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UTILIZATION OF HDPE PLASTIC WASTE FOR ASPHALT MAKING ADDITIVES WITH A COMBINATION OF GLASS WASTE FILLER

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ABSTRACT

Asphalt is one of the materials used as a road pavement material, this material was chosen because of its good and comfortable final result as a flexible pavement. The use of HDPE plastic waste as an additive to asphalt material and glass waste as filler was chosen in making asphalt, because it is an effort to overcome the problem of waste and besides that the content contained in these materials is thought to be an alternative to making asphalt. The purpose of this study was conducted to determine the characteristics of the constituent materials of asphalt mixture with HDPE plastic additives and glass waste filler; Marshall characteristics of asphalt mixture with HDPE plastic additives and glass waste filler; and the optimum composition ratio to produce asphalt with HDPE plastic additives and glass waste filler. The research results of the effect of the addition of plastic (HDPE and glass powder, partial replacement of asphalt and partial replacement of filler with a mixture proportion of 10-15 mm Coarse Aggregate fraction with a composition of 10%, Medium Aggregate 5-10 mm 48%, Fine Aggregate 0-5 mm 38%%% included in the gradation envelope requirements for AC-BC concrete asphalt layers, the Optimum Asphalt Content (KAO) value in the most optimum AC-BC hot asphalt mixture of 7.30%. While the variation of HDPE addition 6%, 4% and glass powder 1%, 2%, 3% is most optimal at the addition rate of 2.5% and 0.5%. The determination is based on the Marshall test by combining the values of VIM, VMA, VFA, Stability, Flow and Marshall Quotient (MQ).

Keyword: *Asphalt, Additives, HDPE, Filler, KAO.*

1. INTRODUCTION

Healthy, clean and comfortable environmental conditions are very necessary for the survival of animals, plants or humans. However, there are environmental problems in various parts of the world, including Indonesia, which are very urgent and require very serious handling, one of which is waste. We often encounter waste problems in everyday life, but rarely can we turn them into useful products [3]. Factors that influence this situation are a lack of awareness and knowledge of waste processing, so that waste is wasted and becomes a source of environmental pollution problems. Awareness and knowledge about good and appropriate waste processing will be able to reduce environmental pollution or disasters caused by waste [4].

Waste is generally divided into two types, namely waste that is easily decomposed (organic) and waste that is very difficult to decompose and takes a long time (inorganic). Based on data from the National Waste Management Information System (SIPSN) [1], the amount of waste generated in Indonesia in 2023 will reach 18.4 million tons/year. The composition of Indonesia's waste consists of organic waste (food scraps, wood, twigs, leaves) at 53.07%, plastic waste at 18.47%, paper waste at 11.06%, and others (metal, textiles, rubber, leather, glass) 17.4%. The average percentage of managed waste in Indonesia is 67.07%, around 12.35 million tons/year. There is still 32.93% of waste that has not been managed, waste

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that is not managed well will have a negative impact. The high amount of waste generation is triggered by the accelerated rate of population growth in Indonesia, including urbanization and increasing community activity and consumption. Lack of innovation in waste processing will result in accumulation of waste. One effort to overcome the waste problem is by utilizing plastic waste and glass waste which are difficult to decompose into additional materials for making asphalt.

Asphalt is one of the materials used as a road pavement material, this material was chosen because the final result is good and comfortable as a flexible pavement. One way to prevent damage to road pavement due to vehicle loads is to improve the quality and stability of the pavement, so that the use of additives becomes an alternative. In general, the process of making asphalt to be applied on roads requires several ingredients, namely asphalt, coarse aggregate, fine aggregate and filler. The filler material can be chalk, limestone, cement or other non-plastic materials [4].

The use of HDPE plastic waste as an additive to asphalt materials and glass waste as a filler was chosen in making asphalt, because it is an effort to overcome the waste problem and apart from that, the content contained in these materials is thought to be an alternative for making asphalt. Plastics generally consist of carbon polymers alone or with oxygen, nitrogen, chlorine, or sulfur (some are also composed of silicon). HDPE plastic is engineered to be low maintenance, safe and durable. The surface of this type of plastic is also textured, so it is not a smooth and slippery surface. While glass is the result of the decomposition of organic compounds which have undergone cooling without crystallization, the main element of glass is silica [6].

Based on these problems, the author will conduct research on the use of HDPE plastic waste as an additive for making asphalt with a combination of glass waste filler as an effort to overcome the waste problem.

The aim of this research is to determine the characteristics of the ingredients that make up asphalt mixtures with HDPE plastic additives and glass waste filler; Marshall characteristics of asphalt mixtures with HDPE plastic additives and glass waste filler; and the optimum composition ratio for producing asphalt with HDPE plastic additives and glass waste filler.

The benefits that can be obtained from this research include: providing data regarding the optimum composition ratio for producing asphalt with HDPE plastic additives and glass waste filler.

2. RESEARCH METHOD

2.1 Research Tools and Materials

Making asphalt using a mixture of HDPE plastic as an additive and glass waste as a filler as a solution to the waste problem is carried out at the Civil Engineering Laboratory, Faculty of Science and Engineering, Bojonegoro University. The tools and materials used in this research are:

The tools used:

1. Sieve to obtain material in a certain size
2. Oven to remove water content in aggregate
3. Picnometer to test aggregate specific gravity
4. Digital scales
5. Mold
6. Asphalt pounder
7. Asphalt mold opener
8. Marshall soaking tub
9. Marshall stability test equipment
10. Cooking utensils (pan, stove, and spatula)
11. Pore paper and pliers

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Ingredients used:

1. Asphalt is used as a binding agent between asphalt and aggregate, in addition to filling voids between aggregate grains. The asphalt used is AC 60/70 asphalt [7].
2. HDPE plastic waste as an asphalt additive. Plastic is obtained from waste detergent bottles, buckets and milk cartons or those that have code number 2 on the type of plastic packaging. Next, this material is ground into small pieces with a size of 3-5 mm and varying percentages of 0%, 2%, 4% and 6% (14).
3. Coarse aggregate (Coral Stone) was obtained from Gondang Bojonegoro District and fine aggregate (Bengawan Solo Sand) from Bojonegoro.
4. Filler material is obtained from crushed glass waste until it passes sieve No. 200 with glass powder content of 0%, 1%, 2%, and 3% [8]. Glass powder is obtained from waste beverage bottles made of glass.

2.2 Research Stages

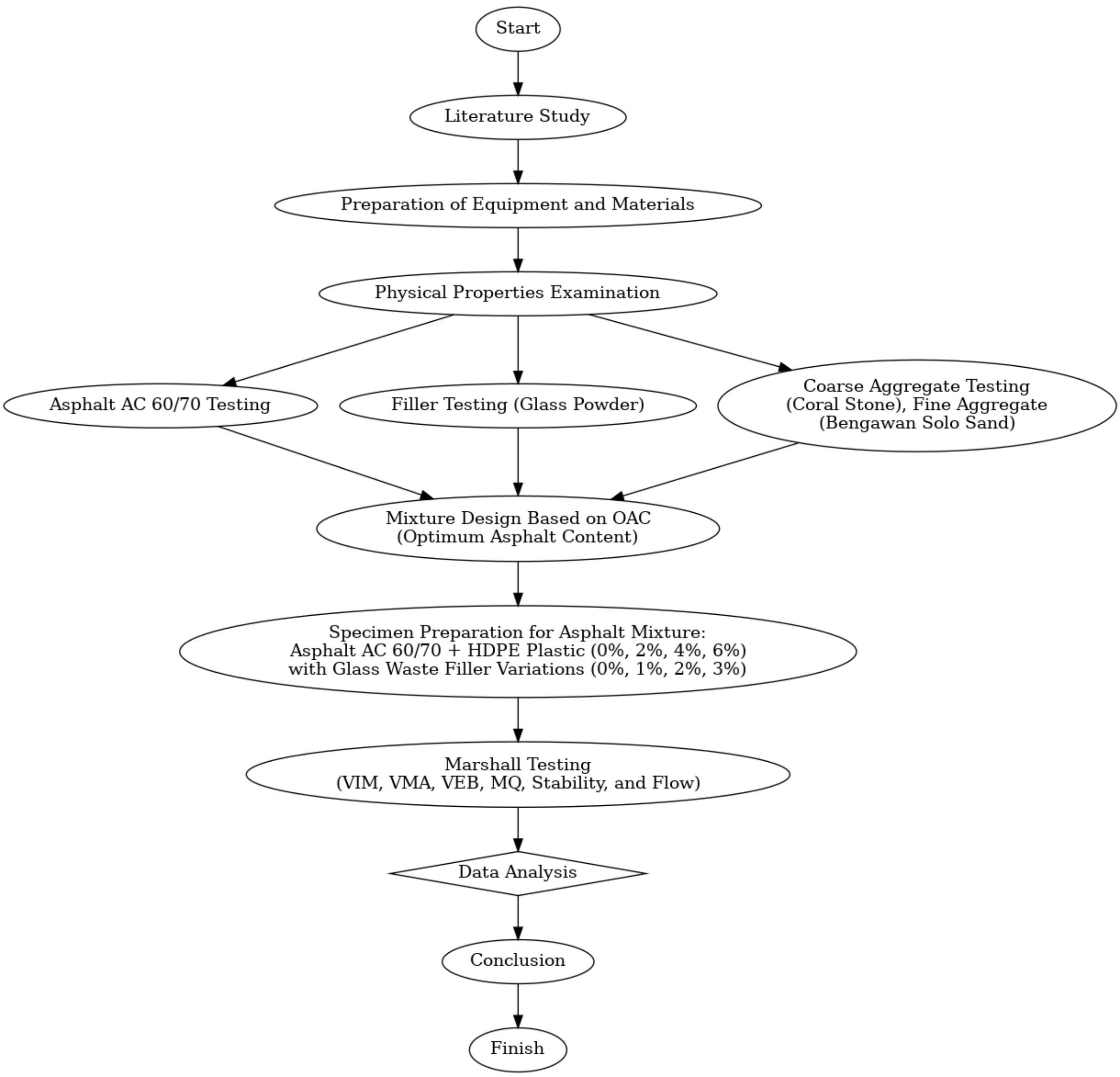

Figure- 1 Research Flow

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The research stages that will be carried out are:

1. Literature Study
   Literature studies are used as a theoretical basis for solving scientific problems. In this stage the author looks for references related to the research topic [9].
2. Preparation of tools and materials
   The second stage is the preparation of the tools and materials used to make asphalt. Tools and materials are prepared as written previously.
3. Physical Properties Examination or Quality Characteristics Testin
   This stage is testing for aggregate, filler and AC 60/70 asphalt. Aggregate testing includes sieve analysis, specific gravity and aggregate absorption and wear [10] At this stage, tests are also carried out for filler including sieve analysis and specific gravity. Asphalt testing includes penetration, softening point, ductility and others. After a physical examination has been carried out and it has met SNI quality standards, you can proceed to the next stage.
4. Making Test Objects
   This stage is the manufacture of test objects before Marshall testing is carried out. At this stage, KAO (Optimum Asphalt Content) is also determined, the estimated KAO presentation in the mixture. Obtain the asphalt content in the mixture using the formula:

   $$Pb = (0.035 \times \%\ \text{crushed stone}) + (0.045 \times \%\ \text{sand}) + (0.18 \times \%\ \text{filler}) + 0.5 \qquad (1)\ [11]$$

   Making test specimens with AC 60/70 asphalt composition mixed with various levels of HDPE plastic 0%, 2%, 4% and 6%, while the next composition is coarse aggregate, fine aggregate mixed with various fillers (glass powder) 0%, 1%, 2% and 3% which will later be mixed with other ingredients according to the size fraction based on the gradation. The total weight of mixed aggregate is the weight of aggregate that can produce one solid specimen 6.35 cm high with a diameter of 10.2 cm. In general, the weight of the mixed aggregate is 1200 grams according to the mold volume. Stages of making test objects:

   a. Preparation of test objects
      Clean the material to be used for the test specimen then dry it in the oven at 110°C for 24 hours. Separate the coarse aggregate, fine aggregate and filler which have been weighed according to the composition to be used to facilitate mixing time. Clean the mold that will be used to mold the test object then make a base for the test object according to the diameter of the test object used then smear the diameter of the mold with oil to make it easier to remove the test object.
   b. Mixture making
      Heat the aggregate and filler used according to the required composition by roasting it to a temperature of 110°C (19). Heat the asphalt and melt the required plastic according to the level, then mix the hot asphalt with the melted plastic until it is homogeneous. After that, pour the hot asphalt into the pan containing the heated aggregate and filler then stir the mixture until evenly distributed.
   c. Compaction of the mixture
      After the asphalt mixture reaches 160°C, transfer the heated asphalt mixture into a mold that has been lined with paper, then fill the mold completely then level it, then place the mold that is completely filled with the mixture on the pounder. Pierce the edge to the middle of the test object, then pound the mold 75 times.
   d. Test object care
      The test object that has been compacted is then removed using a hydraulic jack. After that, place the test object on a flat place or surface to leave for 24 hours at room temperature until it hardens.

5. Marshall Testing
   The principle of the Marshall method is stability and fatigue examination, as well as density and pore analysis of the solid mixture formed. Marshall testing to obtain stability and fatigue follows

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the SNI 06- 2489-1991 procedure (20). The stage of testing the test object, namely the test object that has been printed, then weighed in a dry condition, then left for 24 hours, after that, weigh the test object in a dry condition with a saturated surface. Then the test object was soaked using a water bath at a temperature of 60°C for 30 minutes and then tested using a Marshall test equipment. When testing using a Marshall tool, stability and yield readings were taken on the watch.

6. Data Analysis
   After obtaining the data, data processing and data analysis are then carried out so that conclusions can be drawn.
7. Conclusion
   A conclusion is a short, clear and systematic statement of all the results of discussion and testing in a study. Drawing conclusions is needed to answer the objectives of the research results.

3. RESULT AND DISCUSSION

3.1 Results of Aggregate Characteristics Examination

The aggregate material used in this research consisted of coarse and fine aggregate from Bengawan Solo, Bojonegoro Regency and 60/70 penetration oil asphalt binder. The results of the inspection of aggregate characteristics are in accordance with the test method used and the 2018 Ministry of Public Works and Public Housing specification requirements. The following are the results of testing the specific gravity and water absorption of fine aggregate (Bengawan Solo Sand) presented in table 1; 2; and 3.

Table 1 Fine Aggregate Water Content

Water Absorption Testing of Fine Aggregates	A	B	C	Units
Weight of saturated surface dry (SSD) specimens	500	500	500	Gram
Weight of oven-dried specimens, Bk	496	495	496	Gram
Weight of pycnometer filled with water, B	665.54	669.63	671.96	Gram
Weight of pycnometer + test specimen (SSD) + water, Bt	987.18	991.13	994.52	Gram
Water content		0.87		%

Source : test results, 2024

Table 2 Coarse Aggregate Water Content 0.5 Crushed Stone

Testing Water Absorption of Coarse Aggregate	A	B	C	Units
Weight of oven-dried specimens, Bk	2000	2000	2000	Gram
Weight of saturated surface dry test specimen Bj	2025	2024	2025	Gram
Weight of object in water Ba	1230	1232	1228	Gram
Water content		1.23		%

Source : test results, 2024

Table 3 Coarse Aggregate Water Content 1.1 Crushed Stone

Testing Water Absorption of Coarse Aggregate	A	B	C	Units
Weight of oven-dried specimens, Bk	2000	2000	2000	Gram
Weight of saturated surface dry test specimen Bj	2021	2020	2023	Gram
Weight of object in water Ba	1228	1227	1229	Gram
Water content		1.07		%

Source : test results, 2024

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3.2 Aggregate Specific Gravity Test Results

Table 4 Calculation of specific gravity and absorption of fine aggregate

Calculation of Fine Aggregate Water Absorption Testing	A	B	C	Average	Units
Specific gravity (Bulk)	2.78	2.77	2.80	2.78	%
Saturated surface dry specific gravity	2.80	2.80	2.82	2.81	%
Apparent specific gravity	2.84	2.85	2.86	2.85	%
Absorption	0.81	1.01	0.81	0.87	%

Source : test results, 2024

Table 5 Calculation of specific gravity and absorption of 0.5 crushed stone coarse aggregate

Calculation of Fine Aggregate Water Absorption Testing	A	B	C	Average	Units
Specific gravity (Bulk)	2.52	2.53	2.51	2.52	%
Saturated surface dry specific gravity	2.55	2.56	2.54	2.55	%
Apparent specific gravity	2.60	2.60	2.59	2.60	%
Absorption	1.25	1.20	1.25	1.23	%

Source : test results, 2024

Table 6 Calculation of specific gravity and absorption of coarse aggregate 1.1 crushed stone

Calculation of Fine Aggregate Water Absorption Testing	A	B	C	Average	Units
Specific gravity (Bulk)	2.52	2.52	2.52	2.52	%
Saturated surface dry specific gravity	2.55	2.55	2.55	2.55	%
Apparent specific gravity	2.59	2.59	2.59	2.59	%
Absorption	1.05	1.00	1.15	1.07	%

Source : test results, 2024

From the results of testing the physical properties or characteristics of coarse aggregates 0.5 and 1.1 crushed stone and fine aggregates used in the mixture as shown intable 4; 5; and 6 indicates that the aggregate used meets the specification requirements determined by the Ministry of Public Works in 2018, namely a maximum absorption value of 3%.

A small specific gravity will have a large volume so that the same weight will require a lot of asphalt. The aggregate should be slightly porous so that it can cover the aggregate well and not be absorbed into the aggregate pores, so that a mechanical bond is formed between the asphalt film and the stone grains. Highly porous aggregates will absorb asphalt and require long drying times and higher temperatures compared to aggregates that have low absorption.

3.3 Aggregate sieve test results

Table 7 Sieve analysis of AC-WC Laston mixture

SIEVE SIZE		1"	0.5	Fine	Filler	Quantity	SPEK	
							BB	BA
1"	25	100.00	100.00	100.00	100.00	100.00	100	100
3/4"	19	100.00	100.00	100.00	100.00	100.00	100	100
1/2"	12.5	54.64	99.76	100.00	100.00	95.35	90	100
3/8"	9.5	20.20	79.46	100.00	100.00	82.16	77	90
NO 4	4.75	0.74	40.72	94.41	100.00	59.49	53	69
NO 8	2.36	0.50	11.52	85.79	100.00	42.18	33	53
NO 16	1.18	0.46	1.54	75.40	100.00	33.44	21	40
NO 30	0.600	0.40	1.00	52.21	100.00	24.36	14	30
NO 50	0.300	0.34	0.66	31.94	100.00	16.49	9	22
NO 100	0.150	0.24	0.36	8.18	100.00	7.30	6	15
NO 200	0.075	0.24	0.22	0.24	100.00	4.22	4	9

Source : test results, 2024

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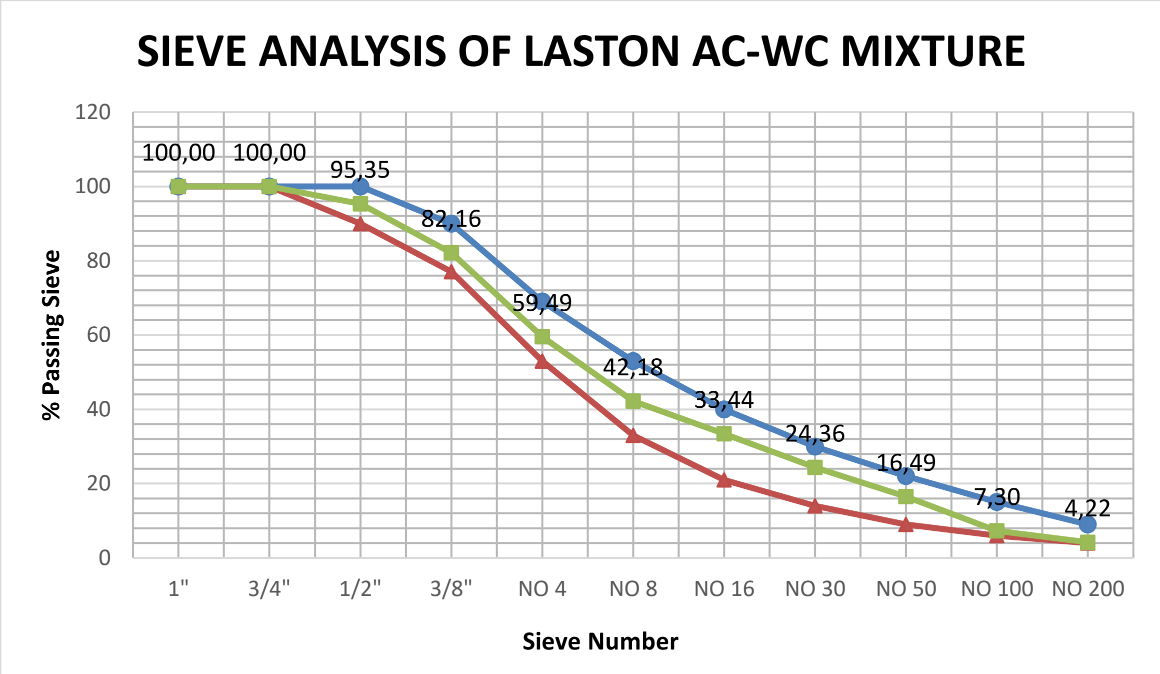

Figure 2 Sieve Analysis of Laston AC-WC Mixture

After carrying out a sieve analysis of the Laston AC-WC mixture, the percentage of each material that will be used for the mixture is obtained, namely coarse aggregate 1.1 at 10%, coarse aggregate 0.5 at 48%, fine aggregate 38%, filler 4% so that if totaled to 100%. This percentage can be seen in table 8.

Table- 8 Results of combined gradation calculations

A. I "	(HOT BIN 1)	10.0	%
B. 0,5	(HOT BIN 2)	48.0	%
C. Fine	(HOT BIN 3)	38.0	%
D. Filler		4.0	%
TOTAL		100.0	%

Source : test results, 2024

Pb = 0.035(%CA) + 0.045(%FA) + 0.18(%FF) + K

Where:
Pb = Design asphalt content, percent of the mixture weight
CA = Coarse aggregate, percent of aggregate retained on sieve no. 8
FA = Fine aggregate, percent of aggregate passing sieve no. 8 and stuck to filter no. 200
FF = Aggregate passes sieve no. 200
K = Constant (K value around 0.5 to 1.0 for AC and 2.0 – 3.0 for HRS
CA = 94,14
FA = 37,95
FF = 4,22
K = 1
Pb = 0,035(%CA) + 0,045(%FA) + 0,18(%FF) + K
= 0,035(94,14%) + 0,045(37,95%) + 0,18(4,22%) + 1
= 6,76274 % rounded up to 7%

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After obtaining the Pb value from several variations, the results obtained are the planned asphalt content to be used (Pb = 7%). In this research, to obtain the optimum asphalt content (KAO) value, 5 variations of asphalt content were made for the combined gradation with a total of 30 test objects, each with 6 test objects. The variations in levels used are (Pb – 1.0)%, (Pb – 0.5)%, (Pb)%, (Pb + 0.5)%, and (Pb + 1.0)%, explained in the table following:

Table 9 composition of asphalt mixture

Estimated Weight of Standard Mold Filling			1260				
Mix Composition		Aggregate Composition					
Plan Asphalt Content		%	6	6.5	7	7.5	8
a	HOT BIN I	10%	118.4	117.8	117.2	116.6	115.9
b	HOT BIN II	48%	568.5	565.5	562.5	559.4	556.4
c	HOT BIN III	38%	450.1	447.7	445.3	442.9	440.5
d	Filler	4%	47.4	47.1	46.9	46.6	46.4
Weight Of Mixed Agregate (Gr)			1184.4	1178.1	1171.8	1165.5	1159.2
Weight Of Asphalt (Gr)			75.6	81.9	88.2	94.5	100.8
Total Planning Weight Of Mix (Gr)			1260.0	1260.0	1260.0	1260.0	1260.0

Source : result of calculation, 2024

Next, the analysis carried out is to obtain Marshall values which are used to determine the mixture characteristics of each variation of HDPE content in the test object, namely test objects that have levels of 0%, 2%, 4% and 6% in the AC asphalt layer mixture formula. -WC pen 60/70. For the combined gradation, it was made with 4 variations of HDPE addition with a total of 24 test objects, each grade of 6 test objects is explained in the following table:

Table 10 Mixture composition with the addition of HDPE and Glass Powder

Estimated Weight of Standard Mold Filling			1260						
			HDPE ADDITION RATE				GLASS POWDER		
Mix Composition		Aggregate Composition	0%	2%	4%	6%	1%	2%	3%
Plan Asphalt Content		%	7.30	7.30	7.30	7.30	7.30	7.30	7.30
a	HOT BIN I	10%	116.8	116.8	116.8	116.8	116.8	116.8	116.8
b	HOT BIN II	48%	560.6	560.6	560.6	560.6	560.6	560.6	560.6
c	HOT BIN III	38%	443.8	443.8	443.8	443.8	443.8	443.8	443.8
d	Filler	4%	46.7	46.7	46.7	46.7	46.3	45.8	45.4
Weight Of Mixed Agregate (Gr)			1168.0	1168.0	1168.0	1168.0	1167.6	1167.1	1166.7
Weight Of Asphalt (Gr)			92.0	90.1	88.3	86.5			
Weight Of HDPE (Gr)			0.00	1.84	3.68	5.52	0.46	0.92	1.36
Total Planning Weight Of Mix (Gr)			1260	1260	1260	1260	1260	1260	1260

Source : result of calculation, 2024

3.4 MARSHALL TESTING

Marshall testing aims to find the density value, VIM (Void in mix), VMA (Void in Mineral Aggregate), VFB (Void Filled with asphalt), melting (flow), Stability and MQ (Marshall quotient). Marshall testing is carried out using the SNI 06- 2489-1991 reference. In this study, 24 test objects were made.

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Table 11 Recapitulation of the Marshall test results for the addition of HDPE

Percentage of Addition	Stabilitas	Flow	VIM	VMA	VFA	MQ	DENSITY
0	1276.96	1.76	10.82	24.72	56.70	742.71	2.12
2	1646.01	1.24	8.37	22.65	63.09	1659.31	2.18
4	1748.34	1.72	11.11	24.96	55.87	1022.87	2.12
6	1869.33	1.43	8.90	23.10	61.52	1346.91	2.17

Source : result of calculation, 2024

Table 12 Recapitulation of Marshall Glass Addition Test Results

Percentage of Addition	Stabilitas	Flow	VIM	VMA	VFA	MQ	DENSITY
0	1562.29	2.58	9.83	23.89	58.92	612.30	2.15
1	1377.13	1.42	10.82	24.72	56.70	976.84	2.12
2	1499.68	1.60	8.95	23.15	61.34	961.73	2.17
3	1712.41	1.54	8.96	23.15	61.40	1136.93	2.17

Source : result of calculation, 2024

Table 13 Recapitulation of Marshall test results Addition of 2% HDPE and Glass Powder

Percentage of Addition	Stabilitas	Flow	VIM	VMA	VFA	MQ	DENSITY
0	1047.97	1.84	8.80	23.01	61.78	568.28	2.17
1	1703.28	1.87	8.45	22.72	62.85	919.30	2.18
2	2456.06	1.61	7.37	21.81	66.25	2013.09	2.21
3	2407.29	1.67	9.64	23.72	59.56	1449.74	2.15

Source : result of calculation, 2024

Table 14 Recapitulation of Marshall test results for the addition of 4% HDPE and glass powder

Percentage of Addition	Stabilitas	Flow	VIM	VMA	VFA	MQ	DENSITY
0	3285.88	2.17	5.17	19.95	74.17	1556.92	2.26
1	1955.08	2.07	3.47	18.52	82.72	949.94	2.30
2	2276.84	2.06	4.89	19.72	75.31	1108.69	2.26
3	1705.36	2.15	3.54	18.58	81.07	796.42	2.30

Source : result of calculation, 2024

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Table 15 Recapitulation of Marshall test results for the addition of 6% HDPE and glass powder

Percentage of Addition	Stabilitas	Flow	VIM	VMA	VFA	MQ	DENSITY
0	2622.77	1.99	3.39	18.45	81.79	1323.01	2.30
1	2113.54	1.97	5.31	20.07	73.74	1072.01	2.25
2	1902.38	2.19	3.37	18.43	82.73	893.94	2.30
3	1523.94	2.00	3.66	18.68	80.47	766.28	2.29

Source : result of calculation, 2024

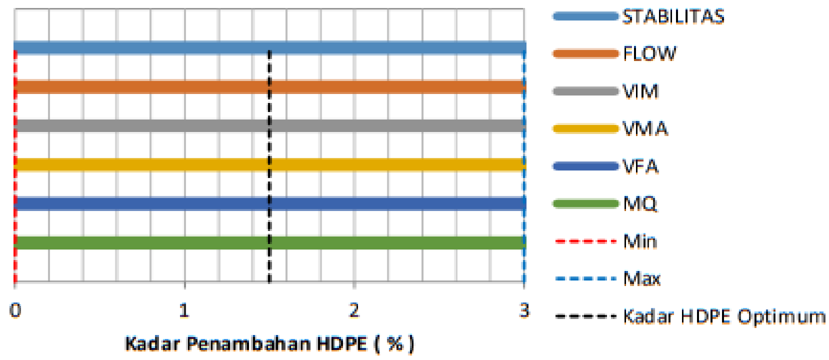

Figure 3 Graph of HDPE Optimum Addition Rate

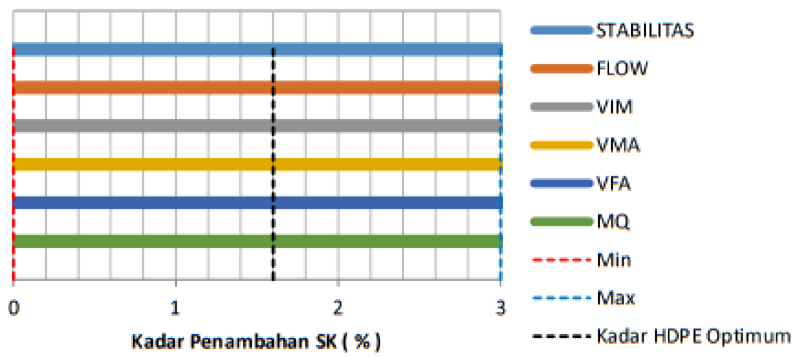

Figure 4 Graph of Optimum Addition Levels of Glass Powder

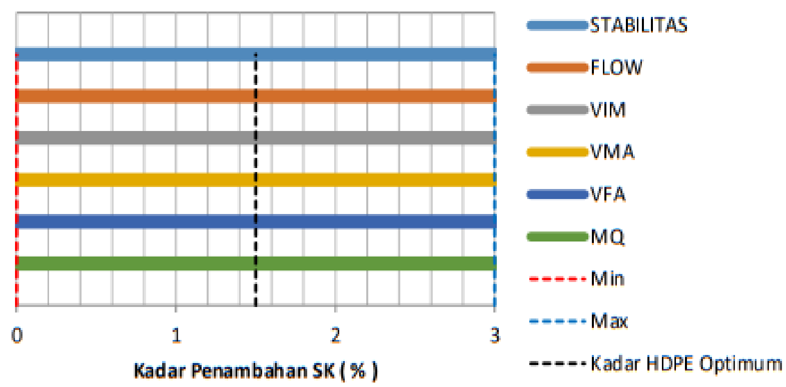

Figure- 5 Graph of Optimum Addition Levels of 2% HDPE and Glass Powder

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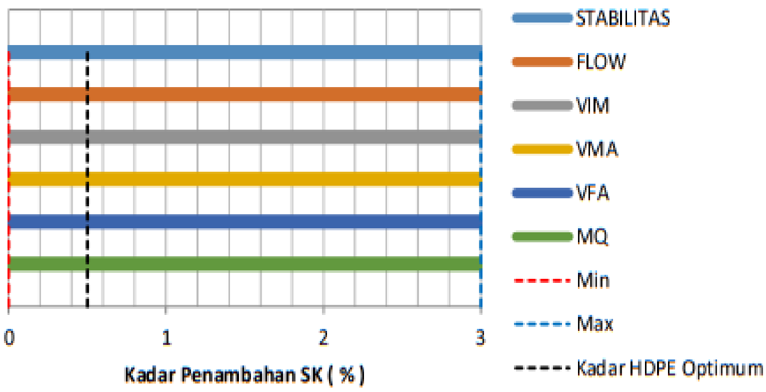

Figure 6 Graph of Optimum Addition Levels of 4% HDPE and Glass Powder

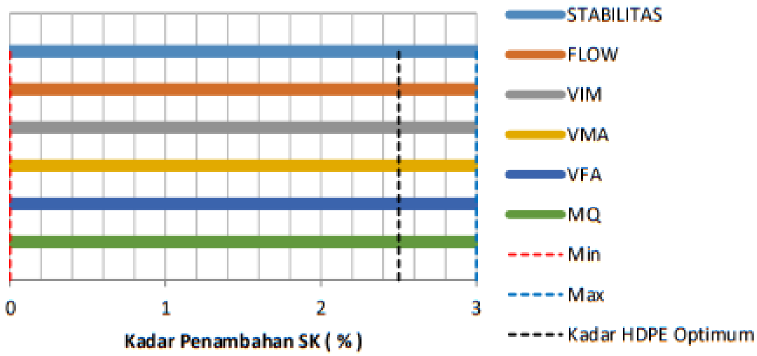

Figure 7 Graph of Optimum Addition Levels of 6% HDPE and Glass Powder

4. CONCLUSION

Based on the analysis of the results of the discussion of the Marshall HDPE 6% and 4% test graph table on the effect of adding HDPE waste and Glass Powder (SK) to the AC-BC mixture, the following conclusions can be drawn:

1. The effect of adding High Density Polyethylene (HDPE) and Glass Powder (SK) as a partial asphalt substitute and a partial filler substitute with a mixture proportion of 10-15 mm Aggregate fractions with a composition of 10%, Medium Aggregate 5-10 mm by 48%, Fine Aggregate 0-5 mm by 38% is included in the gradation envelope requirements for AC-BC asphalt concrete layers, the Optimum Asphalt Content (KAO) value in the AC-BC hot asphalt mixture is most optimal at 7.30%. The KAO value is based on the average of the planned asphalt content which after being tested meets the specifications.
2. The variation of adding HDPE 6%, 4% and Glass Powder (SK) 1%, 2%, 3% is most optimum at an addition rate of 2.5% and 0.5%. Determination based on Marshall testing by combining VIM, VMA, VFA, Stability, Flow and Marshall Quotient (MQ) values.

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