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The Effect of Plastic Bag Waste on the Durability of Asphalt Mixture

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Abstract*—The amount of plastic waste that continues to increase is an important matter of concern in East Borneo. Several ways are carried out to reduce it, namely making plastic waste as an asphalt additive to changing the physical properties of asphalt, increasing hardness, and sensitivity to temperature and reduce peeling and the level of pavement damage. Previous studies have carried out the addition of plastic residue to asphalt mixtures. This study conducted tests intending to determine the level of resistance and stability of asphalt mixtures to immersion, by determining the optimum asphalt content and maximum plastic waste content. The test method used was the Marshall standard test by looking for the Index of Retained Strength (IRS) value between the standard 30-minute Marshall immersion with variations of 1 day, 2 days, 3 days, 4 days, 5 days, and 6 days of immersion. Results of this research it was obtained that the maximum immersion value that met the specifications was at the age of 5 days with an Index of Retained Strength (IRS) value of 90.15%. While the maximum immersion time in the mixture without the addition of plastic bag waste is 4 days with a retention strength index value of 90.51%. The addition of waste plastic can increase the durability value when compared to ordinary asphalt mixtures*.

***Keywords*—** *Asphalt Mixture, Plastic bag waste, Marshall, Index of Retained Strength.*

I. INTRODUCTION

Asphalt concrete consists of at least binder and rock. A typical weight ratio is about 95% aggregate and 5% binder. Volume fractions are typically 88% and 12% [1]. Hot mix asphalt is asphalt made from aggregate and bitumen which is mixed with a high-temperature heating process carried out at an asphalt mixing plant, the hot asphalt mixture is spread to the base layer to the subgrade and then compacted. Hot mix asphalt consists of several types, namely sand sheet (SS), hot rolled sheet (HRS), and asphalt concrete (AC) [2]. The constituent materials of hot mix asphalt consist of asphalt, fine aggregate, coarse aggregate, and filler.

All the materials to mix properly, it is necessary to carry out material tests and gradations in each aggregate size that meet the specifications for hot mix asphalt work to obtain a mixture that has good quality as planned. All types of hot mix asphalt are designed by considering the asphalt fraction, stability, flow, voids in the mix, the porosity of the asphalt content, and the type of traffic [2]. Water is one of the main risk factors for asphalt concrete pavements. The rate and extent of damage to asphalt concrete pavements are exacerbated by the combined impact of vehicles and spray [3]. The construction of flexible pavement is an expensive investment. Many methods are currently being investigated to improve the performance of asphalt mixtures [4]. Hot mix Asphalt is a type of flexible pavement formed by mixing bitumen and aggregate in a specific ratio and compressing the resulting mixture at specific temperatures [5].

Every day, and these plastics end up in landfills. Although it can take years to decompose in a landfill, it never fully decomposes into particles that can be used in nature. This makes plastic one of the worst sources of pollution [6]. Environmental and climatic conditions are two very important factors that influence the flexible asphalt pavement of roads. To address this environmental issue, several research studies have been developed on various recycling technologies and the incorporation of plastic waste into bitumen and asphalt mixtures [7].

The plastic bag waste used in this study came from the Pupuk Kalimantan Timur Company. A problem is a large number of unused plastic bags due to the abundance of raw packaging, production errors such as misspellings of serial numbers, and torn or damaged plastic bags before use. So that the fund management company has problems minimizing the presence of the remaining plastic bags, several options are almost ready to burn the waste, which naturally causes pollution or air pollution around them, in which case the management is forced to remove, the remaining waste. outside the area and it requires a large fee very big. Based on these problems, it is necessary to investigate how many plastic bags affect the performance of mixed asphalt pavements. That it is hoped to reduce the generation of plastic bag waste and to reduce environmental pollution, which can harm health both in the short and long term.

A. Asphalt

Asphalt is a mixture consisting of bitumen and minerals, which is widely used in the construction of flexible pavement layers it functions as a mixture of aggregate binding agents because it has strong adhesion, is adhesive, water-resistant, and easy to crack. Bitumen is also a mixture of about 300-2000 chemical constituents, averaging about 500-700, and is the heaviest and highest boiling (525°C) fraction of crude oil. In recent years, with the rapid development of the global transportation industry, the proportion of asphalt pavement in road construction is increasing. Therefore, as the demand for asphalts and asphalt mixtures increases, so do the quality requirements of the materials [8]. Asphalt is the product of a mixture of binders, aggregates, and fillers. Asphalt is the product of a mixture of binders, aggregates, and fillers. It is used both in the construction and maintenance of roads, sidewalks, and sometimes parking lots [9].

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Asphalt is thermoplastic, asphalt will soften or become liquid when heated to a certain temperature, when the temperature starts to drop, the asphalt will harden and stick, when asphalt is sprayed or mixed with crushed stone, at hot temperatures, the aggregate will harden and infiltrate into the aggregate pores. Asphalt is an expensive material, as a flexible pavement material, the use of asphalt material is very small, usually only 4-10% of the total weight or about 10-15% of the total volume of the mixture. Asphalt is used as aggregate as a binder and acts as a filler and stabilizer in asphalt mixtures. Asphalt fills gaps and thus provides impermeability and particle adhesion [10].

B. Aggregate

Aggregates or granular materials are granular solid materials, these materials include round aggregate, crushed aggregate, sand, and limestone. Aggregate is the main component of flexible road surfaces. As their share is about 90-95% of the total weight of hot mix asphalt. There are two types of aggregates, coarse aggregate, and fine aggregate, depending on the size of the material. Coarse aggregates are tightly compacted granular aggregates such as gravel, quarry, rock ash, and sand. Fine aggregates are natural sand, artificial sand, blast furnace slag, or a combination of thereof. Fine aggregates should be clean, dry, hard, free of clump clay or interfering substances, and consist of sharp edges, and rough surfaces [2]. Coarse and fine aggregates used in this study came from Palu of Central Sulawesi.

C. Plastic

The use of plastic today is inseparable from human life, one of the problems is the disposal of plastic waste. Not only the environmental, impact of plastic also affects health conditions. Plastic is a non-organic material that is difficult to decompose, causing pollution [11]. The increase in plastic products causes the accumulation of plastic waste. Indonesia ranks first among the two countries in terms of plastic waste dumping into the sea [12]. Plastic is used in almost every sector of the economy, its use tends to increase along with the development growth, which also affects the increase in the amount of plastic waste [13]. Currently, several studies are trying to find ways to reduce the amount of plastic waste, one of which is its use in asphalt mixtures. Plastic bags can be used as an addition to high-temperature bitumen [11]. Plastic is not a biodegradable material and is considered a major environmental pollutant. Therefore, it would be beneficial if plastic waste could be reused in road construction [14].

Plastics are polymers with unique and extraordinary properties. Pavement construction is increasing from time to time in line with the economic growth of the region. A large amount of material is required. Traditionally, materials were taken from natural sources. Long-term exploration of natural resources can damage the environment and destroy ecosystems [15]. The collected polyethylene terephthalate (PET) material was chosen to have a maximum thickness of 60 microns. In other cases, the PET fibers were cut into short lengths of 4.0 to 6.0 mm. It is mixed with bitumen as an additive. Adding PET fiber as an additive improves binder properties and overall blending properties [16]. This makes it easier to mix with asphalt below its softening point in the laboratory.

Plastic waste represents a significant and growing environmental problem and includes industrial plastics, plastic bags, and PET bottles [18]. Plastic is made from materials with the basic type of polyethylene (PE), polyethylene is composed of three types of plastic, namely high-density polyethylene (HDPE), low-density polyethylene (LDPE), and low-density polyethylene (LLDPE). Grocery bags are made of HDPE. Dry cleaning garment bags are made of LDPE [17]. Locally recycled waste (PP, HDPE, and LDPE) was identified and selected from the recycling program of Dammam Municipality. This waste was treated to facilitate mixing. Waste plastics can be used in hot mixes to improve the physical properties of bituminous aggregate mixtures by the "dry method" or the "wet method" [18]. Plastic bag waste used in this study were woven sacks made of polypropylene threads which were cut to a size of 0.5 - 1.0 cm as an additive to asphalt in asphalt mixtures.

Fig. 1. Plastic bag waste

Any plastic that melts when mixed creates water droplets on the asphalt. Since the plastic melt does not dissolve in the asphalt binder, the melt creates a distinct phase within the liquid that persists as the mixture cools. This is because the viscosity of the polymer is significantly higher than that of the asphalt binder [1]. Results that incorporating a small amount (5-10% by weight) of plastic into the bituminous mixture (asphalt) improves pavement stability, strength, and durability [19] Water is one of the main risk factors for asphalt concrete pavements. Hot Mix Asphalt (HMA) is considered an ideal place to recycle plastic waste for high-value applications due to its heavy use in road construction [20]

D. Immersion Stability

The rate and degree of asphalt pavement deterioration are intensified by the joint effect of vehicles and spray. Marshall residual stability was obtained by comparing the stability values at 60 °C and 24 h immersion time with those at 60 °C and 30 min immersion time. A road layer needs Marshall residual stability so that the layer can withstand the effects of wear caused by weather, water, temperature changes, or vehicle friction.

The ratio of immersion stability to standard stability, expressed as a percentage, is called the Index of Retained Strength (IRS) and can be calculated using equation.

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$$IRS = \left[\frac{MS_2}{MS_1}\right] x\ 100$$

Where:
S1 = Compressive strength of dry specimens.
S2 = Compressive strength of immersed specimen.

E. Durability

Durability of an asphalt mixture is the ability of an asphalt mixture to maintain its quality and performance over a certain period of time even though it is exposed to various environmental factors, traffic loads and weather conditions. Durability value is a crucial factor in assessing the durability and dependability of an asphalt mixture. Of particular interest is the durability which represents the resistance to stripping, i.e., the moisture damage and the fatigue resistance [20]

II. METHODOLOGY

This study was conducted at the Samarinda State of Polytechnic Materials Laboratory. This study will be tested in stages consisting of testing the physical and chemical properties of asphalt, coarse aggregate, fine aggregate, and filler, as well as plastic bag waste and making specimens for the Marshall test. Next, mix plastic as an additive to asphalt with variations of 2%, 3%, 4%, 5% and 6% to obtain the maximum plastic content value that can be used in the mixture, then from the results obtained an immersion sample is made to test the strength index. remaining with a soaking time of 2 days, 3 days, 4 days, 5 days, and 6 days and carry out the Marshall test. Asphalt durability test by immersion with several variations that have been defined The research stages can be seen in Figure 2 below:

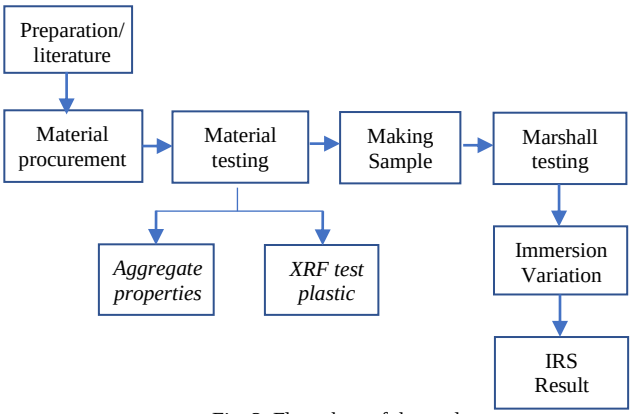

Fig. 2. Flow chart of the study

III. RESULT AND DISCUSSION

A. Material Properties

In this study, to obtain asphalt mixture results that are following the specification standards, it is necessary to test the material properties as a constituent of the asphalt mixture. with material that meet standards spesification will affect the strength and quality of the asphalt mixture 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, The results of the asphalt properties test can be seen in Table I.

TABLE I. Physical properties of asphalt

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	Specific Gravity	Mi. 1	1.031

Then the results of testing the physical characteristics of coarse aggregates that meet the requirements of technical specifications can be seen in the following Table II.

TABLE II. Physical properties of course aggregate

No.	Type of testing	Requirement	Result
1	Dry bulk density	Min. 2.5	2.64
2	Saturated surface dry	Min. 2.5	2.66
3	Apparent density	Min. 2.5	2.7
4	Absorption (%)	Max. 3	0.77
5	Abrasion (%)	Max. 40	20.63

The results of testing the physical characteristics of fine aggregates that meet the requirements of technical specifications can be seen in the following Table II.

TABLE II. Physical properties of fine aggregate

No.	Type of testing	Requirement	Result
1	Dry bulk density	Min. 2.5	2.65
2	Saturated surface dry	Min. 2.5	2.68
3	Apparent	Min. 2.5	2.73
4	Absorption (%)	Max. 3	1.01

B. Marshall Characteristic for Plastice

Asphalt mixtures that use plastic as an additive are subjected to Marshall testing. Marshall testing included: stability, flow, VIM, VMA, VFB and MQ. Based on the results of the Marshall test and calculation of the planned asphalt content with variations of 4.5%, 5.0%, 5.5%, 6.02%, and 6.5% starting from the gradation of the mixture to determine the composition of the mixture. Obtained optimum asphalt content of 5.50% can be seen in Figure 3.

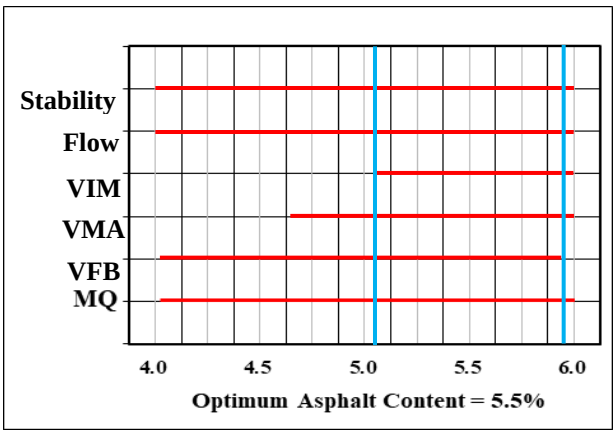

Fig. 3. Optimum Asphalt Content

After the process of mixing asphalt, aggregate, and plastic bag waste, the Marshall test was then carried out to determine the characteristics of the asphalt mixture. This test is also carried out to determine the maximum beg plastic content in accordance with technical specification standards and as a standard mixture which becomes a reference for the next

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immersion sample mixture. The results of testing the characteristics of the asphalt mixture Marshall added with plastic bag waste can be seen in the following Table III.

TABLE III. Marshall Characteristic with add plastic bag waste

Marshall Parameter	Plastic bag waste (%)					Specification	
	2	3	4	5	6	Min.	Max
OAC (%)	5.5					-	-
Stability (kg)	1448,98	1516,41	1527,51	1585,06	1511,76	800	-
Flow (mm)	2,0	2,6	3,4	3,1	3.9	2	4
VIM (%)	3,75	4,00	4,27	4,44	4,84	3	5
VMA (%)	14,13	14,35	14,58	14,74	15,09	14	-
MQ (kg/mm)	738,29	685,43	450,57	604,19	384,69	250	-
VFA (%)	73,44	72,23	70,87	70,07	67,99	65	-
Density (gr/cc)	2,359	2,353	2,3426	2,342	2,332	-	-

Based on Table III, the Marshall characteristic values for plastic content of 2%, 3%, 4%, and 5% still meet the requirements, and plastic content values of 6% the flow and VIM values do not meet the specification requirements, so the maximum plastic content selection is 5%.

C. Index of retained strength (IRS)

The following are the results of the immersion tests that have been carried out between the normal asphalt mixture and the asphalt mixture with the addition of plastic bag waste with the same immersion variation and the results are presented in Table IV. Stability Marshall normal mixture = 1472 kg and addition of plastic bag waste = 1496 kg, minimum Index of Retained Strength standard 90%.

TABLE IV. Index retained strength normal sample with add plastic

Index Retained Strength (IRS)				
Asphalt Mixture				
Standard Immersion			1585.06	kg
Minimum Standard			90	%
Object sample		Stability	Index retained strength (IRS)	Average
Day	Sample			
2	1	1506.43	95.04	95.95
	2	1554.00	98.04	
	3	1502.31	94.78	
3	1	1434.30	90.49	90.01
	2	1419.82	89.58	
	3	1426.00	89.97	
4	1	1412.33	89.10	88.05
	2	1395.38	88.03	
	3	1379.24	87.02	
5	1	1256.09	79.25	76.76
	2	1190.56	75.11	
	3	1203.31	75.92	
6	1	1097.70	69.25	65.58
	2	1018.99	64.29	
	3	1001.60	63.19	

Based on the Table IV, the longer immersion time will reduce the resistance and stability of the mixture, Index of retained strength value of the asphalt mixture with the addition of plastic bag waste is higher than the normal asphalt mixture. The immersion graph can also be seen in the figure 3 below:

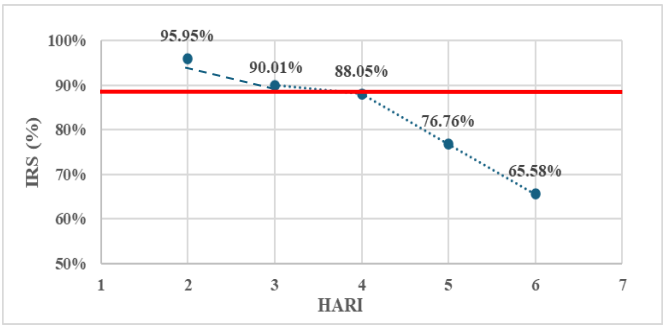

Fig. 3. Graph of Immesion Value

IV. CONCLUSION

Based on the research results, it was found that the immersion compliance value limit that still met the standard limits was on the 3rd day of immersion with a value of 90.01%. Adding plastic to the asphalt mixture will strengthen the bond between the asphalt and the aggregate, providing a high level of durability and stability to the mixture. There are similar properties between asphalt and plastic, namely thermoplastic. The addition of plastic to the asphalt mixture will add voids to the mixture,but is still within the required technical specification standards. The addition of plastic to the asphalt mixture also increases the durability and longevity of the bond between the asphalt and the aggregate as part of the asphalt.

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