Asphalt Modified Plastic Waste To Defend Damage In Asphalt Concrete (Ac-Wc)

Mahmuda¹, Sumiati¹ and Lina Flaviana T¹

¹Civil Engineering Departement, State Polytechnic Sriwijaya, Srijaya Negara street, Bukit Besar Plg, 30139, Indonesian

Email: mahmuda@polsri.ac.id, sumiati@polsri.ac.id, lina_tilik@yahoo.com

Abstract. Plastic bottles (PET) and take-away food containers (PS) waste could be reusable to fix asphalt physical trait that sensitive toward temperature and enhancing the stability of asphalt concrete. Thus it could be used to prevent the damage on rigid pavement such as deformation, corrugation, rutting, and shoving. This research aims to fix asphalt physical trait and to find how much plastic waste percentage (PP+PS) needed so it could replace the asphalt component in Asphalt Concrete (AC-WC). The research is conducted by testing 75 sample with maximum asphalt level of 5.6% and plastic waste percentage ranging from 0%; 2%; 4%; 6%; and 8% compared to asphalt weight. Marshall Test was done in the sample that is soaked in the temperature of 60oC; 70oC; 80oC for 30 minutes and 60oC for 24 hours. Based of Asphalt Pavement Specification (Bina Marga revision 3rd, 2010), hence the percentage of plastic waste that could be used to replace partial asphalt component in Concrete Asphalt (AC-WC) is only 2% of asphalt weight. This percentage is not only fulfilling Marshall characteristic number but also could prevent the further road damage and extremely weatherproof.

Keywords: Asphalt Concrete (AC-WC), Asphalt Modified, Plastic waste, Road damage

1. Introduction

Asphalt concrete is flexible pavement layer of the road that is made from aggregate and asphalt as its binder. Asphalt concrete should have high stability and able to endure the traffic load in order to avoid the deformation. Asphalt is a viscoelastic material and sensitive toward temperature. But, asphalt will freeze at low temperature, and in other hands, it will fuse in the high temperature. Asphalt concrete that used low-quality asphalt will have a side effect if it gets a massive load in high temperature. That side effect is the exfoliation between asphalt and aggregate. Furthermore, it could cause damage to pavement layers such as corrugation, rutting, shoving, fatigue, block cracking, and potholes.

Asphalt characteristic that is sensitive to temperature could be repaired by adding the additive component. However, this step would cost more compared to the regular one. The more economical way to replace this step is by adding an additional component that contained: synthetic rubber such as latex, used-tire, and other plastic material. Polystyrene has the softening point of 90°C, Polyethylene Terephthalate has the softening point of 250°C, and asphalt has the softening point of 48°C. Combining these three materials hopefully could be able to fix asphalt physical properties.

Research aims are to improve the physical properties of asphalt by adding or replacing a portion of asphalt with plastic waste has been widely carried out including: the use of 10% Low-Density Polyethylene (LDPE) and 4% High-Density Polyethylene (HDPE) on asphalt weight can improve the pavement layer against rutting damage and withstand temperatures of 70°C [1]. By adding HDPE into hot asphalt mixtures of 4% to the weight of asphalt, a flexible and plastic mixture will be obtained [2]. Polystyrene modified asphalt can be used in a mixture of asphalt pavement layers to reduce damage to rutting resistance and resistivity [3]. The results of research using PEN 40/50 asphalt and adding 8% mineral water plastic bottle waste to asphalt weight can increase the stability value, improve the value of Void Filled Asphalt (VFA) and minimum Air Voids (AV) and flow from asphalt pavement [4].
Addition of Polyethylene Terephthalate (PET) of 0.41% from the weight of the aggregate will be obtained asphalt pavement mixture which has the highest stiffness value [5]. By using 4.8% optimum asphalt level, and adding 10% plastic bottle waste to the asphalt weight can increase the value of stability, and damage to the pavement layer [6]. The results of the study used 5.88% asphalt PEN 80/100, and adding 0.18% PET to the weight of the aggregate would produce an optimal mixture of asphalt modified [7]. Research [8] using 0.7% recycled PET fiber to the asphalt weight on asphalt concrete will provide effective strength. Research [9] uses asphalt PEN 60/70 for 4% of the total aggregate weight and mixes 16.7% plastic bottle waste with a dry process at 170°C can extend the pavement service life.

In this research, Polyethylene Terephthalate (PET) from plastic bottle’s waste and Polystyrene (PS) from food container waste will be used to fix asphalt physical properties. The modification of asphalt will be used as a binder component in asphalt concrete (AC-WC), hence it will result as Marshall characteristic number and fulfilled the General Specification Division IV Revision 3rd, [10] The primary objectives of this research is to create asphalt concrete (AC-WC) that have high durability toward extreme weather. Thus the road damage such as corrugation, rutting, shoving, fatigue, block cracking, and potholes could be prevented, and the economically eco-friendly component would be attained.

2. Methodology

This research is based on a literature review of the results of several studies that have been carried out and looks at the damage that occurs in the pavement layer and surveying waste materials that have not been optimally utilized. Before making a mixed design of asphalt concrete wearing course (AC-WC) based on Specifications of Asphalt Pavement [10] first test the physical properties of the forming material, consisting of asphalt, aggregate, and plastic waste.

The material used prepared is 80/100 penetration-grade asphalt which is a type of hard asphalt from petroleum distillation produced by PT. Pertamina. Coarse aggregates in the form of broken stones originating from Lahat. Plastic wastes that will be used are 50% bottles of used mineral water with PET (Polyethylene Terephthalate) and styrofoam food container waste PS (Polystyrene) as much as 50% which will substitution some asphalt varies 0%; 2%; 4%; 6% and 8%.

The fine and coarse aggregates to be used must be tested first to determine their physical properties whether they meet the requirements such as: Sieve Analysis of Fine and Coarse Aggregates [11], Specific Gravity and Absorption of Fine Aggregate [12], Specific Gravity and Absorption of Coarse Aggregate [13], Clay lumps and friable particles in aggregate [14], Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate [15], Soundness Of Aggregates By Use Magnesium Sulfate [16], abrasion and impact in the Los Angeles Machine [17], Coating and Stripping of Bitumen-Aggregate Mixtures [18], fine aggregate angularity [19], Coarse Aggregate Angularity [20], Materials Finer than 75µm [21]. Plastic waste modified asphalt and filler were tested for specific gravity [22].

Asphalt modification made by substituting plastic waste PET (Polyethylene Terephthalate) 50% + PS (Polystyrene) 50% against the weight of the asphalt. The mixing process is done by heating the plastic waste and asphalt at a separate place with a temperature of 170°C Combine these two ingredients then [23] mixing with 500 rpm speed for 15 minutes, keep the container closed for further testing. Test the physical properties of asphalt and modified asphalt including Penetration of Bituminous Materials [24], Softening point of Bitumen [25], Flash and fire points [26] and Ductility of Bituminous Materials [27].

To obtain optimum asphalt content, firstly 15Marshall specimens are made [28], with asphalt variation 4.5%; 5%; 5.5%; 6% and 6.5% of the weight of the test object, where each variation of asphalt is made of 3 specimens. Asphalt concrete (AC-WC) test material added (PS + PET) plastic waste varies: 0%; 2%, 4%, 6% and 8% against optimum levels of 60 samples.
To determine the effect of temperature changes on the performance of concrete asphalt mixture will be soaked at a temperature of 60°C; 70°C; 80°C for 30 minutes and a temperature of 60°C for 24 hours before doing the Marshall Test [29].

Marshall characteristic value will be calculated using the related formulas, the results of the calculation will then be analyzed using the regression method shown in the histogram and guided by Division VI, Specifications Asphalt Pavement, Revision 3rd, [10] so that the conclusion of this study will be obtained.

3. Results and Discussion

The results of testing the physical properties of asphalt and aggregate data as shown in Table 1, it can be seen that the ductility value, softening point, asphalt density, flash point, and fire point meet the requirements of asphalt penetration grade 80/100.

The modified asphalt with (PS + PET) plastic waste has increased specific gravity along with the addition of (PS + PET) plastic, this can cause the cavity to shrink in a modified asphalt mixture. Softening points, flash, and fire points also increase along with the addition of (PS + PET) plastic waste, this is because asphalt has a softening point of around 48°C, while Polystyrene foam (PS) has a softening point of 90°C and Polyethylene Terephthalate (PET) has a softening point of 250°C, so Asphalt is more resistant to weather. Asphalt penetration values decreased along with the addition of (PS + PET) plastic waste, making the asphalt a bit stiff, but still fulfilling the requirements of asphalt ductility. Ductility value decreases with increasing (PS + PET) plastic waste. On the addition of (PS + PET) plastic waste > 2% does not meet the specifications. This supports the results of research using polystyrene [30] and using Polyethylene Terephthalate (PET) as an added ingredient in asphalt modified [31] as well as research [32] which used latex as an added ingredient in asphalt modified.

Table 1. Results of Testing Physical Properties of asphalt

| Testing | Asphalt | Asphalt + (PS+PET) 2% | Asphalt + (PS+PET) 4% | Asphalt + (PS+PET) 6% | Asphalt + (PS+PET) 8% | Specification Asphalt Pen 70/80 | Specification Asphalt Modified |
|---------|---------|-----------------------|-----------------------|-----------------------|-----------------------|-------------------------------|-------------------------------|
| Specific gravity | 1,032 | 1,048 | 1,064 | 1,080 | 1,096 | ≥1,0 | ≥1,0 |
| Penetration (mm) | 87,83 | 72,83 | 67,79 | 59,67 | 46,93 | 60-70 | Min.40 |
| Softening point (°C) | 48,5 | 54,5 | 55,5 | 56 | 56,5 | ≥48 | ≥54 |
| Flash & Fire point (°C) | 294 | 297 | 302 | 317 | 335 | ≥232 | ≥232 |
| Ductility (cm) | ≥100 | 100 | 60 | 40 | 30 | ≥100 | ≥100 |

In Table 2 and Table 3, it can be seen that the physical properties of fine aggregate and coarse aggregate test results meet the Asphalt Pavement Specifications [10].

Table 2. Results of testing the physical properties of coarse aggregates

| Testing | notation | Test Result | Specification |
|---------|----------|-------------|---------------|
| Soundness Of Aggregates By Use Magnesium Sulfate | (%) | 2 | Maks. 18 |
| Los Angeles abrasion (500 rounds) | (%) | 20,9 | Maks. 40 |
| Coating and Stripping of Bitumen-Aggregate Mixtures | (%) | 95 | Min. 90 |
| Coarse Aggregate Angularity | 97/95 | Min 95/90 |
| Flat Particles, Elongated Particles in Coarse Aggregate | (%) | 3,7 | Maks. 10 |
| Materials Finer than 75µm | (%) | 0,5 | Maks 2 |
Table 3. Results of Testing Physical Properties of Fine Aggregate

| Testing                                           | notation | Test Result | Specification |
|---------------------------------------------------|----------|-------------|---------------|
| Sand Equivalent Test                              | (%)      | 85          | Min 60        |
| fine aggregate angularity                         |          | 53.95       | Min 45        |
| Clay lumps and friable particles in aggregate     | (%)      | 0.5         | Maks. 1       |
| Materials Finer than 75 µm                        | (%)      | 0.65        | Maks. 10      |

Marshall specimens were made for using coarse aggregate and fine aggregate with composition: 3% aggregate 1/2, 33% aggregate 1/1, 59% stone ash and 5% sand. The aggregate mixture gradation can be seen in Figure 1, where it meets the aggregate specifications of asphalt concrete (AC-WC).

In Figure 2, showing that the replacement of some asphalt with (PS + PET) plastic waste. Resulting in a decrease in VIM values from asphalt without plastic ranges (5.95% - temp 60°C); (6.38% -temp 70°C); (7.68%-temp 60°C) and (6.62%-temp 60°C for 24 hours) become lower, then increase with increasing plastic content and immersion temperature. VIM value is based on the Bina Marga Specification, which is between 3%-5%. VIM value affects the durability of the pavement layer, the higher the VIM value shows the greater the cavity in the mixture. In the partial replacement of asphalt with (PS + PET) plastic waste > 2%, the VIM value exceeds the specifications, this causes the mixture to be less dense, so that water and air can easily enter the cavities in the mixture which causes the asphalt to be easily oxidized, and will cause inter-attachment aggregate granules are reduced, resulting in the release of granules and surface peeling in the pavement layer. VIM values that are too low will cause bleeding due to high temperatures, the viscosity of asphalt will decrease according to the thermoplastic properties. At that time if the pavement layer accepts the traffic load, the asphalt will be pushed out of the surface because there is not enough cavity for the asphalt to penetrate the pavement layer.
Stability is the ability of the coating to resist deformation due to the traffic load acting on it without undergoing changes in shape, such as corrugation and rutting. The stability value is influenced by the shape, quality, surface texture, and aggregate gradation, namely friction between aggregate grains, internal friction and interlocking cohesion, and asphalt content in the mixture.

In Figure 3, it can be seen that the stability value has increased along with the increasing replacement of some asphalt with plastic waste (PS + PET) at immersion temperatures of 60°C, 70°C, 80°C, for 30 minutes and 60°C for 24 hours, rising and falling when > 4%, but it still meets the required stability value of at least 800 kg. Replacement of a portion of asphalt with (PS + PET) plastic waste of 2-6% can improve Marshall's stability value after 60°C immersion for 24 hours, which is required at a minimum of 90%, whereas if > 6% it will reduce the ability of the coating to resist deformation due to past loads cross.

In Figure 4, it can be seen that the flow value has decreased along with the increase in immersion temperature and the increasing replacement of some asphalt with plastic waste (PS + PET). Substitution of some asphalt with plastic waste (PS + PET) will improve the density of the mixture so that the flow value becomes lower. Mixtures that have low melting numbers with high stability tend to become stiffness and brittle. Whereas mixtures that have high melting rates and low stability tend to be plastic and easily change shape such as corrugation and rutting if they get a traffic load, therefore, the specification limits the flow value of 2-4 mm. Low flow values will cause the mixture to become stiffness so that the pavement layer becomes easily cracked when loaded. When viewed from the stability and value of the flow, replacing part of the asphalt with plastic waste (PS + PET) > 6% will actually make the layer stiffness and easily cracked.

**Figure 2. Void in The Mix**
Void Filled Asphalt (VFA) shows the percentage of the cavity that can be filled with asphalt. The higher VFA value means the more cavities in the mixture that are filled with bitumen so that the mixture's compressibility towards water and air are also higher, but the VFA value that is too high will cause bleeding. VFA values that are too small will cause the mixture to be less impermeable to water and air because the asphalt film layer will become thin and will easily crack when receiving additional loads so that the asphalt mixture is easily oxidized which eventually causes the pavement layer not to last long.
The results of the study in Figure 5 shows that the Asphalt Concrete (AC-WC) grade 80/100 penetration- asphalt VFA values do not meet the minimum requirements. Replacement of a portion of asphalt with 2% plastic waste (PS + PET) will improve the nature of the mixture. VFA value will decrease along with the increasing replacement of some asphalt with plastic waste (PS + PET). So it can be concluded that: the more plastic waste that is replaced does not add value to the mixture, it should be limited to 2% to obtain a mixture that is waterproof and durable and not easily cracked.  

Void in Mineral Aggregate (VMA) is the air cavity between particles of asphalt and aggregate mixture that has been compacted including asphalt filled space expressed in percent of the total volume of asphalt aggregate mixture. The expected VMA value in the asphalt mixture is as minimum as possible, with the aim of providing sufficient space on the asphalt so that it can adhere to the aggregate.

![Figure 5. Void Filled With Asphalt](image1)

![Figure 6. Void in Aggregate Minerals](image2)

Factors that influence the value of VMA include aggregate gradation, bitumen content, and compaction method. In Figure 6, it can be seen that the replacement of a portion of asphalt with plastic waste (PS + PET) as much as 2% causes the VMA value to fall, but increases if the replacement of some asphalt with plastic waste (PS + PET) > 2%. This is due to the adhesion of asphalt to aggregates decreases with increasing plastic waste (PS + PET). The VMA value is not significantly different with 24 hours soaking at 60°C. So if it is connected with the Marshall Quotient, it can be concluded that the substitution some asphalt with plastic waste (PS + PET) < 6% of the weight of asphalt will not reduce the adhesion of asphalt to the aggregate.
4. Conclusion

Based on the results of research that has been carried out that plastic waste that can replace part of asphalt is 2% of the asphalt weight that meets the asphalt modified requirements based on the Asphalt Pavement specification [10].

Marshall test results show that, if the asphalt concrete (AC-WC) mixture uses 2% asphalt modified plastic waste on asphalt weight with optimum asphalt content of 5.6%, it can prevent damage: deformation, corrugation, rutting, and shoving.

5. References

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