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Experimental Study of HRS-WC Asphalt Mixture Using Limestone as Aggregate Substitute in Cantabro Test

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ABSTRACT

The commonly used materials in asphalt mixtures are coarse aggregates, fine aggregates, and filler. In flexible pavement mixtures, river stones serve as coarse aggregates, sand as fine aggregates, and cement as filler. However, their availability is limited and their prices are relatively high. This study aims to analyze the wear of HRS-WC mixture using limestone material as an aggregate substitute. The mixture consists of 16% crushed stone aggregate 1-2, 30% crushed stone aggregate 0.5-1, 52% fine aggregate, and 2% filler, based on the 2018 Bina Marga specifications in the laboratory. The optimum asphalt content for the mixture obtained from the Pb calculation is 5.8%, 6.3%, 6.8%, 7.3%, and 7.8%. Wear resistance of the specimens is planned to be tested using Cantabro testing method. The Cantabro test results show that the wear rate at an asphalt content of 6.8% is 3.72%, meeting the Bina Marga specification with a wear value ≤ 20%. Thus, the use of limestone can fulfill the requirements as an aggregate substitute.

1. Introduction

Asphalt concrete for road construction has long been recognized and widely used in road construction, and the use of asphalt concrete in Indonesia has been increasing from year to year. This is also because asphalt concrete has several advantages over other materials, as it is relatively cheaper than concrete because it is able to support high vehicle loads and can be made from locally available materials and is very resistant to weather conditions.

The road surface used in Indonesia is a thin layer of asphalt concrete (Lataston) or commonly known as Hot Rolled Sheet (HRS). HRS-WC is a surface layer consisting of a mixture of interstitially graded aggregates. Interstitially graded aggregates are aggregate gradations where one or only a small fraction of particles is removed, creating voids between aggregates, which are then filled with asphalt and filler materials. The layer has a lower structural value than AC (asphalt concrete) but also improves pavement resistance to degradation due to water impermeability and protects the underlying layers from rain, thereby increasing the overall lifespan of pavement construction.

2. Literature Review

Road pavement is a system consisting of several layers of material placed on the subgrade. The main purpose of constructing pavement is to provide a smooth surface with a certain level of skid resistance, with a sufficiently long service life, and minimal maintenance. Pavement serves to protect the subgrade and the layers forming the pavement from experiencing excessive stress and strain due to traffic loads. Flexible pavement, which uses asphalt as a binding material, is designed to bear and distribute traffic loads to the subgrade.

The surface layer is typically divided into wearing and binder courses placed separately. The base and sub-base layers can also be placed in composite form consisting of different materials, namely the upper base and lower base, or the upper subbase and lower subbase.

According to Bina Marga (2007), Asphalt Concrete is a homogeneous mixture of aggregate (coarse aggregate, fine aggregate, and filler material) and asphalt as the binding material with specific gradation, mixed, spread, and compacted at a certain temperature to withstand high traffic loads.

The combined aggregate gradation for asphalt mixtures, expressed as a percentage of the aggregate and filler material by weight, must meet the specified limits as provided in Table 1.

Table 1. Aggregate Gradation for Asphalt Mixtures

Sieve Size (mm)	% The weight that passes through the total aggregate in the mixture.								
	Latasir (SS)		Lataston (HRS)				Laston (AC)		
			Gap-Graded		Semi Gap-Graded				
	A Class	B Class	WC	Base	WC	Base	WC	BC	Base
37.5									100
25								100	90-100
19	100	100	100	100	100	100	100	90-100	76-90
12,5			90-100	90-100	87-100	90-100	90-100	75-100	60-78
9,5	90-100		75-85	65-90	55-88	55-70	77-90	66-82	52-71
4,75							53-69	46-64	35-54
2,36		75-100	50-72	35-55	50-62	32-44	33-53	30-49	23-41
1,18							21-40	18-38	13-30
0,600			35-60	15-35	20-45	15-35	14-30	12-28	10-22
0,300					15-35	5-35	9-22	7-20	6-15
0,150							6-15	5-13	4-10
0,075	10-15	8-13	6-10	2-9	6-10	4-8	4-9	4-8	3-7

Asphalt concrete pavement is a layer in road construction, consisting of a mixture of hard asphalt and continuously graded aggregate, blended, spread, and compacted in a hot state at a specific temperature. The types of aggregates used consist of coarse aggregate, fine aggregate, and filler, while the asphalt used as a binding material for asphalt concrete pavement must consist of one of the uniform hard penetration asphalts 40/50, 60/70, and 80/100, which, when heated to 175°C, do not foam, are uniform, and meet the specified requirements. The production of Asphalt Concrete Pavement (Laston) is intended to obtain a surface layer or intermediate layer (binder) on road pavements that can provide measurable support and function as a waterproof layer to protect the construction beneath it (Bina Marga, 1987).

Aggregate gradation for asphalt mixtures, shown as a percentage of aggregate and filler weight, must meet the limits provided in Table 1. According to Sukirman (2003), asphalt concrete pavement (Laston) is used for roads with heavy traffic loads, and Laston is also known as AC (Asphalt Concrete). There are seven characteristics that asphalt concrete must possess, as follows:

1. Stability
   Stability refers to the ability of a road pavement to withstand traffic loads without experiencing permanent shape changes such as waves, rutting, and bleeding. Roads serving high traffic volumes, predominantly consisting of heavy vehicles, require a pavement with high stability. Factors affecting the stability of asphalt concrete include internal friction and cohesion.

2. Durability
   Durability is the ability of asphalt concrete to withstand repetitive traffic loads, such as vehicle weight and wheel surface friction, as well as resist wear due to weather and climatic factors such as air, water, or temperature changes. Asphalt concrete durability is influenced by the thickness of the asphalt film or blanket, the amount of pores in the mixture, its density, and waterproofing. A thicker asphalt film can lead to easier bleeding, resulting in a slicker road surface.

3. Flexibility
   Flexibility refers to asphalt concrete's ability to accommodate settlement and movement of the foundation or subgrade without cracking. Settlement can occur due to repetitive traffic loads or self-weight settlement of embankments constructed on native soil. Flexibility can be enhanced by using open-graded aggregates with a high asphalt content.

4. Fatigue Resistance
   Fatigue resistance is the ability of asphalt concrete to withstand repeated bending due to repetitive loading without developing fatigue in the form of ruts and cracks.

5. Skid Resistance
   Skid resistance is the ability of the asphalt concrete surface, particularly under wet conditions, to provide friction to vehicle tires, preventing slipping or skidding. The aggregates used should not only have a rough surface but also withstand becoming slick due to repetitive vehicle passages.

6. Impermeability
   Impermeability refers to asphalt concrete's ability to resist penetration by water or air into the asphalt concrete layer. Water and air can accelerate the aging process of asphalt and cause asphalt film detachment from aggregate surfaces. The level of asphalt concrete impermeability is inversely related to its durability.

7. Workability
   Workability is the ability of asphalt concrete mixtures to be easily spread and compacted. Factors affecting the ease of spreading and compaction include asphalt viscosity, asphalt sensitivity to temperature changes, aggregate gradation, and aggregate conditions.

Aggregate

Aggregate, which is the main material for road structures, is a collection of crushed stones and sand grains, or other minerals, whether natural or artificial. The pavement layer contains 90-95% aggregate based on weight percentage, or 75-85% aggregate based on volume percentage. The aggregate used must be clean from impurities, organic materials, or other unwanted substances, as they will reduce the performance of the mixture (Hary C., 2015)

Aggregate or stone, or granular material, is hard and compact granular material. Aggregates play a very important role in transportation infrastructure, especially in road pavements. The load-bearing capacity of road pavements is largely determined by the characteristics of the aggregates used. The proper selection of aggregates that meet the requirements will greatly determine the success of road construction or maintenance (Hot Mix Asphalt Mixing Work Manual, Ministry of Public Works).

Aggregate or stone, or granular material, is hard and compact granular material. The term aggregate includes, among others, round stones, crushed stones, stone dust, and sand. Aggregates play a very important role in transportation infrastructure, especially in road pavements. The load-bearing capacity of road pavements is largely determined by the characteristics of the aggregates used. The proper selection of aggregates that meet the requirements will greatly determine the success of road construction or maintenance. The quality of an aggregate is greatly influenced by its properties, including strength, durability, adhesiveness to asphalt, and workability.

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3. METHODOLOGY

The method used in this study is laboratory experimental method. Hot asphalt mixtures are produced using limestone as a substitute material for aggregates. Then, an assessment and stability testing are carried out using the Marshall Test. This research was conducted at the Laboratory of the National Road Agency in Abepura, Jayapura.

The materials used are limestone directly extracted from the Koya District in Muara Tami, Jayapura. The materials include coarse aggregates, fine aggregates, and filler.

4. RESULT AND DISCUSSION

Examination of aggregate characteristics is conducted to determine the suitability of the aggregate for use. Tables 1 through 5 show the results of aggregate characteristic testing that has been conducted. Based on the results of the testing of coarse and fine aggregate characteristics, it is evident that the aggregates used meet the specifications set by Bina Marga for required road materials.

Table 2. Results of Aggregate Inspection after 100 and 500 Rotations

No	Testing	Result	Specifications
1	Aggregate Wear (Abration) after 100 Rotations	7.06	Max 7
2	Aggregate Wear (Abration) after 500 Rotations	36.52	Max 40

Table 3. Examination Results of Sand Equivalent Aggregate

No	Testing	Result	Specifications
1	Fine Aggregate Equivalent to Sand	54.76	Min 50
2	Fine Aggregate Equivalent to Sand	51 22	Min 50
	rata rata	**52.99**	

Table 4. Results of Aggregate Density Testing 1-2

No	Testing	Result	Specifications
1	Bulk Density	2.694	Min 2.5
2	SSD Density	2. 718	Min 2.5
3	Specific Gravity (apparent)	2.762	Min 2.5
4	Absorption	0.913	Min 3.0

Table 5. Results of Aggregate Density Testing 0.5-1

No	Testing	Result	Specifications
1	Bulk Density	2.694	Min 2.5
2	SSD Density	2. 718	Min 2.5
3	Specific Gravity (apparent)	2.762	Min 2.5
4	Absorption	0.913	Min 3.0

Table 6. Results of Limestone Aggregate Density Testing

No	Testing	Result	Specifications
1	Bulk Density	2.468	Min 2.5
2	SSD Density	2.539	Min 2.5
3	Specific Gravity (apparent)	2.656	Min 2.5
4	Absorption	2.870	Min 3.0

Asphalt Testing

This calculation is carried out with the aim of determining the physical properties of asphalt that are related to its performance

Table 7. Results of Examination of Asphalt Oil Pen 60/70

No	Testing	Unit	Result	Spec
1	Asphalt Penetration	mm	65	60-70
2	Softening Point	°C	54	> 48
3	Ductility of Asphalt	Cm	150	> 100
4	Flash Point	°C	252	> 232
5	Specific Gravity	gram/ml	1,046	> 1,0

Determination of Mixture Gradation

Based on Figure 1, the combined aggregate composition falls within the specified limits for asphalt mixtures designated for road materials, thereby obtaining a suitable mixture.

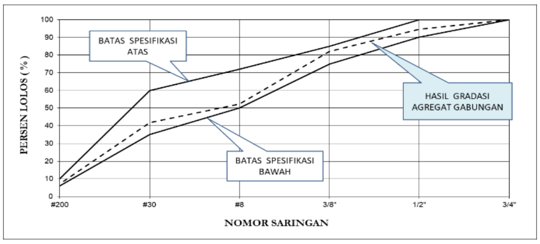

Figure 1. Aggregate Mixture Gradation

Estimated Asphalt Content Calculation

Table 8. Combined Aggregate Mixture Gradation

Sieve Size		Lataston HRS-WC Spec		
ASTM	(mm)	Max Limit	Result	Min Limit
¾"	19	100	100.00	100
½"	12.5	90	94.65	100
⅜"	9.5	75	81.94	85
No.8	2.36	50	52.24	72
No.30	0.6	35	41.70	60
No.200	0.075	6	7.18	10

From the table above, the estimation of asphalt content calculation can be planned as follows.

Pb = 0,035(%CA) + 0,045(%FA) + 0,18 (% FF) + K…
Pb = 0,035 (47.66) + 0,045 (40.48) + 0,18 (7.18) + 2
Pb = 6.788 rounded to 6.8%

From the calculation above, the planned asphalt content obtained is 6.8%.

Aggregate and Asphalt Mixture Calculation

This calculation aims to determine the composition of each test specimen to be used in the asphalt mixture testing process.

Table 9. Aggregate and Asphalt Mixture Calculation

No	Description		Unit	Aspal Content (%)				
	Data Spec	Material Composition	gr	5.8	6.3	6.8	7.3	7.8
1	Crushed Aggregate 1-2	16%	gr	180.9	179.9	178.94	177.98	177.02
2	Crushed Aggregate 0,5 - 1	30%	gr	339.12	337.32	335.52	335.52	331.92
3	Fine Aggregate	52%	gr	587.81	584.69	581.57	581.57	575.33
4	Filler	2%	gr	22.61	22.49	22.37	22.37	22.13
	Total Weight			113.4	1124.4	1118.4	1118.4	1106.4
	Sample Total Weight			1200	1200	1200	1200	1200

Marshall Test

From the flow test, asphalt content results obtained are 5.8% at 2.94 mm, 6.3% at 3.14 mm, 6.8% at 3.42 mm, 7.3% at 3.56 mm, and 7.8% at 3.86 mm

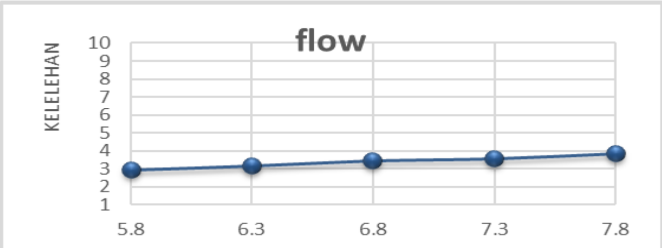

Figure 2. Flow Test Graph

From the Marshal test, the asphalt content results are as follows: 5.8% yielded 291.28 kg/mm, 6.3% yielded 293.26 kg/mm, 6.8% yielded 298.77 kg/mm, 7.3% yielded 284.85 kg/mm, and 7.8% yielded 241.10 kg/mm.

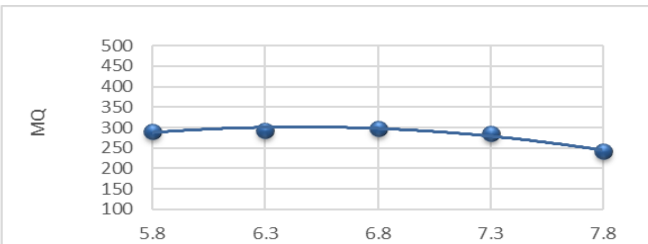

Figure 3. Marshall Test Graph (MQ)

The air voids in the mixture (VIM) resulted in the following asphalt content: 5.8% yielded 5.91%, 6.3% yielded 4.91%, 6.8% yielded 4.52%, 7.3% yielded 3.28%, and 7.8% yielded 2.4%.

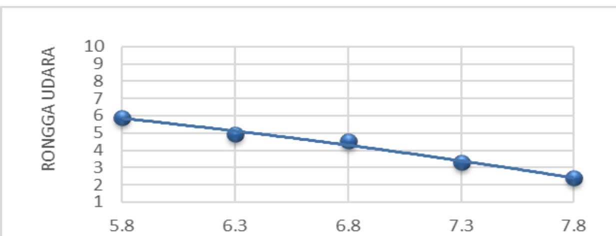

Figure 4. VIM Test Graph

The values of Voids in Mineral Aggregate (VMA) obtained from the asphalt content of 5.8% are 16.72%, 6.3% are 16.87%, 6.8% are 17.56%, 7.3% are 17.52%, and 7.8% are 17.80%.

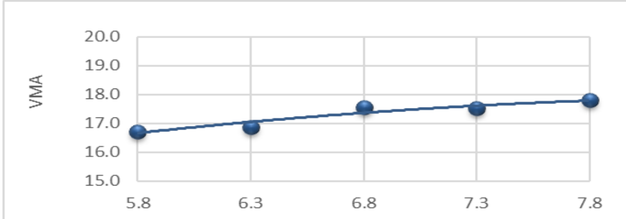

Figure 5. VMA Test Graph

The values of Voids Filled with Bitumen (VFB) obtained from the asphalt content of 5.8% are 64.65%, 6.3% are 170.92%, 6.8% are 74.27%, 7.3% are 81.25%, and 7.8% are 86.47%.

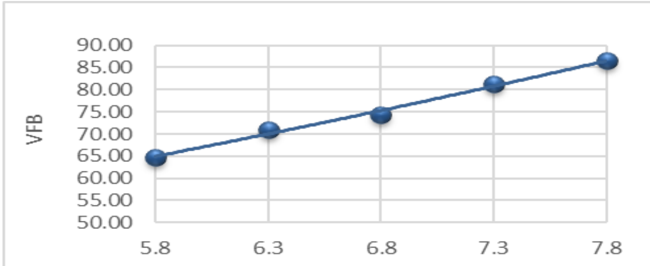

Figure 6. VFB Test Graph

The Marshall stability obtained from the asphalt content of 5.8% is 855 mm, 6.3% is 920 mm, 6.8% is 1021 mm, 7.3% is 1013 mm, and 7.8% is 931 mm.

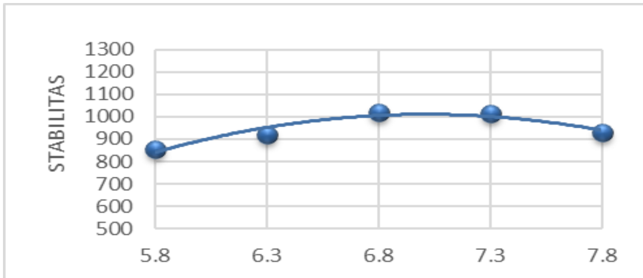

Figure 7. Marshall Stability Test Graph

Based on the Marshall laboratory testing results and the calculated data, the optimum asphalt content is observed in the following graph:

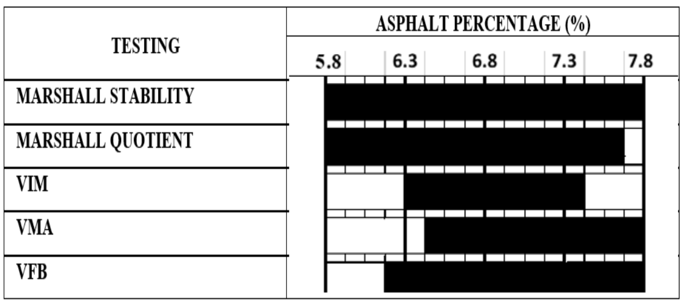

Figure 8. Diagram of Optimum Asphalt Content (OAC) Determination Results

Table 10. Cantabro Test Results at Asphalt Content 6.8%

No	Rotation	Weight 1	Weight 2	Weight 3
	Initial Weight (Gram)	1200	1200	1200
	Final Weight (Grram)	1155	1151	1150
	Weight Loss (Gram)	45	49	50
	Penetration Weight Loss (%)	2.92%	4.08%	4.17%
	Average Penetration Weight Loss (%)		3.72%	

From the volumetric mixture testing and Marshall testing, the optimum asphalt content obtained is 6.8%. Additionally, from the Cantabro testing, a wear value of 3.72% is obtained for an asphalt content of 6.8%. This testing meets the specified requirement of ≤ 20% after 500 rotations.

5. CONCLUSIONS

From the research results, data analysis, and discussions conducted, several conclusions can be drawn, including:

1. Through Marshall testing, the following values were obtained:
   Flow values at asphalt content of 5.8% were 2.94 mm, at 6.3% were 3.14 mm, at 6.8% were 3.42 mm, at 7.3% were 3.56 mm, and at 7.8% were 3.86 mm. Marshall question (MQ) values at asphalt content of 5.8% were 291.28 kg/mm, at 6.3% were 293.26 kg/mm, at 6.8% were 298.77 kg/mm, at 7.3% were 284.85 kg/mm, and at 7.8% were 241.10 kg/mm. Void in mixture (VIM) values at asphalt content of 5.8% were 5.91%, at 6.3% were 4.91%, at 6.8% were 4.52%, at 7.3% were 3.28%, and at 7.8% were 2.4%. Aggregate voids filled with asphalt (VMA) values at asphalt content of 5.8% were 16.72%, at 6.3% were 16.87%, at 6.8% were 17.56%, at 7.3% were 17.52%, and at 7.8% were 17.80%. Voids filled with bitumen (VFB) values at asphalt content of 5.8% were 64.65%, at 6.3% were 170.92%, at 6.8% were 74.27%, at 7.3% were 81.25%, and at 7.8% were 86.47%. Marshall stability values at asphalt content of 5.8% were 855 mm, at 6.3% were 920 mm, at 6.8% were 1021 mm, at 7.3% were 1013 mm, and at 7.8% were 931 mm.
2. Cantabro testing resulted in abrasion values. At an asphalt content of 6.8%, the abrasion value obtained was 3.72%. From this test, it was found that the abrasion of HRS-WC asphalt mixture using limestone as aggregate substitute met the specified criteria of ≤ 20% after 500 cycles.

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