The Effect of Additional Hydrated Lime as Filler on The Permanent Deformation of Asphalt Mixture

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Hydrated lime is one of the alternative fillers that can be used in asphalt mixtures. Hydrated lime as a filler can act as an anti-stripping agent that can increase the durability or resistance of the asphalt mixture in accepting traffic loads such as vehicle weight and friction between vehicle wheels and the road surface. The purpose of this study was to determine how the effect of hydrated lime as a filler on permanent deformation of the AC-WC mixture using a Wheel Tracking Machine (WTM) with a filler composition of 0%, 25%, 50%, 75% and 100% of the weight total fillers. AC-WC (Asphalt Concrete Wearing Course) is the topmost layer of asphalt that serves to receive traffic loads and distribute it to the layers below it in the form of vehicle loads (vertical forces), brakes (horizontal forces) and vehicle wheel vibrations. Because it is on the top, this layer is very susceptible to damage and deformation due to traffic loads or also known as permanent deformation. From the results of the study, it was found that the best mixture of AC-WC is a mixture that has an aggregate that is in accordance with the gradation of the mixture, with an Optimum Asphalt Content of 6.5%, a maximum filler composition of 75% of the weight of the filler and also hydrated lime as a filler in the AC-WC mixture can increase the stability of the asphalt mixture from 1708.25 kg to 1910.55 kg, and also hydrated lime as a filler can slow down the permanent deformation of the asphalt mixture from 1312.5 tracks/mm to 5727.7 tracks/mm.

Keywords: AC-WC, Hydrated Lime, Permanent Deformations

Introduction

Asphalt is one of the materials used in the manufacture of road pavement construction, especially on the surface layer because of its advantages, including having elastic properties when receiving vehicle loads, having resilience, being able to withstand noise, and being comfortable. One of the asphalt pavements that is often used is AC-WC (Asphalt Concrete Wearing Course) pavement. AC-WC pavement layer is a type of layer that is commonly used in Indonesia. The AC-WC layer is the top layer of asphalt that is in direct contact with the vehicle wheels. Because it is on the top, this layer is very susceptible to damage and deformation. Damage that often occurs in asphalt pavement is a change in shape due to traffic loads or also called permanent deformation. This damage is caused by high temperatures and repeated loading provided by the vehicle.

Permanent deformation (rutting) [1] is a decrease in the surface of the wheel tracks caused by plastic deformation in any or all of the pavement layers and subgrades.Various efforts have been made to overcome the deformation of the asphalt layer, such as adding additives to the asphalt to replacing or adding fillers. One of the filler materials that has been used in asphalt mixtures is hydrated lime [2, 3]. Hydrated lime comes from limestone. Limestone contains Calcium Carbonate ($CaCO3$), heating is carried out which results in the release of Carbon Dioxide contained in the limestone so that only lime (CaO) is left or also called quicklime. Lime from this combustion when added with water will give off heat like boiling and will produce Calcium Hydroxide ($Ca(OH)_2$) which is called hydrated lime.Hydrated lime as a filler can act as an anti-stripping agent [4] that can increase the durability or resistance of the asphalt mixture in receiving traffic loads such as vehicle weight and friction between vehicle wheels and the road surface.

Figure 1. Lime Hydrate

Previous research have found that asphalt mixtures with added hydrated lime as a filler can improve performance of asphalt mixtures and also can increase resistance to permanent deformation in asphalt mixtures [3], [5]. There are variations in the addition of hydrated lime as a filler in the asphalt mixture. For example, the addition of hydrated lime with a filler composition of 1.0%, 1.5% and 2.0% to the aggregate weight where the optimum filler is 1.5% [6]. Then there are those who studied the filler composition of 5%, 10%, 15%, 20% and 25% where the optimum filler is 5% [7].This can be interpreted that the use of too much hydrated lime is also not good for asphalt mixtures which will cause the mixture to be too stiff and its resistance increases. The purpose of this study was to determine the value of permanent deformation in the AC-WC mixture using the Optimum Asphalt Content and the maximum filler composition by testing the Wheel Tracking Machine.

Method

The Research was carried out at the Laboratorium Test Balai Pelaksanaan Jalan Nasional (BPJN) III. This method used is the experimental method, which is the method performed by conducting experiments to obtain data. The testing was based on General Specifications of Construction 2018 2nd Revision [8].

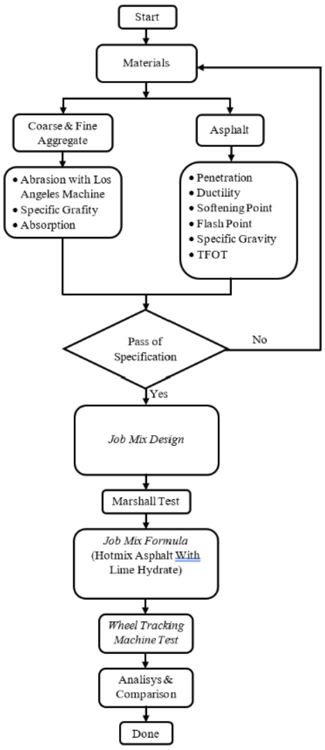

Figure 2. Research Method

Result and Analysis

AC-WC Mixed Aggregate Gradation

Aggregate gradation is the distribution of variations the size of the aggregate grains. The gradation of aggregates is determined by means of sieve analysis where the aggregate passes through a set of sieves that have been determined by the specifications used. In this AC-WC mixture, it is required that the aggregate particles must be in a certain proportion which is commonly referred to as the upper and lower limits. The sieve analysis of AC-WC gradation aggregate for this case study is presented in table 4 based on General Spesification of Highways 2018 2nd revision [8].

Table 1. Gradation of Aggregate

Sieve Size		Percentage Passing (%)	Result Test
ASTM	mm	range	
¾”	19	100	100
½”	12,5	90-100	91.16
3/8”	9,5	77-90	87.35
No.4	4,75	53-69	60.75
No.8	2,36	33-53	35.39
No.16	1,18	21-40	23.60
No. 30	0,6	14-30	16.98
No. 50	0,3	9-22	11.25
No. 100	0,15	6-15	7.11
No. 200	0,075	4-9	4.70

Characteristics of AC-WC Mixtures

The characteristic value of the AC-WC mixture can be determined by analyzing the value of density, void in mixture (VIM), void filled with asphalt (VFA), void in aggregate (VMA), stability, Flow, and Marshall Quotient. Each value is obtained from the Marshall Test results which have certain predetermined specifications. The specification is a reference to get the value of Optimum Asphalt Content. Table 8 and table 9 shows the result of Marshall test and Optimum Asphalt Content.

Table 5. Marshall Test Results

Caracteristic	Spec	Unit	Asphalt Content				
			5,0%	5,5%	6,0%	6,5%	7,0%
Stability	800	Kg	1738.2	1768.2	1633.3	1895.6	1858.1
Flow	2-4	Mm	3.52	3.73	4.03	4.17	4.50
VIM	3-5	%	11.97	11.06	10.68	8.98	8.32
VFA	>65	%	45.72	48.95	50.85	56.53	59.46
VMA	>15	%	22.03	21.64	21.72	20.65	20.51
MQ	250	Kg/mm	493.35	473.62	404.96	454.93	412.91

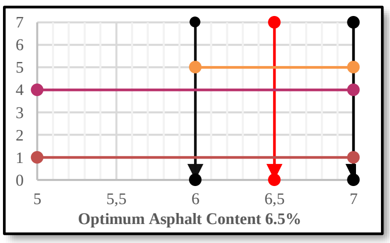

Figure 3. Optimum Asphalt Content

Caracteristics of AC-WC Mixture with Addition of Lime Filler Test

The next test is to make the specimens with the addition of hydrated lime filler with the composition of hydrated lime 0%, 25%, 50%, 75% and 100% of the weight of the filler and re-do the Marshall test to see the characteristic values which include density, stability, flow, VIM, VFA, VMA and Marshall Quotient as seen in table 6.

Table 6. Marshall Test Results of AC-WC Mixture with Addition of Hydrated Lime

Caracteristic	Spec	Unit	Filler Compotitions				
			0%	25%	50%	75%	100%
Stability	800	Kg	1708.25	1854.35	1741.97	1910.55	1764.44
Flow	2-4	Mm	3.43	3.45	3.53	3.73	3.58
VIM	3-5	%	4.20	4.19	4.10	3.80	4.06
VFA	>65	%	66.03	66.59	67.59	70.52	68.83
VMA	>15	%	18.23	18.11	17.88	17.27	17.64
MQ	250	Kg/mm	498.76	537.49	494.18	512.90	493.55

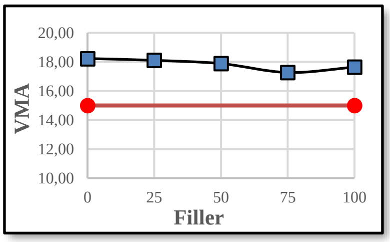

Figure 4. Filler vs VMA

From the results of the value of the VMA characteristics that is shown in the figure 4, as the filler content increases, the VMA value decreases. This shows that the increase in filler content will cause the mixture to be denser because the voids in the mixture are increasingly filled with hydrated lime. At 100% filler content the VMA value has increased, this is because the hydrated lime has filled too much of the mixed cavity so that the distance between the cavities is larger and causes a lack of density in the mixture.

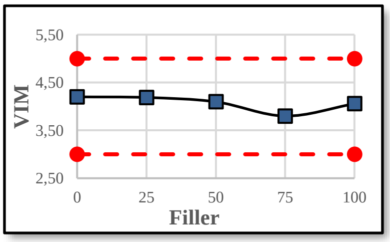

Figure 5. Filler vs VIM

Figure 5 shows the influence of added hydrated lime on the VIM characteristics, it can be seen the VIM value tends to decrease as the filler composition increases. So the smaller the VIM value, the smaller the cavity in the mixture which causes the cavity in the mixture to become more dense and makes the mixture more impermeable to water. The VIM value decreased until the filler composition was 75%. At the composition of 100% increased. This is because the hydrated lime has filled all the voids in the mixture so that the mixture becomes less strong and causes the mixture to bleed or deformation occurs in the mixture.

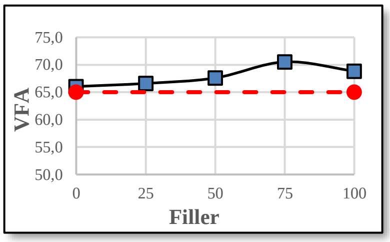

Figure 6. Filler vs VFA

Figure 6 shows the VFA value has increased to 75% filler composition. At 100% composition, the value of VFA decreased. This is due to the increasing number of hydrated lime makes the available voids in the mixture smaller until it reaches its maximum level. If it reaches the maximum level, the VFA value decreases because the hydrated lime has filled too many voids in the mixture.

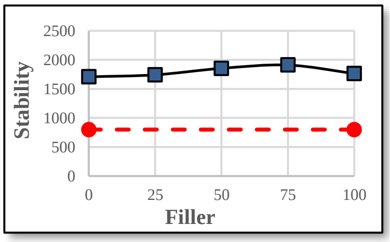

Figure 7. Filler vs Stability

As it is shown in the figure 7, the more filler composition in the mixture, the higher the stability value until it reaches a composition of 75%. This means that the addition of hydrated lime can increase the strength of the asphalt mixture until it reaches its maximum capacity. At 100% composition the stability value decreases. This is because the hydrated lime has filled the mixture too much so that the voids in the mixture are almost completely filled, making the mixture soft and the value of strength or stability decreases.

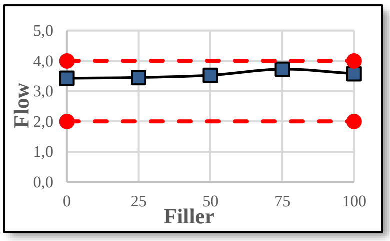

Figure 8. Filler vs Flow

Figure 8 shown the flow characteristics, it can be seen that the more the filler composition increases, the higher the melting value of the mixture and it is still within the specified specifications. This means that the addition of hydrated lime as a filler in the AC-WC mixture can increase the flexibility of the mixture caused by the hydrated lime particles that increasingly fill the voids in the AC-WC mixture.

So, from the results of the overall Marshall characteristics, it can be concluded that hydrated lime can increase the characteristic value of the AC-WC mixture until it reaches its maximum composition, which is at a level of 75%.

AC-WC Mixtures Testing with Wheel Tracking Machine (WTM)

The next test is to make the specimens with optimum Asphalt Content (KAO) and Optimum Filler Content which have been obtained from previous tests where the KAO obtained is 6.5% and the optimum filler is 75%. Furthermore, dynamic stability testing is carried out using the Wheel Tracking Machine (WTM) where the test object with a size of 30 x 30 x 5 (cm) is loaded with wheels that pass back and forth as a simulation of the vehicle wheel load for 60 minutes with a total of 1260 tracks as seen in table 7, 8 and figure 9, 10.

Table 7. Dynamic Stability Test Results with Optimum Asphalt Content and Conventional Filler

Time (minute)	Number of Tracks	Deformation	Unit
0	0	0.00	mm
1	21	0.84	mm
5	105	1.72	mm
10	210	2.32	mm
15	315	2.77	mm
30	630	3.67	mm
45	945	4.28	mm
60	1260	4.76	mm
DO = Initial Deformation		2.84	mm
RD = Deformation Speed		0.0320	mm/minute
DS = Dinamic Stability		1312.5	tracks/mm

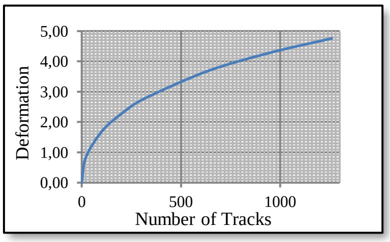

Figure 9. AC-WC Mixture with Optimum Asphalt Content and 0% Filler Composition

Table 8. Dynamic Stability Test Results with Optimum Asphalt Content and Maximum Filler

Time (minute)	Number of Tracks	Deformation	Unit
0	0	0.00	mm
1	21	0.17	mm
5	105	0.41	mm
10	210	0.56	mm
15	315	0.67	mm
30	630	0.87	mm
45	945	1.01	mm
60	1260	1.12	mm
DO = Initial Deformation		0.68	mm
RD = Deformation Speed		0.0073	mm/minute
DS = Dinamic Stability		5727.27	tracks/mm

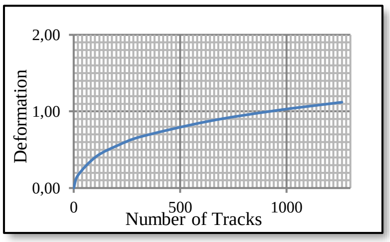

Figure 10. AC-WC Mixture with Optimum Asphalt Content and Maximum Filler

From the table and graph, it can be seen the comparison of the permanent deformation value between the AC-WC mixtures without hydrated lime filler and AC-WC mixture using hydrated lime filler. In the mixture without hydrated lime filler, the results of dynamic stability are 1312.50 tracks/mm and dynamic speed of 0.032 mm/minute where the results obtained do not meet the specified specifications. While the mixture using the optimum hydrated lime filler obtained dynamic stability results of 5727.27 tracks/mm and dynamic speed of 0.0073 mm/minute where the results obtained meet the predetermined specifications.

Cost Analysis

Cost analysis was carried out to estimate the amount of costs required to complete this research. This cost analysis is guided by the 2022 Unit Price Analysis. The calculation of the cost analysis is carried out in two ways, namely the price analysis for the AC-WC mixture using conventional filler and the AC-WC mixture using hydrated lime filler.

Table 9. Price Analysis of Conventional AC-WC Mixture

Component	Unit	Coefisient	Unit price	Total price
Coarse Aggregate	m3	0.3341	264,430.66	88,346.28
Fine Aggregate	m3	0.4236	264,430.66	112,012.83
Cement	kg	9.5880	1,413.20	13,549.76
Asphalt	kg	59.1600	7,032.26	416,028.50
Total Price (Rp)				629,937.37

Table 10. Price Analysis of AC-WC Mixture Using Hydrated Lime Filler

Component	Unit	Coefisient	Unit price	Total price
Coarse Aggregate	m3	0.3341	264,430.66	88,346.28
Fine Aggregate	m3	0.4236	264,430.66	112,012.83
Hydrated Lime	kg	0.02	700.00	14.00
Asphalt	kg	59.1600	7,032.26	416,028.50
Total Price(Rp)				616,401.61

Table 9 and table 10 shows the results of the price analysis, a comparison can be made between the price of a conventional AC-WC mixture using cement filler and a mixture using hydrated lime filler. This is because the price of hydrated lime is cheaper than the price of cement per kilogram.

Conclusions

1. Optimum Asphalt Content (KAO) was obtained at 6.5%;
2. The addition of hydrated lime as a filler in the AC-WC mixture can increase the strength or stability of the mixture until it reaches its maximum limit, namely the composition of 75%;
3. In the AC-WC mixture using conventional filler or without the addition of hydrated lime filler, the results of dynamic stability are 1312.50 passes/mm and dynamic speed is 0.032 mm/minute. It can be interpreted that this mixture has a large deformation and does not meet the specified specifications where the permanent deformation standard is at least 2500 passes/mm;
4. In the AC-WC mixture using the optimum hydrated lime filler, which is 75% of the weight of the filler, the results of dynamic stability are 5727.27 passes/mm and dynamic speed is 0.0073 mm/minute. It can be

interpreted that the AC-WC mixture that uses hydrated lime as a filler has a smaller deformation compared to the mixture that does not use hydrated lime.

4. From the test results above, it can be concluded that the addition of hydrated lime as a filler in the asphalt mixture can increase the stability of the AC-WC mixture, slow down the deformation of the pavement mixture, and in terms of cost it is also smaller than the asphalt mixture using conventional fillers.

Acknowledgment

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