
The homogeneous mixture was molded using a Marshall Mold mold with a diameter of 101.6 mm and a height of 63.5 mm. The mixture is fed into a preheated mold, then compacted using a Marshall Compactor for 75 strokes per side. The sample is allowed to cool at room temperature for 24 hours before being tested.


a. Material Stirring


b. Pounding Process


c. Sample Printing


d. Marshall Test

Figure 1. AC-BC Pavement Manufacturing Process

The test was carried out using the Marshall Test to evaluate the mechanical characteristics of the asphalt mixture. The parameters tested include stability, flow, density, void in mix (VIM), void in mineral aggregate (VMA), and void filled with asphalt (VFA)[8]. Stability measures the maximum load before the sample breaks down, while flow measures vertical deformation

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when the maximum load is reached. The density of the mixture was evaluated to assess homogeneity, while VIM and VMA were used to determine the volume of air as well as the cavity in the aggregate. VFA indicates the percentage of cavities filled by asphalt[11]. Each parameter is tested three times to ensure consistency of results and is compared to specifications referring to SNI 8470:2017 on Hot Mix Asphalt. The results of the analysis were used to identify the effect of the addition of PET waste on the performance of the AC-BC mixture.

RESULTS AND DISCUSSION

Marshall Test Results

The results of Marshall's test for AC-BC mixtures with variations in the addition of PET waste (0%, 6%, 8%, and 14%) are summarized in Table 3.1. The tests include key parameters such as stability, flow, VIM (Void in Mix), VMA (Void in Mineral Aggregate), and VFA (Void Filled with Asphalt).

Table 3. Marshall AC-BC Test Results

Prosentase PET (%)	Stability (Kg)	Flow (mm)	VMA (%)	VFB (%)	VIM (%)
0	6200	3,4	14	74,5	3,5
6	6300	3,5	13,5	75	3,2
8	6100	3,6	13,2	74,8	3
14	5900	3,8	13	74,6	2,9

Marshall's test results showed that the highest stability was achieved at a 6% PET content of 6300 kg, slightly higher than the 0% PET content of 6200 kg. Flow increased from 3.4 mm at 0% PET to 3.8 mm at 14% PET, indicating increased blend flexibility. VMA and VIM tend to decrease as PET levels increase, indicating an increase in density. VFB achieves an optimal value at 6% PET of 75%. Overall, the 6% PET content results in the best blend performance with high stability and optimal density.

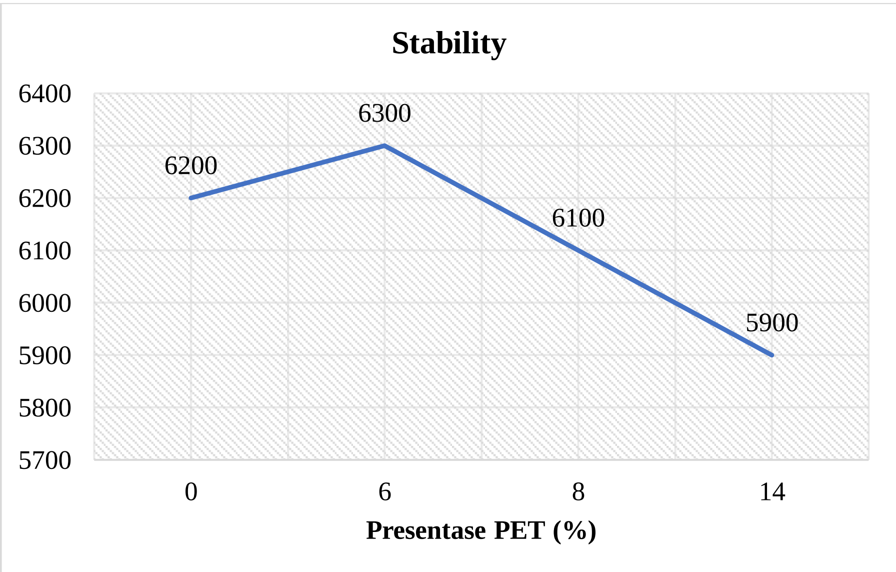

Figure 2. Stability Test Results

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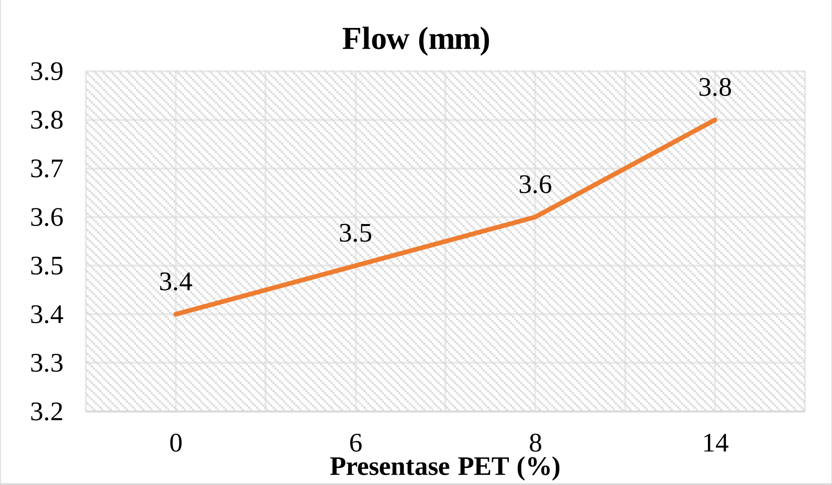

Figure 3. Flow Test Results

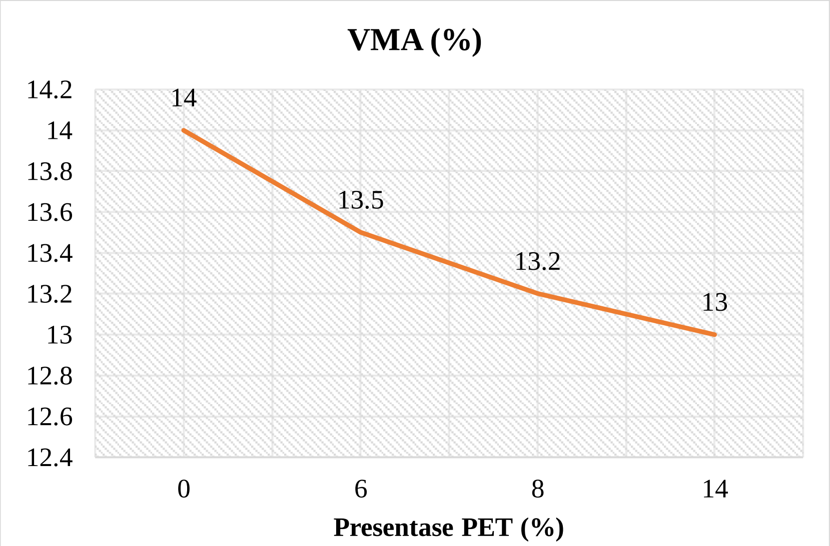

Figure 4. VMA Test Results

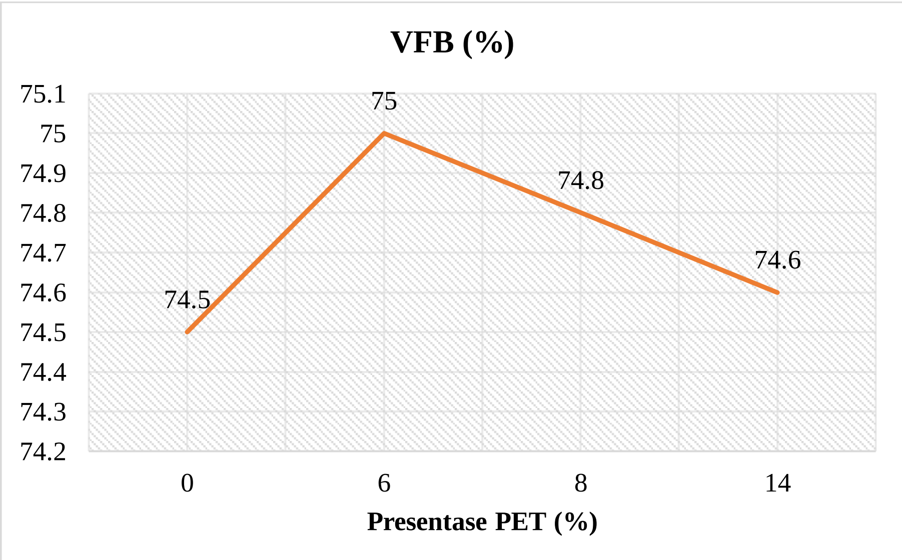

Figure 5. VFB Test Results

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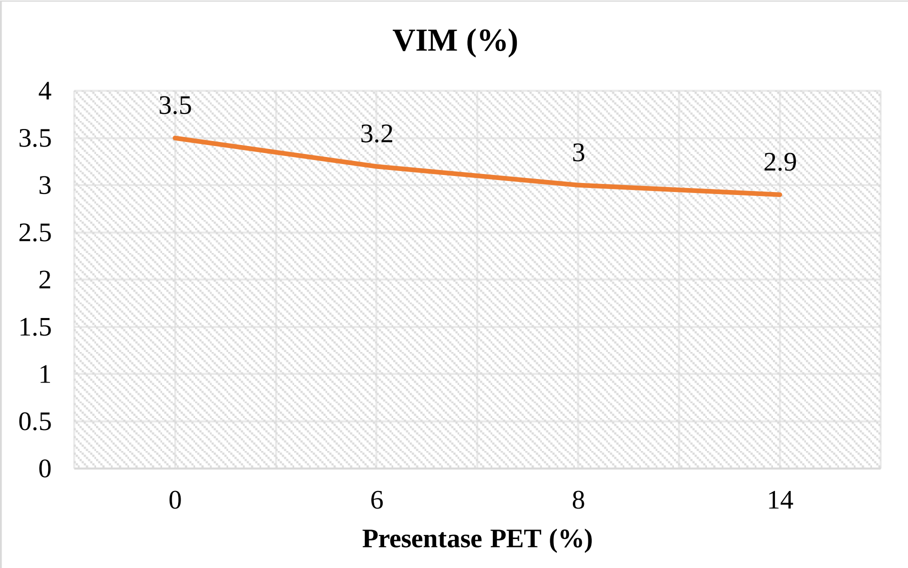

Figure 6. VIM Test Results

Discussion

The addition of PET waste by up to 6% improves the stability of the mixture, indicating structural strengthening. However, at 8% and 14%, stability decreases due to the excessive properties of PET plastics, disrupting the bonds between materials. The flow that increases with PET content reflects the more pliable properties of the mixture. While providing the advantage of flexibility, the increase in flow must remain within the standard limits so as not to reduce structural strength. Decreased VMA and VIM indicate a decrease in cavities in the mixture, indicating better density. However, at high PET levels, the risk of segregation and long-term performance degradation needs to be considered.

CONCLUSION

Based on the results of the study, the addition of PET waste to the AC-BC mixture has a significant impact on the characteristics of Marshall. The stability of the mixture increased with the highest value of 6300 kg at 6% PET, indicating optimal strength compared to 0% PET. Flow has also been increased to 3.8 mm at a PET level of 14%, but is still within the allowable standard limit. Additionally, VMA and VIM tend to decline with increasing PET levels, reflecting an increase in the density of the mixture. The value of VFB peaks at a PET content of 6%, indicating the efficiency of filling cavities by asphalt. Overall, the 6% PET content results in the best performance in terms of stability, flexibility, and density of the mixture. The utilization of PET waste at this level not only improves the performance of asphalt mixtures but also becomes an innovative solution to reduce plastic waste in infrastructure applications.

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