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INVESTIGATION ON THE PERFORMANCE OF LIMESTONE AS FILLER ON VARIOUS PAVEMENT MIXTURES

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Abstract

Additives added to the flexible pavement mixture aim to increase the strength of the pavement. Limestone which is a sedimentary rock consists of the mineral calcium carbonate (calcite) or the double carbonate of calcium and magnesium (dolomite). The use of limestone in pavement mixtures is expected to increase the performance of Marshall parameters. This study aims to determine the suitability of limestone as a filler for 3 types of pavement mixtures, namely Asphalt Concrete Wearing Course, Hot Rolled Sheet and Split Mastic Asphalt. In this study, the limestone used was sourced from Jorong Durian, Nagari Kamang Mudiak, Kamang Magek District, Agam Regency, West Sumatra Province. The tests were carried out using following variations of limestone; 0%, 25%, 50%, 75%, 100% of the total amount of filler in the mixture. The results of the study using limestone as filler obtained at an optimum content of 29% for AC-WC, 22% for HRS, and 82.5% for SMA. In addition, AC-WC pavement was found to the best increase in Marshall stability performance. Therefore, it can be concluded that limestone from Kamang Mudiak is most suitable to be added to AC-WC pavement mixtures.

Keywords:

Asphalt Concrete-Wearing;
Course;
Hot Rolled Sheet;
Split Mastic Asphalt;
Limestone;
Marshall Test.

1 Introduction

Flexible pavement is a pavement with asphalt binder, which has lower strength than rigid pavement. Additives added to the flexible pavement mixture aim to increase the strength of the pavement, either in the form of additives mixed into asphalt or added to aggregate, such as Styrofoam, Gondorukem, Latex [1]–[4]. In this research the materials that can be used as additives is limestone [5], [6].

Limestone is a sedimentary rock consisting of the mineral calcium which generally functions as a building material as well as a base soil stabilizer for roads. The main content of limestone is $CaCO_3$ (calcium carbonate) or the double carbonate of calcium and magnesium (dolomite)[7]. Due to this content, limestone is commonly used as a modifier of the characteristics of a material such as asphalt mixture both in terms of resistance and humidity [8]. In addition, limestone of hydrated lime type is usually used as a penetration enhancer and lowering the viscosity of asphalt cement. In this study, the limestone used was sourced from Jorong Durian, Nagari Kamang Mudiak, Kamang Magek District, Agam Regency, West Sumatra Province [9].

The abundant availability of limestone is a great potential as an additive for pavement mixtures. For this reason, this research was carried out on various types of pavements so that it can be known which pavement is more suitable for the application of limestone into the pavement mixtures.

There are three types of pavements selected in this study, namely Asphalt Concrete Wearing Course (AC-WC), Hot Rolled Sheet (HRS) and Split Mastic Asphalt (SMA). AC-WC is a layer of asphalt concrete which functions as a wear layer on a road pavement construction with a minimum thickness of

4 cm. AC-WC multigrade is one of the implementations of hot mix technology developments in Indonesia, considered very suitable for use on highways with heavy and dense traffic. AC-WC has the smoothest texture compared to other types of asphalt concretes [10].

Meanwhile, HRS wearing course is an asphalt mixture that is flexible and has high durability, because HRS is made of gap-graded materials, they have large enough cavities in the mixture which enable them to absorb large amounts of asphalt (7%-8%) without bleeding or excess. This characteristic increases the durability of the pavement so that the impermeability to water and air becomes high. This type of pavement functions as a cover layer consisting of a mixture of gap-graded aggregate, filler (mineral dust) and hard asphalt with a penetration of 60 or 80 with a certain ratio, which is mixed and compacted in hot conditions according to the new hot mix asphalt specifications at Puslitbang Jalan.

Whereas SMA itself is a type of pavement with a surface layer having a higher percentage of coarse aggregate than AC or HRS. Coarse aggregate percentage of 70% of the total mix made this pavement more resistant to deformation and has a higher level of strength and durability. SMA is a type of hot mix asphalt which has a solid gradation with most of the aggregate being coarse aggregate. Coarse aggregate itself is known to have high stability and longer durability.

This research was conducted at the Padang III National Road Implementation Center Testing Laboratory. This study aims to compare 3 types of pavement using Kaptan Mesh 100 limestone from Jorong Durian Quarry, Agam Regency as filler. The three types of pavement mixtures studied were AC-WC, HRS and SMA mixtures. Namely those that produce high Marshall stability values and other parameter values that are in accordance with the standards used.

The Marshall parameters reviewed include stability, flow, voids in the mix (VIM), voids filled with asphalt (VFA), voids between mineral aggregates (VMA), and Marshall Quotient (MQ) according to the 2018 Revision 2 General Specification standard.

2 Materials and methodology

2.1 Materials

Lime-based material consists of limestone or dolomite, which contains calcium carbonate ($CaCO_3$) or the double carbonate of calcium and magnesium (dolomite). Lime-based materials can be used as a binder because it has good plastic properties (not brittle), hardens quickly, has good workability, and has good bonding ability for stone and brick. The type of lime used is limestone (Kaptan Mesh 100) Jorong Durian Quarry, Nagari Kamang Mudiak, Kamang Magek District, Agam Regency.

There are 3 types of asphalt pavements compared in this study, namely AC-WC, HRS, and SMA which have gradations as shown in Table 1.

Table 1: Combined Aggregate Gradation Distribution (%).

Sieve No	Sieve Size (mm)	*Asphalt Concrete (AC), %*	*Hot Rolled Sheet (HRS), %*	*Split Mastic Asphalt (SMA), %*
		WC	*WC*	Coarse
1"	25	-	-	100
3/4"	19	100	100	90 – 100
1/2"	12,5	90 – 100	90 – 100	50 -88
3/8"	9,5	77 – 90	75 – 85	25 – 60
#4	4,75	53 – 69	-	20 – 28
#8	2,36	33 – 53	50 – 72	16 – 24
#16	1,18	21 – 40	-	-
#30	0,600	14 – 30	35 – 60	-
#50	0,300	9 – 22	-	-
#200	0,075	4 – 9	-	8 - 11

(**Source**: General Specifications for Highways 2018 Revision)

2.2 Methodology

The test specimens are made based on the variation of lime used, namely 0%, 25%, 50%, 75% and 100% of the filler volume used for each pavement. The research was conducted at the Padang III National Road Implementation Centre Testing Laboratory.

Mixing Maximum Specific Gravity Test (Gmm) covers the standards and specifications of SNI 03-6893-2002 (Testing Method for Maximum Specific Gravity of Asphalt Mixture): General Specifications of Highway Division 6 of 2010 Revision 2. This test aims to determine the maximum specific gravity of asphalt concrete mixture and the effective specific gravity of aggregate for a certain asphalt content. The maximum specific gravity of the asphalt mixture is determined by measuring the weight and contents of the test object where the air that is between the grains of the test object is removed by means of suction.

The number of specimens was made based on the theoretical optimum asphalt content (TAC) obtained by subtracting and adding the theoretical optimum asphalt content values of 0.5% and 1% with 3 samples for each asphalt content.

After obtaining the theoretical asphalt content (TAC), then specimen is made using additional limestone filler mixed into optimum asphalt content, so that the asphalt content in the mixture remains constant for all variations of limestone filler [11], [12]. Three samples will be made for each lime filler replacement. Thus, a total of fifteen samples will be used with lime filler replacement in one type of asphalt mixtures.

To investigate which pavement is more suitable, Marshall test was carried out [13]. This test determines the resistance (stability) to plastic melting (flow) of the asphalt mixture. Where stability is the ability of an asphalt mixture to accept loads until plastic melting occurs which is expressed in kilograms and plastic melting (flow) is a state of change in the shape of an asphalt mixture that occurs due to a load up to the collapse limit expressed in mm or 0.01".

3 Result and discussion

3.1 Material Compliance Check

The results of the aggregate inspection can be seen in Table 2.

Table 2: Aggregate inspection results.

No	Checking Type	Unit	Value	Standard	Specification	Details
1	Coarse aggregate					
	Dry specific gravity	gr/cc	2.669		≥2.5	Complied
	Surface Dry Saturated Specific Gravity	gr/cc	2.722		≥2.5	Complied
	Apparent Specific Gravity	gr/cc	2.819	SNI 1969: 2008	-	Complied
	Absorption	%	2.001		Max 3%	Complied
	Aggregate specific gravity	gr/cc	2.669		Min 2.5	Complied
2	Coarse Aggregate					
	Dry specific gravity	gr/cc	2.559		≥2.5	Complied
	Surface Dry Saturated Specific Gravity	gr/cc	2.634		≥2.5	Complied
	Apparent Specific Gravity	gr/cc	2.768	SNI 1970: 2008	-	Complied
	Absorption	%	2.955		Max 3%	Complied
	Aggregate specific gravity	gr/cc	2.559		Min 2.5	Complied
3	Aggregate adhesiveness to bitumen	%	>95%	SNI 2439: 2011	>95%	Complied
4	Aggregate Wear with Los Angeles Machinery	%	12.286%	SNI 2479: 2008	Max 40%	Complied
5	Aggregate Strength Against Pressure	%	27.167%	BS:182 Part 111:1990	Max 30%	Complied
6	Aggregate Strength Against Collision	%	2.75%	BS:812: Part 112:1990	Max 30%	Complied

Based on Table 2, it can be concluded that the results of the aggregate inspection for all tests meet the standards according to the 2018 Revision 2 General Highways Specifications. Asphalt inspection results can be seen in Table 3.

Table 3: Asphalt inspection results.

No	Asphalt Physical Properties	Unit	Value	Standard	Specification	Details
1	Penetration	(0.1mm)	62.425	SNI 2456: 2011	60-70	Complied
2	Flash point	˚C	255˚C	SNI 2433: 2011	≥232˚C	Complied
3	Burn Point	˚C	280˚C	SNI 2433: 2012	≥232˚C	Complied
4	Ductility	cm	>100	SNI 2432: 2011	≥100	Complied
5	Asphalt Specific Gravity	gram	1.020	SNI 2441: 2011	≥1.00	Complied
6	Soft Point	˚C	54	SNI 2434: 2011	>48˚C	Complied

Based on Table 3, it can be concluded that the asphalt inspection results for all tests meet the standards according to the 2018 Revision 2 General Highways Specifications.[11], [13]. The results of examining the specific gravity of lime can be seen in Table 4, using a Le Chatelier bottle. This test is intended to determine the value of the Portland cement/limestone hydrated with water.

Table 4: Limestone specific gravity test results.

Test	Result	Standard	Unit
Dry Weight of Limestone (A)	45	SNI 03-2531-1991	Gram
Oil Volume (V1)	0.1		ml
Oil + Limestone Volume (V2)	18.1		ml
Limestone Specific Gravity (A/(V2-V1))	2.350		gram/ml

Based on Table 4, the results of the lime specific gravity test were 2.350 grams/ml. The results of examining the maximum specific gravity of the mixture (Gmm) can be seen in Table 5.

Table 5: Results of the inspection of the maximum specific gravity of the mixture.

No. Example		Test result		
		AC-WC	HRS	SMA
Weight of dry specimen (gr)	A	1171.1	1170.0	1151.6
Weight of container + specimen in water (gr)	P	4494.3	4489.1	4484.7
Weight of container in water (gr)	Q	3797.6	3802.8	3802.8
Weight of test object in water (gr)	C = P - Q	696.7	686.3	689.0
SSD test object weight (gr)		1173.2	1174.4	1162.3
Gmm corrected (gram/ml)	A/(A-C)	2.469	2.419	2.446

Based on Table 5, the results of examining the maximum specific gravity of the mixture were 2.469 gr for AC-WC, 2.419 gr for HRS, and 2.446 gr for SMA. The test method refers to SNI 03-6893-2002 (Testing Method for Maximum Specific Gravity of Asphalt Mixture) and General Specifications of Highways Division 6 of 2010 Revision 2 [1], [2], [13], [14].

3.2 Determination of Aggregate Content

The method used to determine aggregate content is the median limit method, where the weight of aggregate is obtained by taking the median value of the specifications of each asphalt mixture according to the general specifications of the 2018 Highways Division 6 revision 2 [13]. Determination of aggregate content can be seen in Table 6.

Table 6: Median limit method.

Aggregate size	AC-WC		HRS		SMA	
	% passing	Specification (%)	% passing	Specification (%)	% passing	Specification (%)
1"	-	-	-	-	100	100
3/4"	100	100	100	100	95	90 - 100
1/2"	96	90 - 100	93	90 - 100	69	50 - 88
3/8"	85	77 - 90	80	75 - 85	42	25 - 60
#4	59	53 - 69	-	-	24	20 - 28
#8	43	33 - 53	61	50 - 72	20	16 - 24
#16	31	21 - 40	-	-	-	-
#30	24	14 - 30	38	35 - 60	-	-
#50	15	9 - 22	-	-	-	-
#100	11	6 - 15	-	-	-	-
#200	5	4 - 9	6	6 - 10	9	8 - 11
PAN	0	-	0	-	0	-

Based on Table 6, the aggregate content is obtained using the median limit method for standard asphalt mixtures in accordance with the 2018 General Highways Division 6 Revision 2 General Specification standards. Aggregate gradation using the median limit method can be seen in Fig. 1.

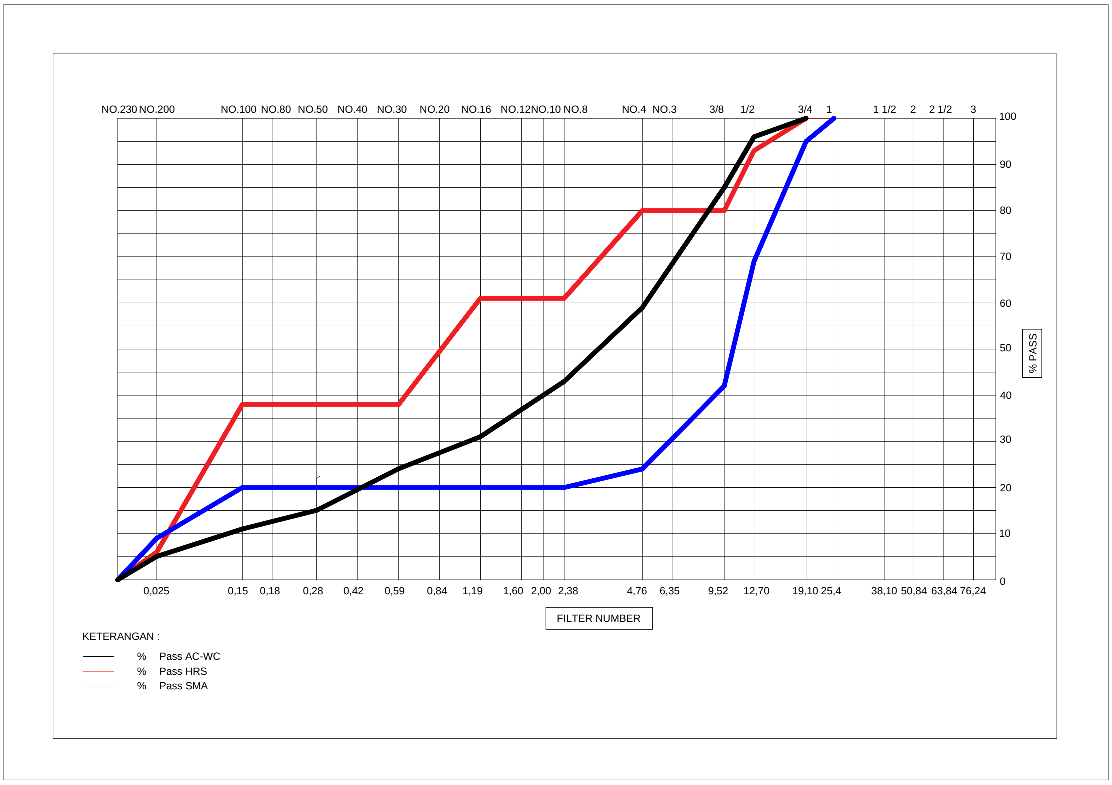

Fig. 1: Median method aggregate gradation graph.

As can be seen in Fig. 1, the aggregate gradation of the AC-WC asphalt mixture can be considered as well-graded, where the aggregate contained in the mixture is distributed evenly. As for the mixture of HRS and SMA, they can be classified as a gap-graded. Because there are several sieve sizes that are not used in the gradation of the aggregate, and therefore will affect the Marshall test results.

3.3 Determination of Theoretical Asphalt Content

Theoretical asphalt content (TAC) was determined using the Depkrimpraswil 2002[11] method based on the values from Table 6, with the equation:

$$P = 0.035\ (\%\ CA) + 0.045\ (\%\ FA) + 0.18\ (FF) + K \tag{1}$$

where:
P = Percent estimated bitumen content,
CA = Proportion of coarse aggregate fraction,
FA = Proportion of fine aggregate fraction,
FF = Filler proportions,
K = Constant value.

The P value of each type of asphalt mixture will be rounded to the nearest unit and the rounded value is the TAC value. Calculation indicated that the TAC value of the AC-WC asphalt mixture is 5% and for both HRS and SMA asphalt mixture, the TAC value is 6%.

3.4 Analysis of Marshall Test Results Without Limestone Variation

From the examination of the Marshall parameters without lime variation, the optimum asphalt content (OAC) value for each asphalt mixture is obtained. The details of which can be seen in Table 7.

Table 7: Determination of OAC Marshall without Limestone Variation.

Asphalt Mix	Specified Parameters	OAC
AC-WC	Stability, Flow, VIM, VMA, VFB, MQ	5.5%
HRS-WC	Stability, Flow, VIM, VFB, MQ	5.685%
SMA	Stability, Flow, VIM, VMA, VFB	5.85%

In Table 7, it can be seen that the AC-WC has six Marshall parameters that meet the specifications with OAC of 5.5%. For HRS, only VMA parameter does not meet the specifications with OAC 5.685%. Meanwhile SMA asphalt mixture, the OAC value was 5.85% with the MQ parameter not fulfilling the 6 parameters reviewed. The OAC value of each asphalt mixture is used to make 15 samples per type of asphalt mixture with different filler percentages.

3.5 Analysis of Marshall Test Results with Limestone Variations as Filler

After examining the Marshall parameters with limestone variations, from the fifteen samples made, five Marshall parameter values will be produced from the average percentage of different fillers which can be seen in Table 8.

Table 8: Marshall results with variations of lime filler.

Asphalt Mix	% Limestone	VMA (%)	VIM (%)	VFB (%)	Stability (kg)	Flow (mm)	MQ (kg/mm)
AC-WC	0 %	15.070	3.640	75.810	1670.790	3.600	469.000
	25 %	15.450	4.460	71.540	1595.870	3.570	447.400
	50 %	15.200	3.670	75.430	1449.310	3.730	409.020
	75 %	14.210	3.040	78.650	1432.910	3.600	399.630
	100 %	14.420	3.390	76.480	1408.560	3.800	372.650
HRS-WC	0 %	17.290	4.310	74.620	1409.590	3.500	403.870
	25 %	17.590	4.790	72.960	1353.210	3.333	408.570
	50 %	16.860	4.070	76.750	1486.650	3.400	436.890
	75 %	16.320	3.590	79.720	1584.390	3.200	499.880
	100 %	16.800	3.870	77.190	1404.100	3.000	468.400
SMA	0 %	19.092	5.646	70.429	839.141	5.433	154.304
	25 %	19.686	6.338	67.803	869.111	6.100	141.953
	50 %	18.243	4.656	74.480	869.111	5.567	154.705
	75 %	18.308	4.732	74.156	846.634	5.300	168.168
	100 %	18.398	4.837	73.712	771.710	5.400	146.033

Graphical analysis of the Marshall parameter examination results with lime variations as follows:

a) *Impact of Limestone Filler to the Stability*

The stability graph of the Marshall test can be seen in Fig. 2.

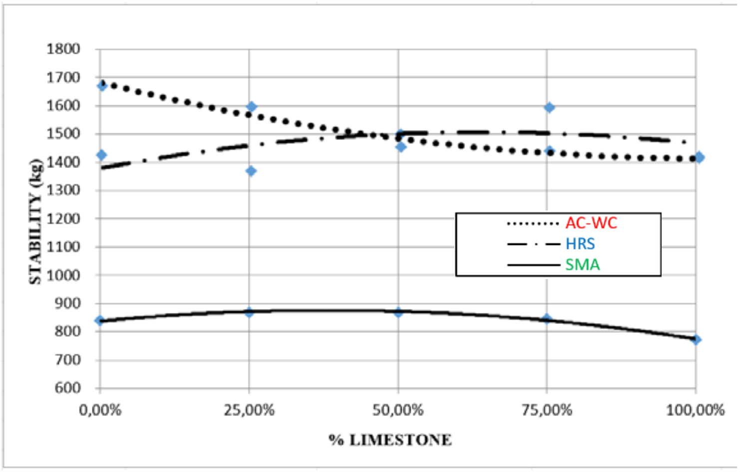

Fig. 2: Graph of Stability vs % Limestone.

As can be seen in Fig. 2, it can be concluded that AC-WC has the highest stability value at 1670.790 kg. The lowest stability value was produced in the SMA asphalt mixture test, which was 771.710 kg. Regardless, all three types of asphalt mixtures tested had a stability value that met the 2018 General Highways Specification Standards Division 6 Revision 2. The stability value standard for AC-WC was ≥ 800 kg, while for HRS and SMA, both attained stability value ≥ 600 kg.

b) *Impact of the Limestone Filler to the Flow*

For the value of the melting chart (flow) from the Marshall test results can be seen in Fig. 3.

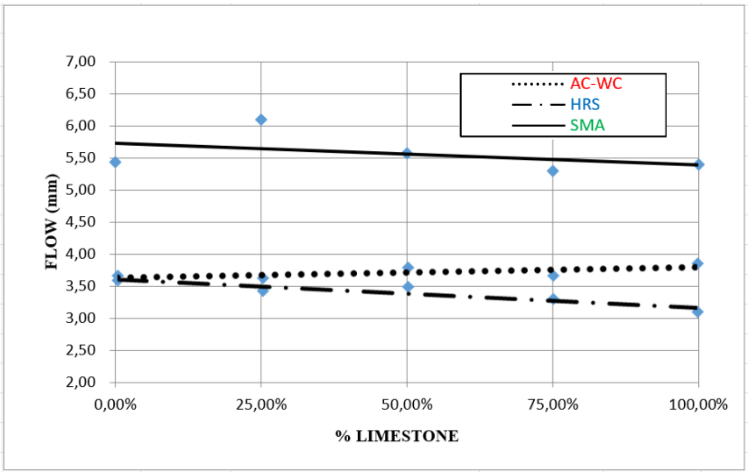

Fig. 3: Graph of Flow vs % Limestone.

As can be seen in Fig. 3, the flow value of the SMA asphalt mixture is very high compared to other asphalt mixtures. For comparison, the flow value specification for SMA is ≥ 2 mm to ≤ 4.5 mm. A flow value that is too high can cause the mixture to change shape easily. In the SMA asphalt mixture however, there is no flow value that met the specifications. As for the asphalt mixture AC-WC and HRS, the overall melting value is compiled to the specified specifications. For AC-WC the specifications are ≥ 2 mm to ≤4 mm and for HRS the specifications are ≥ 3 mm to ≤ 5 mm.

c) Impact of Limestone Filler to the VIM

The VIM value of the test results made in the graph can be seen in Fig. 4.

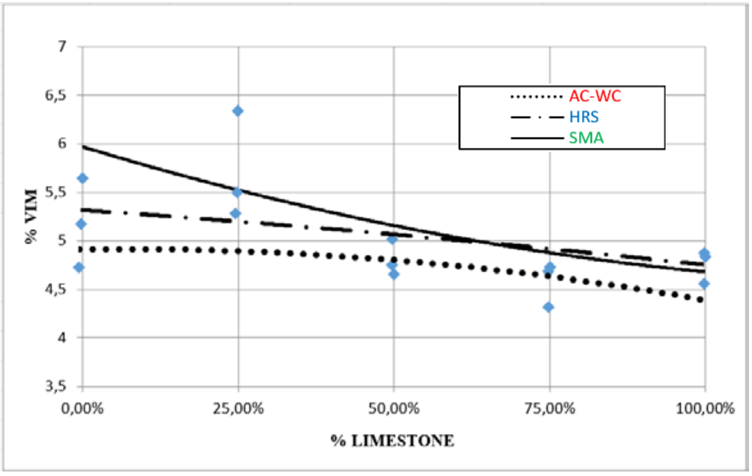

Fig. 4: Graph of % VIM vs % Limestone.

Based on the General Specification Standards for Highways 2018 Division 6 Revision 2, the VIM value of the AC-WC and HRS asphalt mixture is in the range of 3% to 5%. Meanwhile, for SMA, the minimum is 4% and the maximum is 5%. From Fig. 4, it can be seen that the VIM value of the AC-WC and HRS asphalt mixture is fully within the specified specifications. However, for the SMA asphalt mixture, only the VIM value obtained from the limestone percentage ranges from 60% to 100% met the specification.

d) Impact of Limestone Filler to the VMA

The VMA graph from Marshall testing can be seen in Fig. 5.

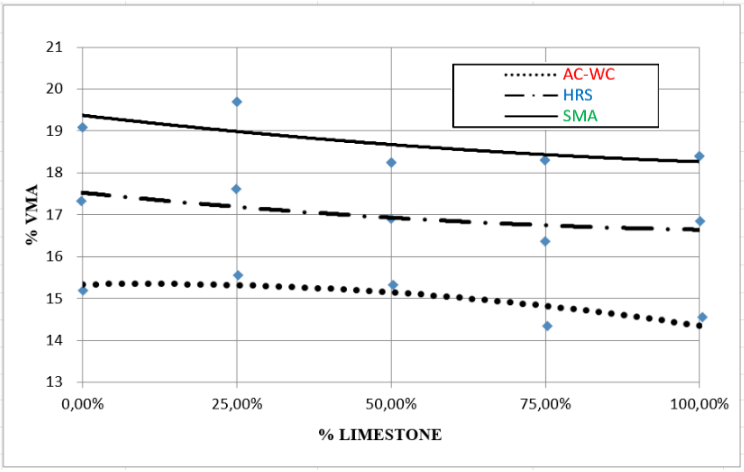

Fig. 5: Graph of % VMA vs % Limestone.

From the picture above it can be concluded that the VMA value of SMA has the highest stability value at 19.686%. The lowest VMA value was produced in the AC-WC asphalt mixture test, at 14.210%. Only the SMA asphalt mixture has a stability value that meets the Specification Standards, whereas for AC-WC and HRS asphalt mixtures with a lime percentage of more than 50%, no VMA value complied to the specifications. For record, the standard VMA values from AC-WC, is ≥ 15%, while HRS and SMA is ≥ 17%.

e) Impact of Limestone Filler to VFB

The value of the VFB graph from the Marshall test results can be seen in Fig. 6.

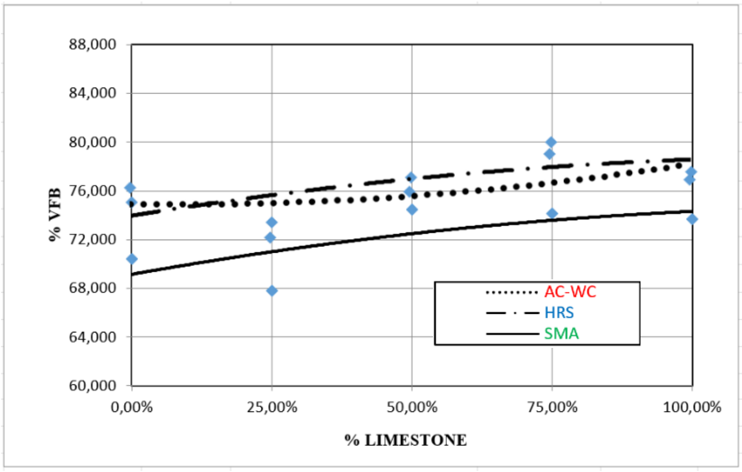

Fig 6: Graph of % VFB vs % Limestone.

As can be seen in Fig. 6, the VFB value of the SMA asphalt mixture is lower than the other asphalt mixtures. For specifications, the SMA VFB value is≥ 76 mm to ≤ 82 mm. A low VFB value can cause the mixture to have cavities and the mixture becomes hollow. In the SMA asphalt mixture, the VFB values obtained did not meet the specification standards. As for the asphalt mixture AC-WC and HRS, the overall value complied to the specifications. For record, for AC-WC the specification is ≥ 65% and for HRS the specification is ≥ 68% [6], [15].

f) Impact of Limestone Filler to the MQ

The MQ value of the test results made in the graph can be seen in Fig. 7.

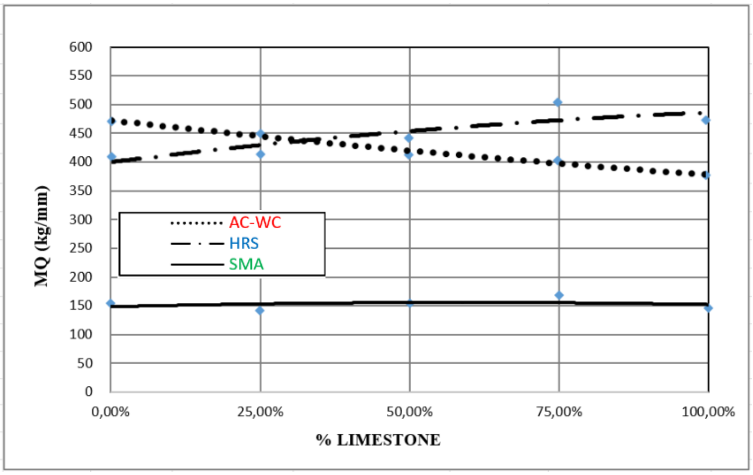

Fig. 7: Graph of MQ vs % Limestone.

Based on the General Specification Standards for Highways 2018 Division 6 Revision 2, the MQ value of the AC-WC and HRS asphalt mixture is > 250 kg/mm. While for SMA at least 600 kg/mm. From Fig. 7 it can be seen that the MQ value of the AC-WC and HRS asphalt mixture is fully complied to the specified specifications. However, for the SMA asphalt mix, none of the MQ values met the specifications. The highest value produced from the SMA asphalt mixture was 141.953 kg/mm.

g) Determination of Marshall Optimum Lime Content with Variations of Limestone Filler

Based on the Marshall test results, the optimum lime filler content (OLC) value for each asphalt mixture was obtained. It can be seen in Table 9, that the three types of asphalt mixtures have different optimum lime content. In the AC-WC and HRS mixture, all Marshall parameters fit into predetermined specifications. As for the SMA asphalt mixture, only three of the six parameters met the specifications, including stability values, VIM, VMA. The resulting optimum lime content is 29% for AC-WC, 22% for HRS, 82.5% for SMA.

Table 9: Determination of Marshall Optimum Limestone Content (OLC) with variations of limestone filler.

Asphalt Mix	Specified Parameters	OLC
AC-WC	Stability, Flow, VIM, VMA, VFB, MQ	29%
HRS-WC	Stability, Flow, VIM, VMA, VFB, MQ	22%
SMA	Stability, VIM, VMA	82.5%

3.6 Comparison of Marshall Test Results for Asphalt Mixture AC-WC, HRS, and SMA at Optimum Limestone Content

Comparison of the results of the Marshall test of asphalt mixture AC-WC, HRS, and, SMA at the optimum limestone content can be seen in Table 10 below.

Table 10: Comparison of Marshall Parameter Values at Optimum Lime Content.

Asphalt Mix	OLC	Stability	Flow	VFB	VIM	VMA	MQ
AC-WC	29%	1572.420	3.600	72.160	4.330	15.410	441.020
HRS	22%	1359.971	3.250	73.161	4.735	17.557	431.972
SMA	82.5%	824.157	5.333	74.023	4.764	18.335	161.518

Based on the test results, the Marshall parameter values were different for the three types of asphalt mixtures studied. From Table 10 it can be concluded that the use of limestone as a filler will have a different impact in each asphalt mixtures. For AC-WC and HRS mixtures, the use of limestone as a filler produces asphalt mixtures that complies with the specifications for highways, because all Marshall parameter values meet the specifications. As for the SMA asphalt mixture, the use of lime filler produces a mixture that does not comply with the specifications because only three out of six Marshall parameters reviewed meet the specification.

The value of Marshall parameters can describe the characteristics of each asphalt mixtures. Stability is the strength of a road to withstand deformation and plastic melting against traffic loads. High value of stability causes the pavement layer to become stiff and easily cracked. However, if it is too low, it can cause the road to become bumpy. The melting (flow) value determines the extent to which a mixture can change shape when given a load and is expressed in units of mm. If the melting value is high, then an asphalt mixture is easily deformed. Meanwhile, VFB is a cavity in the mixture filled with asphalt. A high VFB value can result in a mixture that bleeds easily. VIM is the number of cavities in the mixture. A low VIM value indicates that the mixture is prone to plastic deformation due to repeated loads. VMA is the number of voids between the aggregates in the mixture. A high VMA value can cause the mixture to have low stability. Lastly, Marshall Quotient (MQ) is a comparison between stability and flow. At low MQ values, the characteristic of the mixture is plastic, so it is easy to change shape.

4. Conclusion and recommendation

4.1 Conclusion

From the results of the analysis and testing carried out, several things can be concluded, including:

1. The standard mix Marshall test obtained the optimum asphalt content of each asphalt mixtures namely AC-WC at 5.5%, HRS at 5.685%, and SMA at 5.85%. The optimum asphalt content is used for the mix design of the asphalt mixture using limestone as a filler with content of 0%, 25%, 50%, 75%, 100% of the total amount of filler in the mixture. From these tests, it was found that the optimum lime content of AC-WC was 29%, HRS was 22%, and SMA was 82.5%.
2. From a comparison of the three types of asphalt mixtures, SMA has a striking difference in results because out of the six Marshall test parameters tested, only three meet the specifications. In addition, it was found that the stability and MQ values produced are too low for the AC-WC and HRS asphalt mixture type. Due to the high flow value, it can be concluded that the use of limestone filler in the SMA asphalt mixture produces asphalt mixture that easily deformed and unable to withstand high loads.

The proper use of limestone filler in asphalt mixtures can contribute to improved strength and production efficiency while considering environmental and cost aspects. Balancing the composition and proportion of the filler is crucial to achieve the desired balance between strength and workability in the asphalt mixture.

4.2 Recommendation

From the research that has been done, there are several suggestions, namely:

1. For further research, different methods can be used as comparisons with the tests that have been carried out, both for determining the theoretical asphalt content, as well as determining the composition of mixed aggregates.
2. For further research, new application of limestone as additional ingredient can be tested to be compared to its performance as a filler. For example, the use of limestone as an additive in asphalt mixtures.

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