Analysis of Marshall Characteristics on Asphalt Concrete: Wearing Course with Addition of Plastic Bag Waste from Pupuk Kalimantan Timur Companies

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Abstract: There have been many ways to reduce damage to road pavements, one of which is by adding additives to asphalt, therefore, changing the properties of the asphalt mixture, especially hardness, sensitivity to temperature, and peeling. This of course requires a high additional cost. One way is to add plastic bags as an additive to the asphalt. The problem faced by Pupuk Kalimantan timur Companies is the amount of unused plastic bags left due to abundant raw materials and production errors. This research was carried out by designing the composition of the asphalt mixture, adding plastic bags with each variant of plastic 2%, 3%, 4%, 5%, and 6% of the asphalt weight using the dry process method. Based on the test results, the optimum asphalt content value is 6.20% with stability value = 1381 kg, flow = 3.587 mm, VIM = 3.695%, VMA = 14.73%, VFA = 78.17%, and MQ = 391 kg/ mm and a maximum plastic content of 5%, with stability value = 1426 kg, flow = 3.83 mm, MQ = 315.85 kg/mm, VIM = 4.44%, VMA = 16.81%, VFA = 73.58%. The addition of plastic bags can increase the value and durability of the Asphalt Concrete Mixture.

1 INTRODUCTION

One of the components of flexible pavement, the use of asphalt is relatively low, generally only 4%-10% of the total weight or 10%-15% of the total volume, but asphalt is an expensive material (Istiar, Adi, & Sutikno, 2019). Asphalt is used in aggregates as a binder and also acts as a filler and stabilizer in asphalt mixtures. Offers permeability and particle adhesion as asphalt fills voids (Akter & Efficacious, 2019. Plastics are synthetic materials derived mainly from refined crude oil products. High melting temperature, high decomposition temperature, and resistance to Ultra Violet radiation provide many benefits, but also mean that plastic waste remains in the environment for hundreds of years (Evode et al. 2014) creates increasing environmental challenges. In addition, the toxic chemicals in most plastics are bio-cumulative, posing safety and security risks throughout the food chain, including Humans (White & Reid, 2018). The use of plastic as an additive in asphalt mixtures is expected to provide stability and durability to the mixture, so that it can be used widely and can reduce the presence of waste that can endanger the safety of ecosystems, the environment and humans.

In previous research, testing the characteristics of Marshall with different percentages of plastic waste, namely 4%, 6%, 8%, and 10% by weight of asphalt as an additive. The results showed that the Optimum Bitumen Content (OBC) of plastically modified asphalt mixture at 4%, 6%, 8%, and 10% were 4.98, 5.44, 5.48, and 5.14, respectively. On the other hand, the controlled specimens showed better volumetric properties compared to the plastic mixtures. However, the addition of 4% plastic showed that it was better than the controlled one (Abd Kader et al., 2017).

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2 MATERIAL AND METHOD

2.1 Asphalt Concrete

Asphalt concrete is a layer on highway construction consisting of a mixture of hard asphalt and well graded aggregate, mixed, spread out in a hot state and compacted at a certain temperature (Sukirman, 2003). As a surface layer of road pavement, Asphalt concrete (AC) has structural value, is waterproof and has high stability. Another characteristic is that it has few voids in its aggregate structure, interlocking with each other, therefore asphalt concrete has high stability and is relatively rigid.

2.2 Asphalt Concrete- Wearing Course (AC-WC)

Asphalt Concrete - Wearing Course (AC-WC) is the topmost pavement layer and functions as a wear layer. Even though it is non-structural, AC-WC can increase pavement resistance to quality degradation so that overall it increases the service life of the pavement construction. AC-WC has the smoothest texture compared to other types of Asphalt Concrete.

2.3 Plastic

Plastic is a polymer which has unique and extraordinary properties. PET materials such as plastic bottles and plastic cups were used. Plastic waste was collected from houses and schools. The collected PET materials were chosen with a maximum thickness of 60 micron. This would facilitate mixing them with asphalt at the laboratory under its softening point. Also, in order to provide appropriate plastic particles, the bottles and cups were cleaned then slashed into small pieces then crushed and sieved such that it passes through 3-5 mm sieve using shredding machine (Naghawi H. at al, 2018). Asphalt and plastic waste coated aggregates caused by the intermolecular bonding which improves asphalt mix strength. This would be reflected in the enhanced durability and stability of the asphalt mix which would lead to enhancing pavement resistance to fatigue cracking and rutting or permanent deformation (Naghawi, Ajarmeh, Allouzi, & Alklub, 2018).

The local recycled wastes (PP, HDPE and LDPE) were identified and handpicked from Dammam municipality recycling programme. The processing involved washing, shredding and grinding (Dahlat M. et al, 2016). The effect of polypropylene, high-and low-density polyethylene (PP, HDPE and LDPE)-recycled plastic wastes (RPW) on the viscoelastic performance of the local asphalt binder has been investigated. The recycled plastics were obtained by shredding and grounding the RPW to a desirable size for easier blending with the asphalt binder (Dahlat & Wahhab, 2015). Recycled plastic wastes (RPW) such as polypropylene (PP), polyethylene (PE) packages and polyvinyl chloride (PVC) has been previously utilised to enhance the performance of asphalt concrete (AC) (Dahlat & Wahhab, 2015).

Polypropylene when interacted with 80 pen base bitumen enhances its performance characteristics which were brought about by altered rheological properties of the modified bitumen (Habib, Kamaruddin, Napiah, 2011). Polypropylene can be found in food packaging, microwave-proof containers, pipes, and automotive parts. It has been used as a mixture modifier through the wet process in percentages that range between 0.5% and 11% by weight of bitumen, while the most common percentage used for the production of RPMB ranges between 3% and 5% (Brasileiro et al, 2019).

Figure 1: Plastic Bag from Pupuk Kaltim Company.

In this study, 3 specimens were made from each sample on variations in the asphalt content of the plan, namely 4.7%, 5.2%, 5.7%, 6.2% and 6.7% to find the optimum asphalt content value. The number of tests as many as 15 samples. After getting the optimum asphalt content, then making test specimens with 5 variations of plastic content as additional material in asphalt with variations of 2%, 3%, 4%, 5%, and 6%, the number of specimens as many as 15 samples. Before making the sample, the plastic bag is cut into pieces with a size of 0.5-1.0 cm and then considered according to the composition of the mixture that has been determined. Designing the composition of the mixture and then making a bricket sample, then Marshall testing is carried out to determine the Marshall properties and characteristics of the asphalt mixture. The number of test objects as many as 30 samples of the bricket.

3 RESULTS AND DISCUSSION

3.1 Result of Testing Material

Based on the results of testing in the asphalt testing laboratory, the values of specific gravity, penetration, softening point and ductility meet the requirements of asphalt, then the results of testing the physical characteristics of aggregates that meet the requirements of technical specifications can be seen in the following tables.

Table 1: The Result of Asphalt properties.

No.	Type of testing	Requirement	Result
1	Penetration, 25ºC	60-70	68.2
2	Softening point (ºC)	Min. 48	51.63
3	Ductility 25ºC (cm)	Min. 100	125
4	Spcific Ggrafity	Mi. 1	1.031

Table 2: The results of testing the specific gravity and absorption of coarse aggregate.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.64
Saturated surface dry (SSD)	Min. 2.5	2.66
Apparent density	Min. 2.5	2.70
Absorption	Maks. 3%	0.77
Abration	Maks. 40%	20.63

Table 3: The results of testing the specific gravity and absorption of fine aggregate.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.65
Saturated surface dry (SSD)	Min. 2.5	2.68
Apparent density	Min. 2.5	2.73
Absorption	Maks. 3%	1.01

Table 4: The results of testing the specific gravity and absorption of Palu sand.

Type of testing	Requirement	Result
Dry bulk density	Min. 2.5	2.55
Saturated surface dry (SSD)	Min. 2.5	2.60
Apparent density	Min. 2.5	2.68
Absorption	Maks. 3%	1.83

3.2 Calculation of Optimum Asphalt Content

Based on the results of calculations starting from the combined gradation to find the composition of the mixture, it was obtained that the design asphalt content was obtained with variations of 4.7%, 5.2%, 5.7%, 6.2% and 6.7%. After that make a sample with 3 pieces in each variation of asphalt content so that the number of samples is 15 pieces. From the results of the marshal test, the asphalt content value is 6.20%, while the results of the Marshall characteristic test can be seen in table 5 below.

Table 5: The Results of Marshall Characteristic Asphalt Concrete – Weraing Course.

Asphalt (Pb) (%)	4.70	5.20	5.70	6.20	6.70	Spec.
Stability(kg)	1,181	1,350	1,1383	1.381	1,330	Min. 800
Flow (mm)	2.96	3.39	3.913	3.587	3.717	2 – 4
VIM (%)	3.020	3.038	3.292	3.695	3.762	3 – 5
VMA (%)	12.29	13.42	14.02	14.73	17.26	Min. 15
VFA (%)	75.83	78.32	79.06	78.17	78.84	Min. 65
MQ(kg/mm)	403	412	354	391	358	Min. 250

3.3 Marshall Characteristic

After getting the Optimum Asphalt Content value of 6.20%, then making samples with variations of plastic bag of 2%, 3%, 4%, 5%, and 6%, while the relationship between adding plastic bag and Marshall characteristics can be described as follows:

3.3.1 Relation of Plastic Bag Waste with Stability

Stability is the ability of the road pavement layer to accept the load without deformation in accordance with the planned traffic load level. Low stability will facilitate the occurrence of deflection, on the other hand, too high stability can cause the mixture to become stiff and cause the mixture to crack relatively quickly. Stability occurs due to shear between grains, locking between aggregates and the binding capacity of the asphalt.

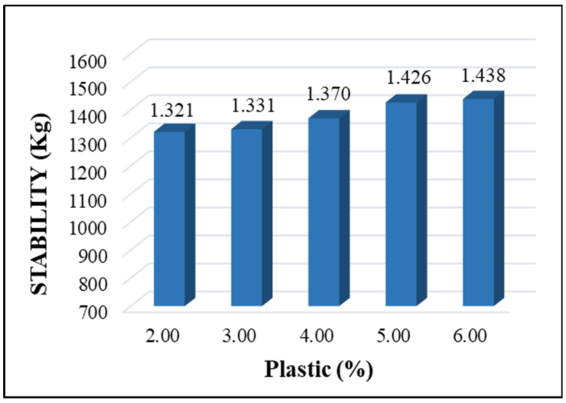

Figure 2: Graph of the relationship between stability and variations in use of plastic bags.

Figure 2. Shows that with various variations in the content of plastic bag it can show an increasing trend. This is because plastic waste at the time of mixing and compaction of some plastics has occurred, causing obstacles to one another which can increase the effect on high values. The highest stability was achieved by a mixture of 6% asphalt content, which was 1438.49 kg, while the lowest stability value was achieved by a mixture of 2% plastic content with a stability value of 1321.36 kg. All variations of this grade of plastic bag content have met the specification requirements.

3.3.2 Relation of Plastic Bag Waste with Flow

Flow is the amount of deformation that occurs in the pavement layer due to holding the load it receives. Good mix density, sufficient asphalt content and good stability will have an effect on decreasing the flow value. A low flow value can cause the mixture to become stiff so that the pavement layer becomes easy to crack, while a high flow value will produce a plastic pavement layer so that the pavement will easily deform such as waves (wash boarding) and grooves (rutting).

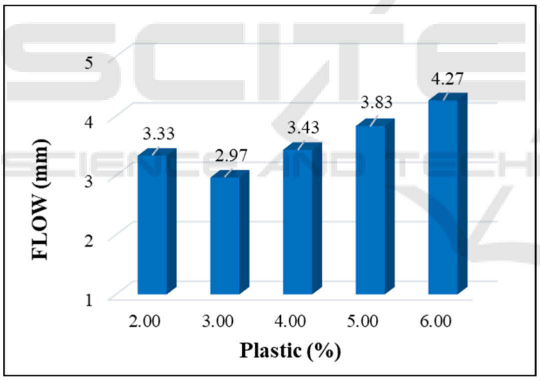

Figure 3: Graph of the relationship between Flow and variations in use of plastic bags.

Based on Figure 3 shows that the addition of plastic bag into the concrete mixture can increase the value of melting, the more the addition of plastic bags, the higher the melting value of the test object. The average flow value of the mixture with a plastic bag content of 2%, 3%, 4%, 5%, 6% was 3.33 mm, 2.97 mm, respectively. 2.93 mm, 2.77 mm, 3.63 mm, while the flow value without plastic mixture is 3.9%. The flow value at the highest plastic bag content was obtained 6%, which was 4.27 mm but did not meet the requirements of the 2018 General Specifications, namely a minimum of 2.0 mm and a maximum of 4.0 mm and the lowest value in the mixture of adding 3% plastic bag, which was 2.97 mm.

A mixture that has a flow value that is too high can cause the aggregate grains to be more easily shifted from their position, this shows that the locking properties between aggregates are low so that the aggregates easily shift when loaded with traffic. However, if the amount of compaction is increased, the asphalt mixture will become denser so that the vertical deformation decreases.

3.3.3 Relation of Plastic Bag Waste with Void in Mixture (VIM)

Voids in the mixture (VIM) is the percentage of voids present in the total mixture. The VIM value affects the durability of the pavement, the higher the VIM value means the larger the cavity in the mixture. This causes the mixture to become less dense so that water and air can easily enter the cavities in the mixture and cause the mixture to be porous. VIM value that is too low will cause bleeding due to high temperatures, so asphalt viscosity will decrease according to its thermoplastic properties.

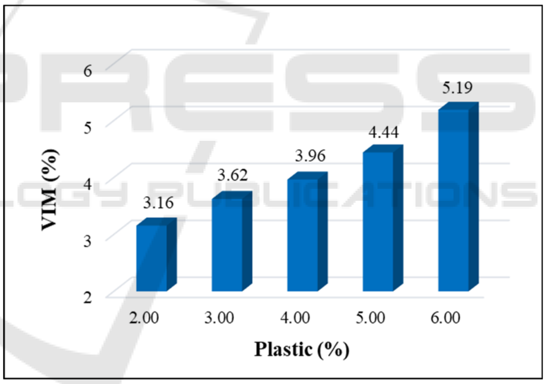

Figure 4: Graph of the relationship between VIM and variations in use of plastic bags.

Figure 3 shows that the value of VIM has increased with respect to the addition of plastic bag content. The highest VIM value is the addition of 6% plastic sack content, which is 5.19% but does not meet the requirements of the 2018 General Specifications, which is a minimum of 3% and a maximum of 5%. mm while the lowest value for adding 2% plastic bag content is 3.16%, this is due to the increasing levels of plastic bag causing the asphalt to not optimally fill the voids in the aggregate because it has a larger cavity and the less asphalt content is filled making the mixture less dense because interconnected and broken aggregates due to imperfect compaction process.

3.2.4 Relation of Plastic Bag Waste with Void in Mineral Agregat (VMA)

Voids Mineral aggregate (VMA) are air voids that exist between the particles of the asphalt aggregate mixture that have been compacted including the space filled with asphalt which is expressed in percent of the total volume of the mixture. The expected value of VMA in the asphalt mixture is the minimum possible, with the aim of providing sufficient space for the asphalt to adhere to the aggregate.

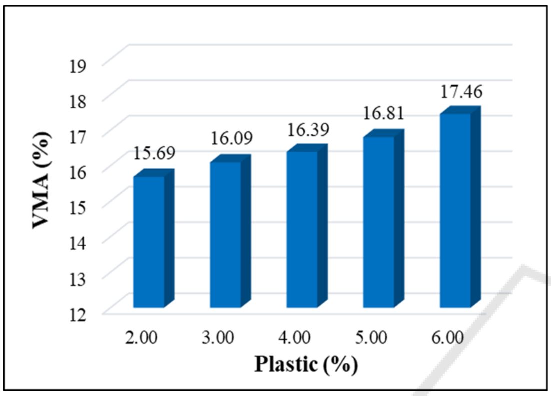

Figure 5: Graph of the relationship between VMA and variations in use of plastic bags.

Figure 5 the basic material that adding the value of plastic bag as an added causes VMA to tend to increase with the addition of plastic bags. The VMA values for plastic content of 2%, 3%, 4%, 5%, 6% were 15.69%, 16.09%, 16.36%, 16.81%, 17.46%, respectively. A VMA value that is too high indicates that the air voids between mineral aggregates are larger, this condition will cause the pavement to not last long. The VMA results still meet the requirements of the 2018 Bina Marga General Specification for the mixture, which is at least 15%.

3.2.5 Relation of Plastic Bag Waste with Void Filled with Asphalt (VFA)

Void filled with asphalt (VFA) is the percentage of the void that can be filled with asphalt. The higher the VFA value, the more voids in the mixture filled with asphalt, so that the mixture's resistance to water and air is also higher, but VFA value that is too high will cause bleeding. VFA value that is too small will cause the mixture to be less impermeable to water and air because the asphalt film layer will become thin and will crack easily when receiving additional loads so that the asphalt mixture is easily oxidized which ultimately causes the pavement layer to not last long.

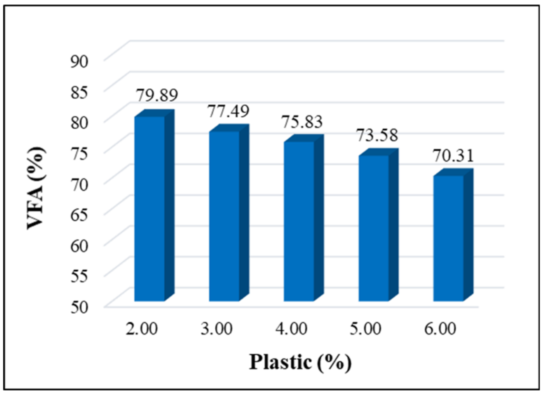

Figure 6: Graph of the relationship between VMA and variations in use of plastic bags.

Figure 6 shows that the VFA value decreased along with the addition of plastic bag, namely 6% by 70.31% while the VFA value of normal asphalt content without plastic mixture was obtained at 79%. The VFA value for each plastic bag content still meets the general specifications for 2018 which is at least 65%. VFA value that is too high will cause bleeding.

3.2.6 Relation of Plastic Bag Waste with Marshall Quotient (MQ)

Marshall Quotient (MQ) is the quotient between stability and flow. Marshall Quotient value will give mixed flexibility value. The larger the Marshall Quotient value, the more rigid the mixture will be, conversely the smaller the Marshall Quotient value, the more flexible the mixture will be.

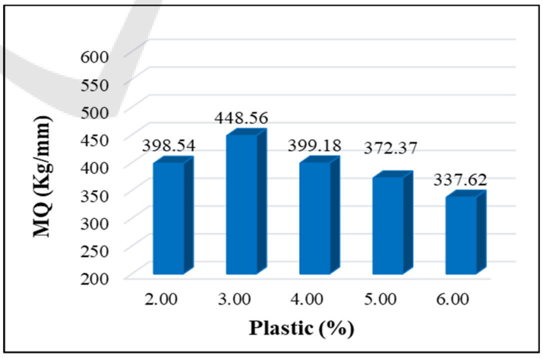

Figure 7: Graph of the relationship between MQ and variations in use of plastic bags.

Based on Figure 7 shows that the use of plastic bags resulted in the Marshall Quotient value decreased. The highest Marshall Quotient value was at 3% plastic sack content, which was 448.56 kg/mm, while the MQ value at normal asphalt content without mixture was 390%. The Marshall Quotient value shows a decrease because as the percentage of the addition of plastic bags to asphalt increases, this indicates that the mixture tends to become stiff when the asphalt mixture increases in the amount of compaction.

4 CONCLUSIONS

The test results of the Asphalt Concre – Wearing course (AC-WC) with addition of plastic bag can affect the value of Marshall characteristics. Based on the test results, the optimum asphalt content value is 6.20% with stability value = 1381 kg, flow = 3.587 mm, VIM = 3.695%, VMA = 14.73%, VFA = 78.17%, and MQ = 391 kg/ mm and a maximum plastic content of 5%, with stability value = 1426 kg, flow = 3.83 mm, MQ = 315.85 kg/mm, VIM = 4.44%, VMA = 16.81%, VFA = 73.58%. The addition of plastic bag can increase the value and durability of Asphalt Concrete mixture.

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