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Asphalt Concrete Mixture Innovation Using Styrofoam Waste

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Abstract

The purpose of this research is to determine the properties of an AC-BC concrete asphalt mixture with additional Styrofoam waste to bitumen. This study was conducted fully at the State University of Makassar's Laboratory of Materials Testing. The amount of Styrofoam utilized in this investigation was 6 percent, 8 percent, 10 percent, and 12 percent of the total weight of KAO asphalt (Optimum Asphalt Weight). This study used a total of 15 specimens, with 5 being used to determine KAO and 12 being used following KAO. The Marshall method was utilized, which involved immersing the test object in a water bath at 60 degrees Celsius for 30 minutes. Density, stability, flow, Marshall Quotient (MQ), VIM, VFA, and VMA were all determined using the Marshall test. The General Bina Marga 2018 specification revision 3 was utilized as a guideline. The findings of this investigation show that the asphalt penetration value falls as styrofoam material increases. Stability values in the additions of 6 percent and 8 percent, MQ values at 6 percent, VIM 12 percent, and VFA 6 percent do not satisfy criteria, while density values, flow, and VMA in all variations of styrofoam addition meet the General Bina Marga specifications in 2018 refisi 3. Based on the results of the Marshall test with an Optimal Asphalt Content (KAO) of 5.7 percent, this research suggests that a percentage substitution of 10% can be employed to get positive outcomes.

Introduction

Roads are the basic and main infrastructure in driving the wheels of the national and regional economy, considering the importance and strategic function of roads to encourage the distribution of goods and services as well as population mobility. The availability of roads is an absolute prerequisite for the entry of investment into an area. On the other hand, damaged roads will certainly hinder activities and can be the cause of accidents, road damage is indeed one of the problems in Indonesia that often occurs, especially on roads with heavy traffic volume and many heavy vehicles passing by. If that happens, it requires the ability to plan or design a layer mix on asphalt, especially a layer of hot asphalt mixture by adding other materials.

Asphalt is a binder for flexible pavement. Various methods can be used to improve the performance of asphalt mixture, one of which is by replacing Styrofoam waste (Vasudevan et al., 2012). The use of Styrofoam for various purposes and not balanced with proper waste treatment causes a large accumulation of Styrofoam (Chaukura et al., 2016). Styrofoam is a type of plastic group 6 made of polystyrene and thermoplastic gas which when heated will become soft and will harden again when it is cold (Sukirman, 2003; Sukirman, 1999). The use of Styrofoam as an additive to the asphalt mixture is expected to change Styrofoam waste into something more useful and increase better adhesion in the mixture so that the pavement is not easily deformed (Soandrijanie, 2011).

Styrofoam waste or foam plastic was investigated as an additive in asphalt which forms a new binder for road construction pavements due to its thermoplastic nature at room temperature (Wu & Montalvo, 2021). This research utilizes the properties of styrofoam in mixing bitumen and asphalt which is expected when styrofoam waste is mixed in hot asphalt it will melt and blend in liquid asphalt together with bitumen which is a binder in the asphalt mixture. To achieve the expected results, the determination of the type of styrofoam waste used greatly influences the properties of bitumen as a binder.

Methods

This research is an experimental study that begins with taking samples from community waste, namely Styrofoam waste. Followed by the preparation of asphalt mixture aggregates such as fine aggregate (stone ash or sand), and coarse aggregate (crushed stone size 10-20 mm and 20-30 mm). The plan for the variation of the test object to be made is as follows.

Table 1. Research Design

No	**Sample**	**Addition of *Styrofoam* waste (%)**	**Number of test objects**
1	Styrofoam A	6%	3
2	Styrofoam B	8%	3
3	Styrofoam C	10%	3
4	Styrofoam D	12%	3
		TOTAL	**12**

In the implementation of testing the effect of added Styrofoam waste on the characteristics of the mixture on the asphalt layer using a press (Marshall) this tool is used to measure the stability value and to measure the plastic melt or flow on the test object. In this test, 3 samples A, B, C and C were used on Styrofoam waste with the type of polystyrene.

Determination of the proportion of each aggregate to be tested must meet the requirements of the 2018 Highways General Specification. The combined gradation is indicated in percent of the aggregate weight. In the General Specifications of Highways 2018 the combined gradation for asphalt mixtures must meet the grading limits. In addition, the asphalt used in this test is 60/70 penetration asphalt for the AC-BC layer. Tests on asphalt mixtures include testing the maximum specific gravity of the asphalt mixture (SNI 03-6893-2002) and testing the marshall properties (SNI 06-2489-1991)

Results and Discussion

The aggregate material used in this study consisted of coarse aggregate and fine aggregate. Coarse aggregate is in the form of crushed stone with the size of 2-3 cm, 1-2 cm, 0.5-1 cm, while the fine aggregate is in the form of stone ash. The type of asphalt used in this research is PEN 60/70 asphalt which was obtained from PT Sinar Jaya Abadi ACC. Collecting aggregate from the Batching plant using a shovel and plate, the plate is used to hold the aggregate so that the aggregate mound taken does not slide. Aggregate taken from the Batching plant is put into sacks, transported on a car and brought to the laboratory.

Styrofoam waste was obtained from the Antang TPA where at the time the author found that a lot of Styrofoam was not intact or had been burned, according to local residents who were close to the Styrofoam TPA location, it was very flammable and also because there was no selling value, no collectors collected Styrofoam waste.

The testing to obtain primary data was carried out fully at the Testing Laboratory of Civil Engineering and Planning Educational Materials, Faculty of Engineering, Makassar State

University. Secondary data in the form of styrofoam. Before carrying out material testing, the first step is the preparation of tools and materials. Material retrieval uses the intersection method where the material in sacks is stacked in a wide, watertight container at the test site, then divided by four and taken two parts from the four sides. crosswise. Then do the method as above until you get the amount of material needed.

Table 2 provides a summary of the characteristics of fine and coarse aggregate tests. By using SNI 03-1968-1990 as a reference.

Table 2. Aggregate Characteristics Test Results

PHYSICAL CHARACTERISTICS	**Test Results**			
	Coarse aggregates			**Fine aggregates**
	BP 2-3	**BP 1-2**	**BP 0,5-1**	**Stone ash**
Type weight		–	–	–
Apparent specific gravity	2,74	2,64	`	2,55
Bulk specific gravity	2,49	2,48	2,58	2,62
Bulk specific gravity SSD	2,58	2,54	2,64	2,73
Volume weight	-	-	-	-
Solid conditions	0,46	1,4	1,35	1,67
Loose conditions	1,23	1,25	1,22	1,45
Abrasion	12,18		-	-
mud rates	0,42	0,4	0,44	-
weight of contents				-
Solid conditions	0,44	0,43	1,41	1,74
Smelt Condition	0,37	0,38	1,27	1,51
Sieve Analysis	max 20 mm	max 40 mm	max 10 mmm	zone 3

The manufacture of AC-BC must go through the aggregate blending design process. Blending design is required so that the gradation of the mixture of each aggregate fraction (coarse and fine aggregate) according to the specification criteria. The specifications used are the General Bina Marga specifications in 2018. The aggregate design has 2 methods [Puslitbang for Roads and Bridges, 2018]. These methods are graphical and analytical methods. The analysis method can be divided into 2 ways, namely "Trial and Error" analysis and analysis with inequalities. Linear research and development center for Roads and Bridges has applied the graphical method and “Trial and Error”. In this study, the determination of the percentage composition of the aggregate fraction for the mixed gradation method used is the "Trial and Error" analysis. Furthermore, the combined aggregate percentage value for hot asphalt mixture (AC-BC) based on the calculation results can be seen in the attachment and the calculation conclusion can be seen in the following table.

Table 3. AC-BC Hot Asphalt Mix Plan

No. Saringan	% Lolos BP 2-3	% Lolos BP 1-2	% Lolos BP 0,5-1	% Lolos Abu Batu	BP 2-3	BP 1-2	BP 0,5-1	Abu batu	Total Agregat	Spesifikasi			Spek. Ideal
					12%	13%	34%	41%					
25.4 (1")	100,00	100,00	100,00	100	12,00	13	34	41	100,00	100	-	100	100
19,1 (3/4")	88,65	98,70	100,00	100	10,64	12,83	34	41	98,47	90	-	100	95
12,7 (1/2")	41,70	61,30	100,00	100	5,00	7,97	34	41	87,97	75	-	90	82,5
9,52 (3/8")	0,10	25,00	100,00	100	0,01	3,25	34,00	41	78,26	66	-	82	74
No. 4	0,10	0,15	49,90	100	0,01	0,02	16,97	41	58,00	46	-	64	55
No. 8	0,10	0,05	0,30	86	0,012	0,006	0,10	35,22	35,34	30	-	49	39,5
No. 16	0,10	0,05	0,30	63	0,012	0,006	0,102	25,85	25,97	18	-	38	28
No. 30	0,10	0,05	0,30	47	0,012	0,006	0,102	19,23	19,35	12	-	28	20
No. 50	0,10	0,05	0,30	26	0,012	0,006	0,102	10,74	10,86	7	-	20	13,5
No. 100	0,10	0,05	0,30	13	0,012	0,006	0,102	5,35	5,47	5	-	13	9
No. 200	0,10	0,05	0,30	9	0,012	0,006	0,102	3,55	3,67	4	-	8	6

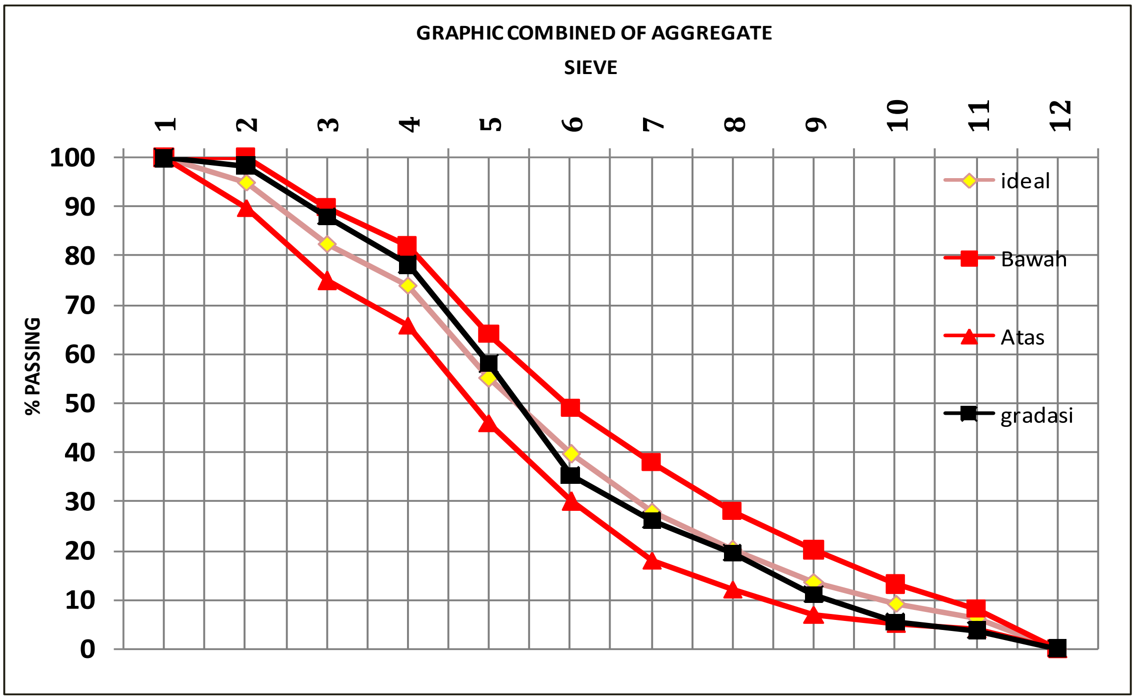

Figure 1. Aggregate Combination Graph

In table 3 the method used is the trial and error method of the percentage of each aggregate fraction so that the gradation of the mixture is in accordance with the range in Figure 4.7 of the required gradations. According to Ramu et al [2006] the drawback of the trial and error process is that it needs to be repeated many times on the aggregate proportions of each type of fraction in order to meet the limits of gradation considering the number of possible answers and the fractions obtained are BP 1-2 12%, BP 2 -3 13%, 0.5-1 35% and Rock ash 41%.

To determine the effect of Styrofoam variations by substitution on bitumen, the Marshall test results are obtained as follows:

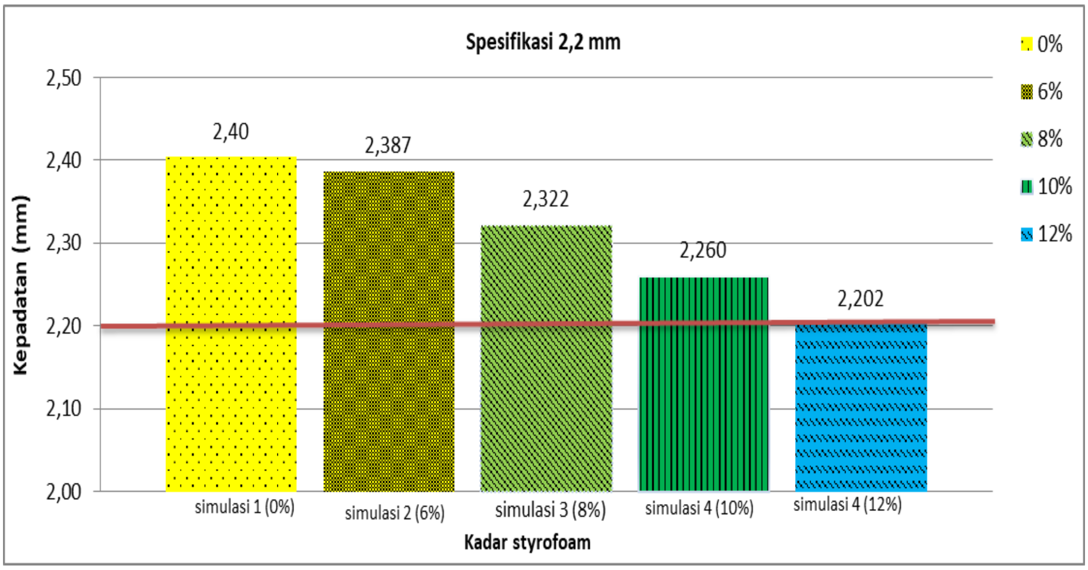

Figure 2. Graph of Styrofoam substitute relationships to density

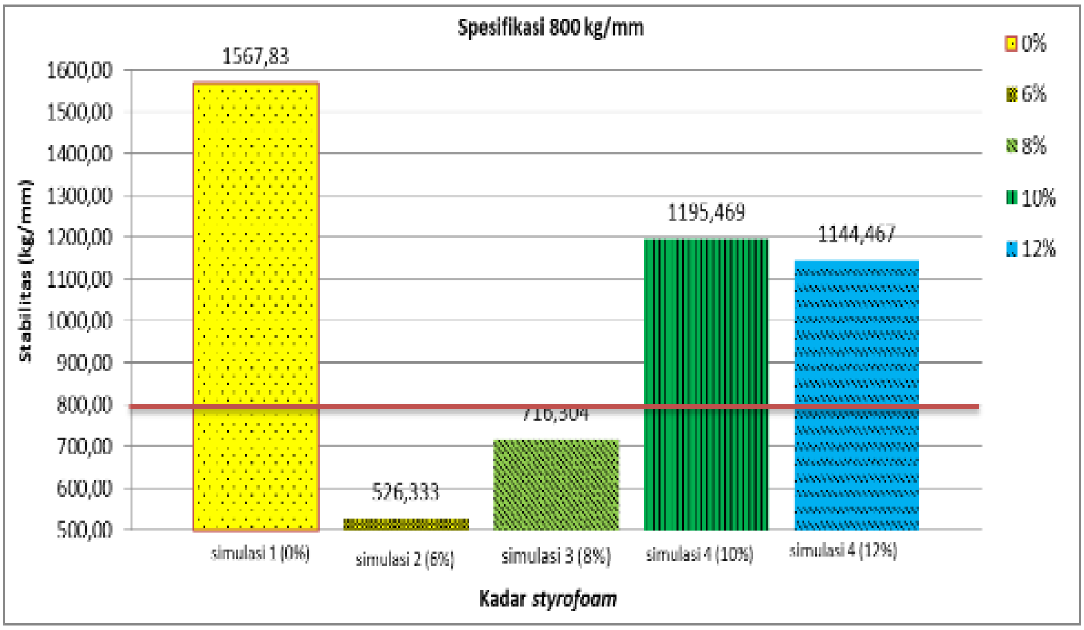

Figure 3. Graph of Styrofoam's substitute relationship to Stability

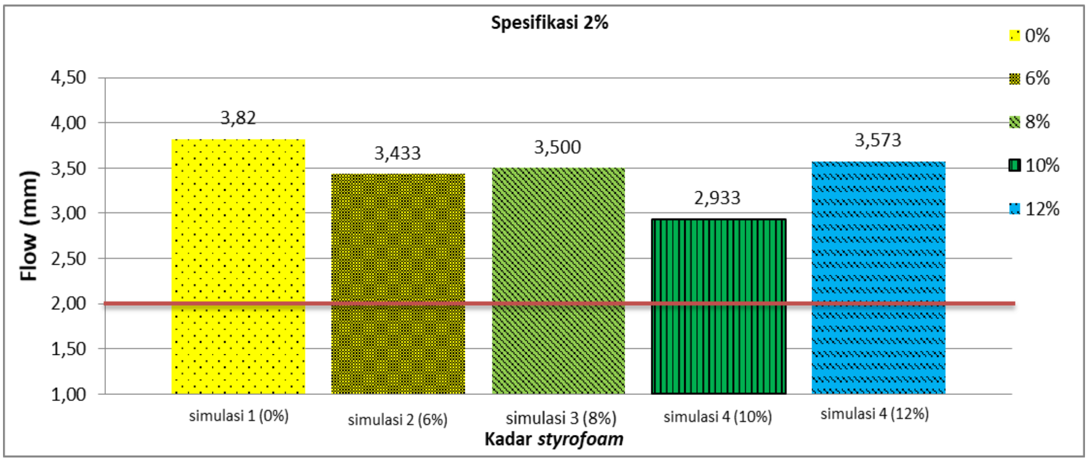

Figure 4. Graph of Styrofoam submits relationship to flow

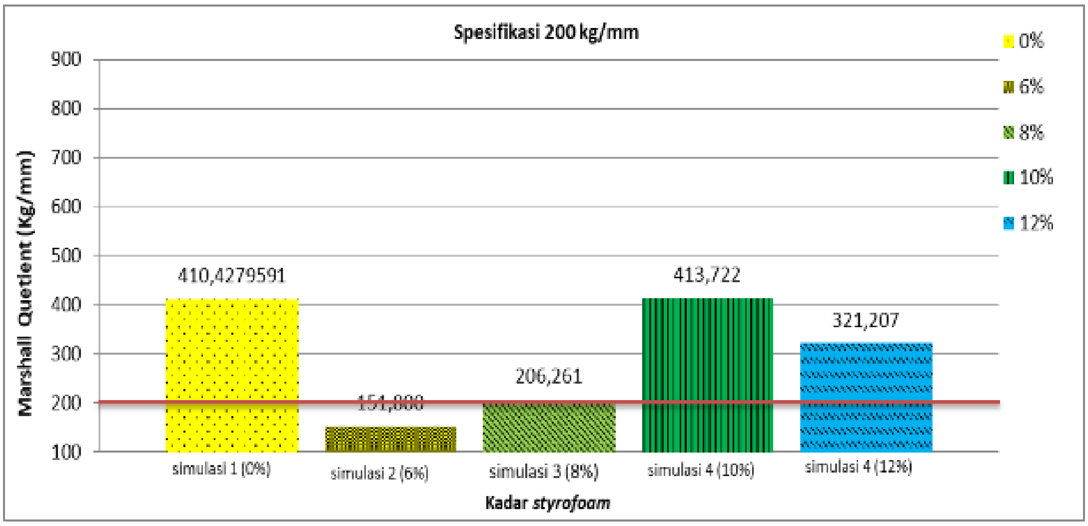

Figure 5. Graph of the relationship between days of Styrofoam substitution and the value of Marshall Quotient

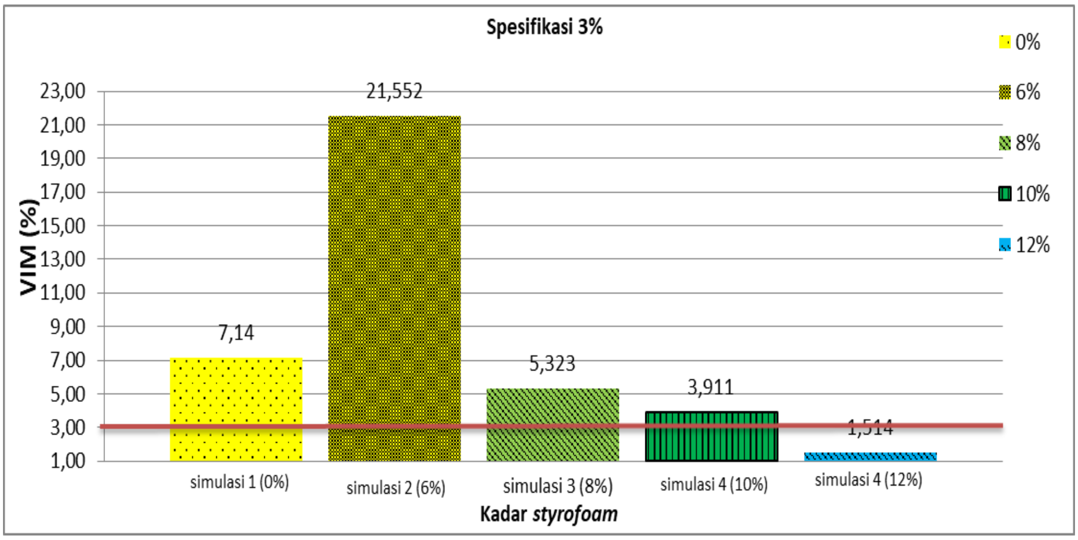

Figure 6. Graph of Styrofoam substitute relationship to VIM value

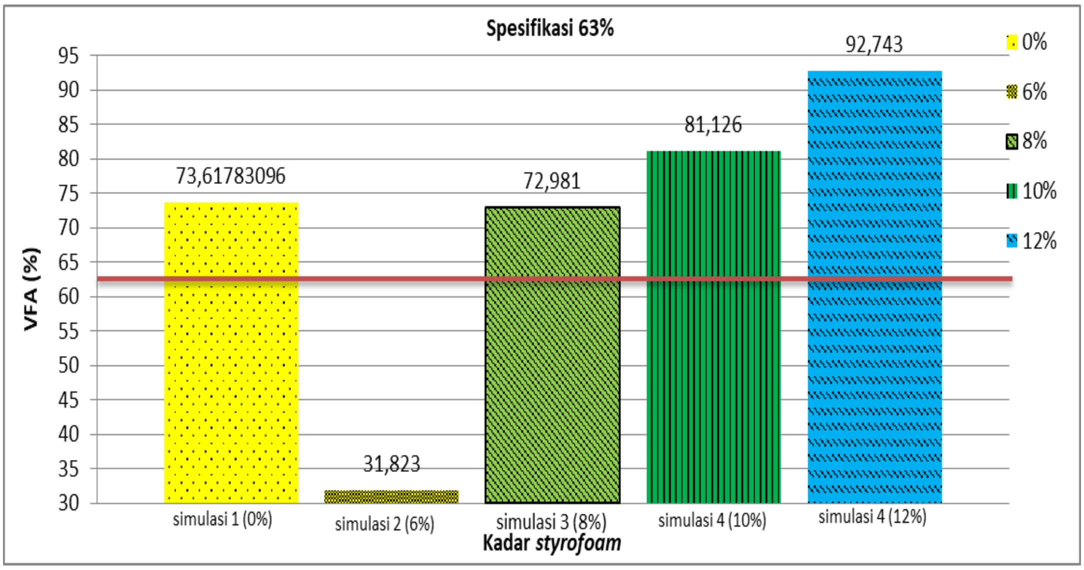

Figure 7. Graph of Styrofoam substitute relationships to VFA values

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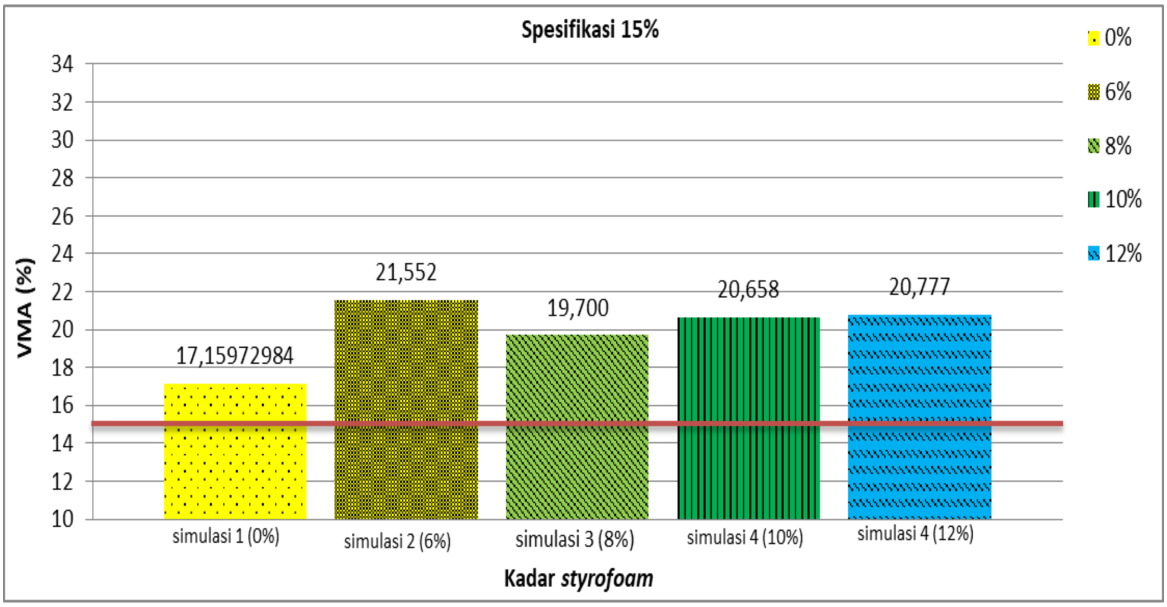

Figure 8. Graph of the relationship of the Styrofoam substitute of the day to the VMA value

Based on the Marshall Test results, the percentage addition of 6%, 8%, 10% and 12% to determine the percentage of styrofoam waste that can be used can be seen in Figure 9.

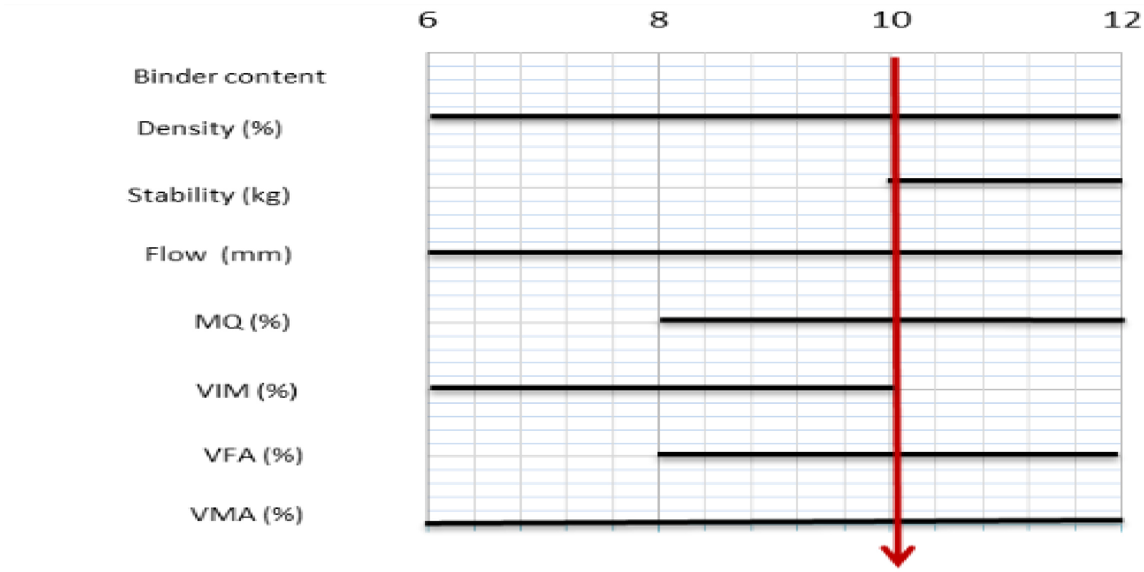

Figure 9. Marshall test with Styrofoam substitute

Figure 9 based on the Marshall Test results obtained, the percentage value of the addition of styrofoam waste that can be used on the AC-BC asphalt concrete layer at the Optimum Asphalt Content (KAO) 5.7% by substitution, namely at 10% styrofoam content, because of the four additional substitutions The styrofam content is 10% which meets the seven results of the Marshall Tests of the General Specifications of Highways 2018 revision II. So this has a positive impact because in addition to reducing Styrofoam waste, we can also reduce the use of asphalt content.

Conclusion

The density value along with the substitution of styrofoam variations has decreased due to a reduction in asphalt content and styrofoam as a substitute for asphalt cannot fill air voids. Stability values decreased when compared to 0% for substitution of 6% and 8% Styrofoam levels which were below the specification line but along with the substitution of Styrofoam

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variations increased at 10% and 12% this was due to Styrofoam dissolved into asphalt has a harder nature and more sticky so that the strength of the asphalt in binding the aggregate increases. The value of the melt (flow) of the four variations of Styrofoam substitution decreased when compared to 0% Styrofoam. This is due to the reduction in the amount of asphalt content and the hard nature of Styrofoam after melting. The Marshall Quetment (MQ) value of the four variations of Styrofoam substitution decreased when compared to 0% Styrofoam. This is due to a reduction in the amount of asphalt content, causing the 6% styrofoam value to be below the minimum specification line, but along with the substitution of the styrofoam content, the MQ value has increased due to the hardening properties of styrofoam after melting so that the mixture becomes stiffer. The value of the cavity in the mixture (VIM) has the highest increase in the addition of 6% styrofoam but causes substitution at 12% styrofoam content below the minimum specification. This is because the reduction in the amount of asphalt and styrofoam as a substitute for asphalt causes the cavities in the asphalt to change. The value of the void filled with asphalt (VFA) along with the substitution of styrofoam, the VFA value increased at 10% and 12% asphalt content compared to 0% addition but at 6% asphalt content was still below the minimum specification line. This is because there is a reduction in the amount of asphalt and the higher the value of voids in the mixture (VIM) causes the voids filled with asphalt to be lower and vice versa so that it can be concluded that the VFA and VMA values are inversely proportional. The value of the cavity in the aggregate (VMA) of the four variations has increased when compared to 0% styrofoam. This is because the VIM value in styrofoam substitution also increases, so it can be concluded that the characteristics of the cavity in the reinforcement (VIM) and the cavity in the aggregate (VMA) are directly proportional. Based on the results of research and data analysis that has been carried out by looking at the characteristics of the marshall test with Styrofoam waste substitution on AC-BC concrete layers with a composition of 6%, 8%, 10% and 12%. Styrofoam with Optimum Asphalt Content (KAO) 5.7% by way of substitution of Styrofoam levels that can be used, namely at a level of 10%.

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