Increasing the Stability of Asphalt Concrete Mixture Using Crumb Rubber

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Abstract. Stability is a measure of the strength of an asphalt mixture in resisting deformation due to loading. If a road construction structure cannot withstand the existing load, it will result in road damage that endangers road users. This study aims to improve the stability of the asphalt concrete mixture with the use of crumb rubber. Crumb rubber is used because it has good resistance and elasticity. The research was conducted experimentally by making test objects in the laboratory. In this study, five variations crumb rubber (2%, 4%, 6%, 8%, and 10% of the weight asphalt mixture) were carried out with the size of the powder retained on a 40 sieve. Marshall test and analysis of volumetric was carried out to determine the characteristics of the asphalt-concrete mixture. The results showed that the highest Marshall stability was obtained at 10% crumb rubber with a stability value of 1422 kg. The use of rubber powder can significantly increase the strength and quality of the asphalt-concrete mixture. Thus, crumb rubber can be used, and this percentage can be used as a reference in the manufacture of asphalt-concrete mixtures in order to obtain good road pavement quality.

Keywords: Asphalt Concrete, Crumb Rubber, Marshall Stability, Road Constructions

1 Introduction

Asphalt Concrete is a mixture composed of aggregates, filler materials, and asphalt as a binding material [1]. Asphalt Concrete is used as a road pavement material with light, moderate, to heavy traffic. Asphalt Concrete has watertight properties so that it can protect the construction under it. There needs to be the design of the correct Asphalt Concrete mixture to get good pavement quality. The planning includes the selection of materials to determine the use of added materials [2].

Improper design of the mixture will affect the characteristics and quality of the Asphalt Concrete mixture. This causes the combination not to work correctly. The material design must meet several characteristics and behavior, economics, and environmental impact [3]. The elements of Asphalt Concrete consist of several properties that must be met, including stability, flexibility, durability, resistance to melting, workability, impermeability, and surface fatigue [4]. Stability in road pavement is defined as the ability of paved mixtures to resist changes due to load. If the pavement layer cannot serve the load received, there will be permanent changes such as bumpy. Cracks can also occur as a result of repeated loads [5].

Improvement efforts and quality improvements can be done with the use of added materials. Crumb rubber

can be used as an alternative in improving the quality of Asphalt Concrete mixtures. Crumb rubber are products obtained from used tire waste that has an essential role in increasing elasticity in Asphalt Concrete mixtures [6][7]. The increase in modes of transportation and transportation users makes an increase in rubber tire waste [8]. Crumb rubber has good sticking properties, are durable, resistant to gasoline and oil, and resistant to weather. Crumb rubber can be produced through the milling process or shredded to make a certain size Crumb rubber [9]. In addition to rubber as the main constituent element, Crumb rubber also contains silicate, sulfur, and carbon elements [10]. The use of Crumb rubber as an Asphalt Concrete mixture can provide several benefits, such as reducing traffic noise, improving pavement performance, and reducing costs [11]. In addition, the use of Crumb rubber with suitable composition and proportions will provide advantages in improving the performance of asphalt mixtures, such as reducing shape changes, increasing attachment to increase resistance to cracks [12]. It can be used to repair the damage that generally occurs in the layer of Asphalt Concrete that is cracked. The injury occurs because the Asphalt Concrete mixture has a high level of stiffness.

Several studies on the use of Crumb rubber as Asphalt Concrete mixtures have been widely used and developed. The results showed that the use of crumb rubber affects the characteristics and quality of Asphalt

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Concretemixtures [13][14]. However, the use of crumb rubber with a percentage of 2%, 4%, 6%, 8%, and 10% of the weight of the asphalt mixture and the percentage effect to marshall stability has not been developed enough. Asphalt Concrete is often applied as a surface layer, leveling layer or binding layer.

2 Research Method

Research is carried out by experimental methods, namely by making test objects in the laboratory. The test object used was cylindrical in diameter of 10.15 cm and a height of 7.5 cm (4x3 inches). Crumb rubber is utilized by adding the material to the Asphalt Concretemixture with a percentage of 2%, 4%, 6%, 8%, and 10% of the weight of the asphalt mixture. Marshall testing is done to find out the characteristics of the Asphalt Concrete mixture. In this study, the mixing of Crumb rubber was done with a dry process system that is by mixing Crumb rubber and aggregates before mixing with asphalt [15][16][17].

2.1 Research Materials

The material used consists of aggregates, namely fine aggregates and coarse aggregates, fillers in the form of cement, binding materials in the form of asphalt, and added material in the form of crumb rubber with the following entries:

2.1.1 Aggregate

The aggregates used are fine aggregates and coarse aggregates. Fine aggregate in the form of Lumajang sand with the size of escape filter no. 8 and retained filter no. 200 (0.075 mm). While the coarse aggregate used in the form of coral is held in filter no. 8 (2.38 mm). In fine aggregates, tested water content, mud content, type weight, and absorption. While on coarse aggregates conducted weight testing type, absorption, and wear level [18].

2.1.2 Asphalt

Asphalt in Asphalt Concrete mixture serves as a binding material. Asphalt is an adhesive that will soften or melt when heated [19]. This study used asphalt penetration of 60/70 and tested the ductility, flash point, and weight of asphalt type.

2.1.3 Filler

The filler material in Asphalt Concrete mixture can be cement, light ash, and others. The filler used must pass filter no. 200 (0.075 mm). The use of filler material in Asphalt Concrete mixtures is intended to fill cavities in the mix and increase the connective power of concrete asphalt. Fillers in this study are used Portland Cement Type I [20].

2.1.4 Crumb Rubber

Crumb rubber is one type of rubber obtained from the processing of used tire waste [21]. Crumb rubber used in the study consisted of a particle with a retained size of 4.75mm stuck in filter no. 4.

2.2 Mixed Planning

Mix planning aims to determine the proportion of the mixture to obtain a mix that matches the specified specifications. Some things to do in planning mixture is to know the following elements:

- Maximum type weight= $\left\{100 \left(\frac{\%agr.}{B.J\ agr.} + \frac{\% asphalt}{B.J\ asp} \right) \right\}$
- Sample Weight = $\frac{C}{F}$
 In eq:
 C : weight of contents
 F : weight when saturated
- Asphalt Weight (Gb) = $Pb \times Bj\ max$
 In eq:
 Pb : heavy type of asphalt
 Bj max : Maximum type weight
- Aggregate weight= $G - Gb$
 Dimana :
 G : Sample Weight
 Gb: Asphalt Weight

2.3 Marshall Test

Marshall testing is done by the test object suppression method. The marshall test is performed to obtain the stability and exhaust values of the Asphalt Concrete mix test object. In addition, from marshall testing will be known the density and pores of the test object. Marshal tool is equipped with proving ring (test ring) and flowmeter that serves to measure the value of stability; flowmeter also operates to see plastic or flow. The Marshall test results will be obtained stability values and volumetric characteristics [22][11].

Fig. 1. Marshall Test

2.3.1 Void In Mix (VIM)

Void in the mix is the percentage of total air volume present in the aggregate covered in asphalt in the test

object. The following formula can calculate VIM percentage:

$$VIM = [1 - \frac{Gse}{BJ_{max}}] \times 100 \%$$

$$Gse = \frac{Pmm - Pb}{\frac{Pmm}{BJ_{max}} - \frac{Pb}{Gb}}$$

In Eq:

- VIM = mixed air cavity (%)
 Gse = Effective aggregate type weight
 Pmm = Percentage of total weight of the mixture (=100)
 BJ max = Maximum mix type weight
 Pb = Asphalt content
 Gb = Weight of asphalt type

2.3.2 Void in Mineral Aggregate (VMA)

Void in mineral aggregate is the percentage of cavities between grains of Asphalt Concrete mixture. The value of the VMAs will increase as the asphalt blanket increases. The following formula can calculate the percentage of VMAs:

$$VMA = 100 - \frac{100 - P}{Gsb} \times Gmb$$

In Eq:

- VMA = Pore size between aggregate grains on Asphalt Concrete(%)
 Gsb = Total type weight of dry aggregates
 Gmb = Dry mix volume weight (gram/cm³)

2.3.3 Void Filled with Asphalt (VFA)

Void Filled with Asphalt is a percentage of cavities among the aggregate minerals filled with effective asphalt. The following formula can calculate the percentage of VFA:

$$VFA = \frac{100(VMA - VIM)}{dVMA} \% \times VMA$$

Dimana:

- VFA = Pore size between aggregate grains containing asphalt
 VMAs = Pore size between aggregate grains on solid Asphalt Concrete(%)
 VIM = volume of air cavities in the mixture (%)

2.3.4 Marshall Stability

Stability is the ability of the Asphalt Concrete mixture to receive loads until fatigue occurs. The following formula can calculate the stability value:

$$\text{Stability} = O \times E' \times Q$$

In Eq:

- O = stability watch reading (Lbf)
 E' = Sample volume correlation number
 Q = Marshall tool calibration

2.3.5 Flow

Flow indicates the value of the decrease or deformation that occurs in the Asphalt Concrete mixture due to withstanding the load it receives a reduction. Flow

values are obtained from readings on the Marshall test tool.

2.3.6 Marshall Quantity

Marshall quantities are approach values that indicate the rigidity value of an Asphalt Concrete mixture. The MQ value is obtained from the comparison of stability values and fatigue values with the following description:

$$MQ = \frac{S}{F}$$

In Eq:

- S = Stability (kg)
 F = Flow value (mm) [23]

3 Result and Discussion

3.1 Aggregate Testing Result

Aggregate testing is conducted on fine aggregates and coarse aggregates. The tests carried out include weight testing of type, absorption, and wear and tear with the following description:

Table 1. Aggregate Testing Result

No	Type of Testing	Specification	Value
Coarse Aggregates			
1	Bulk Type Weight	Min. 2,5	2,79
2	Pseudo-Type Weight	Min. 2,5	2,846
3	Effective Type Weight	Min. 2,5	2,942
4	Water absorption	Maximum 3%	2,15
5	Abration	Maximum 40%	25,70%
Fine Aggregate			
1	Bulk Type Weight	Min. 2,5	2,807
2	Pseudo-Type Weight	Min. 2,5	2,862
3	Water absorption	Maximum 3%	2,355

Table 1 indicates that the aggregate used meets the required specifications to be used as a Asphalt Concrete mixture.

3.2 Asphalt Testing Result

Asphalt testing is done on fine aggregates and coarse aggregates. Tests conducted include testing of flashpoints, ductility, as well as weight types with the following descriptions:

Table 2. Asphalt Test Results

No	Testing	Specifications		Result
		At least	Maximum	
1	Flashpoint	200	-	320°C
2	Ductility	100	-	115 cm
3	Type Weight	1	-	1,01 gram/cc

Table 2 shows that the asphalt used has met the required specifications to be used as a Asphalt Concrete mixture.

On asphalt used has a characteristic flashpoint of 320°C with an asphalt validity rate of 115 cm and a 1.01 grams/cc type weight.

3.3 Marshall Testing Result

Marshall testing is performed on each variation of the test object. From the results of the test using the marshall test tool is arranged stability, flow, and volumetric characteristic values with the following description:

Table 3. Marshall Test Results

No	CR	Void (%)			Stability (Kg)	Flow (mm)	MQ
		VIM	VMA	VFA			
1	2%	4,39	16,85	75,36	1232	3,42	360,23
2	4%	4,59	16,87	74,56	1278	3,31	386,10
3	6%	5,09	16,94	73,96	1326	3,23	410,53
4	8%	5,39	17,04	73,56	1374	3,18	432,08
5	10%	5,49	17,12	72,86	1422	3,14	452,87

Table 3 indicates that all results meet the required specifications. Marshall testing results showed that the highest percentage of VIM and VMA were obtained at the addition of Crumb rubber by 10% with consecutive values of 5.49% and 17.12%. While the highest percentage of VFA is obtained at the addition of Crumb rubber by 2%, with a VFA value of 75.36%.

Fig. 2. Stability Marshall

The stability value increases as the percentage of Crumb rubber increases. The highest stability is obtained at a percentage of 10% rubber crumb with a stability value of 1422 kg. Test object testing using marshall tests is depicted in figure 3 below

Fig. 3. Marshall Testing

4 Conclusion

The use of Crumb rubber is strong against the characteristics of Asphalt Concrete Mixtures. Crumb rubber can improve the stability of the Asphalt Concrete mixture. With the increase in the percentage of Crumb rubber, the stability of the Asphalt Concrete mixture increases. From this study, the highest stability was obtained from the addition of Crumb rubber by 10% with a stability value of 1422 kg. While the exhaustion decreases with the increase in the percentage of Crumb rubber. The lowest flow obtained is 3.14mm obtained from the addition of Crumb rubber by 10%. The known values can be used as a reference in producing a mixture of rubber asphalt with the right percentage so that the quality of the Asphalt Concrete mixture is produced according to the needs.

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