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Jurnal Pensil Pendidikan Teknik Sipil

Journal homepage: http://journal.unj.ac.id/unj/index.php/jpensil/index

DURABILITY OF ASPHALT CONCRETE MIXTURE (AC-WC) USING CRUMB RUBBER WASTE AS AN ADDITIONAL MATERIAL AND PALM FRUIT ASH AS FILLER

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P-ISSN: 2301-8437
E-ISSN: 2623-1085

ARTICLE HISTORY
Accepted:
8 Agustus 2023
Revision:
30 Januari 2024
Published:
31 Januari 2024

ARTICLE DOI:
10.21009/jpensil.v13i1.37742

Abstract

The mixture of road pavement layers that is commonly used in Indonesia is a mixture of Asphalt Concrete (AC-WC). Addition of wastecrumb rubber (crumb rubber) in asphalt concrete mixture is a solution for highway planning and reducing waste pollutioncrumb rubber (crumb rubber) produced from a rubber tire factory. The purpose of this research is to determine the maximum percentage addition crumb rubber (crumb rubber) in the AC-WC mixture withfiller palm fruit bunch ash and to determine the residual strength index (RSI) value of the mixture which has a durability value that meets the requirements of General Specifications for Highways 2018 Revision 2. This study uses bitumen content with the percentage of mixed wastecrumb rubber used in the determination of OAC of 0%, 3%, and 6% by weight of asphalt andfiller palm fruit bunch ash 4% by weight of one AC-WC sample. The results of this study indicate testing marshall on variations crumb rubber 0% (without crumb rubber) as a normal mixture and 3% has met the specifications while the 6% variation does not. Maximum test results on the combination crumb rubber 3% resulted in the highest stability value of 1,028.85 kg at 0.5 hour immersion. The results of the durability test showed that the RSI value with a variation of 0% and 3% only fulfilled the 3 hour immersion time.

Keywords: Crumb Rubber, Palm Bunch Ash, Filler, Durability, AC-WC

Introduction

Durability or resilience is the ability of asphalt concrete to accept repeated traffic loads such as vehicle weight and friction between vehicle wheels and the road surface, as well as withstanding wear and tear due to weather and climate influences, such as air, water, or changes in temperature (Nugroho, 2019). Durability is related to the durability of the mixture against the effects of water and temperature for a long time (Haris, 2019; Memon et al., 2019). Water is one of the causes of damage to road pavement (Fithra, 2017). If the pavement is submerged in water for a long time and vehicles continue to pass over the pavement, a pumping effect will occur on the pavement (Apriyadi, 2018). If this effect is allowed to persist for a long time, the pavement oxidizes and granules are released, resulting in holes (Ardiansyah et al., 2021). On road pavement, segregation often occurs due to the load received or during flooding (Suyuti et al., 2014).

Crumb rubber functions as an additive material in asphalt mixture (Purnomo et al., 2015). Crumb rubber is waste from used tires that has elastic properties and increases the adhesive power of asphalt (Ritonga et al., 2019). The filler material in the asphalt concrete mixture affects the resistance to destruction against mechanical loads (Hamzami, 2023). Meanwhile, palm bunch ash functions as a filler. Palm bunches as waste from processing palm oil mills in solid form are burned and will produce palm bunch ash (Winayati et al., 2017). It is hoped that the addition of crumb rubber and palm bunch ash as filler can further increase the stickiness between the grains because palm bunch ash contains lime (CaO) and compounds in the form of silica and alumina (Rahman & Fathurrahman, 2017). Crumb rubber has the advantage of higher viscosity at a temperature of 60ºC, so it is more durable and the surface is more elastic.

Based on data from the Central Statistics Agency (BPS, 2023), the area of oil palm plantations in Riau Province is 3,494, 583 ha. The production of oil palm plantation area will continue to increase and the waste produced will also increase, which will cause environmental problems (Fahmi et al., 2021). The utilization of palm bunch ash can reduce the use of cement and can reduce the amount of waste so that it is beneficial for the preservation of the surrounding environment (Laila et al., 2022)

Apart from being a province that produces a lot of palm oil, Riau is also the largest rubber producing region in Indonesia. According to the Central Bureau of Statistics (BPS, 2023), the total rubber production in Riau reached 9,984.30 tons, which is the third production in Indonesia after North Sumatra. Usage Rubber in Indonesia can be used for several items, one of which is tire rubber. As the number of vehicle growth increases, the need for tire rubber increases, so the amount of used tire waste will also increase (Gunawan, 2022). This used tire waste has potential in pavement mixtures after being converted into crumb rubber. Crumb rubber from used tires as an added material aims to increase resistance to cracking and rutting on pavement and reduce noise levels (Sari et al., 2022).

There are several studies conducted to increase the adhesion and viscosity of asphalt including the use of latex materials, and the use of used tires (Halim & Sepriyanna, 2022). Addition of crumb rubber powder to the laston mixture can provide indications for improving shear resistance at high temperatures and increasing water resistance(Putri et al., 2022). Other research results by using the percentage of waste rubber 6%, 8%, 10% and 0% as a normal mixture. From the results of the rubber waste mixture, it produces an optimization value on marshall stability at a percentage of 6% rubber waste of 93.68% and on the Marshall Quotient at a percentage of 6% rubber waste of 272.20 kg/mm. With the addition of waste rubber mixtures affecting the flexibility and durability of asphalt, the Marshall Quotient value and the remaining Marshall stability affect flexibility and durability when compared to normal mixtures (Farlin Rosyad, Niko Prastyo, 2017). The other research, using variations in crumb rubber composition of 5%, 10%, and 15% of the asphalt weight, the results obtained are that for the AC-WC mixture using used tire powder with #60 mesh (size) as an additive, it greatly influences the stability and flow values. Marshall Quotient, the results of this research concluded that crumb rubber from used tires can be used as an additive (Erna Frida, 2017).

The use of palm bunch ash as a filler for asphalt concrete mixtures has also previously been studied. This research shows that palm bunch ash is suitable for use as a filler. This research used variations of 0%, 2%, and 4% filler with a soaking time of up to 3 hours, the IKS value was obtained at more than 90%, 4% filler with a soaking time of 0.5 hours gave the highest stability value of 919.93 kg so that it met specification (Badry et al., 2021)

In this study there are similarities and differences with previous researchers. The difference is the range of proportions of crumb rubber additives used 0%, 3%, 6%, by weight of asphalt and palm bunch ash filler 4% of the weight of the mixture while the similarity is to use crumb rubber as an additive to the asphalt mixture.

Literature Review

Infrastructure

Infrastructure in general includes public facilities prepared by the central and regional governments as public servants (as a result of market mechanisms not working) to support and encourage the economic and social activities of a community (LaMonaca & Ryan, 2022; Prapti et al., 2015).

Road Pavement

According to (Sukirman, 2010), based on the binder, road pavement construction can be divided into flexible pavement, rigid pavement, and composite pavement.

Ingredients of Asphalt Concrete Mix

Making asphalt concrete as a pavement layer involves several constituent materials that must meet predetermined specifications and requirements (Arshad & Ahmed, 2017). The requirements for the constituent materials of asphalt concrete before use can be seen from the following description.

1. Asphalt. Asphalt is defined as black or dark brown material; at room temperature it is solid to slightly dense (Hamzah et al., 2015). If heated to a certain temperature, asphalt can become soft/liquid so that it can wrap aggregate particles when making asphalt concrete or can enter the pores that exist when spraying/watering macadam pavement or resurfacing (Tahir, 2019).
2. Aggregates. Aggregates are natural mineral granules that function as fillers in mortar or concrete mixtures (Saikia & Brito, 2009). The aggregate used in the concrete mixture can be natural aggregate or artificial aggregate. The aggregate content in the concrete mixture is usually very high. Aggregate composition ranges from 60% -70% of the weight of the concrete mixture (Dumyati, 2015).
3. Filler. Filler is the filling material in the asphalt layer. Filler is a material that passes the No. 200 filter as a cement substitute which is commonly used in asphalt layer mixtures(Bancin et al., 2021; Wu et al., 2021).

Asphalt Concrete Layer (Laston)

The asphalt concrete layer (laston) consists of a mixture of coarse aggregate, fine aggregate, filler and asphalt. Asphalt Concrete Pavement (Laston) is a road pavement consisting of a mixture of aggregate and asphalt with or without additives. The materials that make up asphalt concrete are mixed at a certain temperature, then transported to the location, spread and compacted (Pratama et al., 2021). Asphalt concrete consists of 3 types of layers namely: (1) Asphalt Concrete-Wearing Course (AC-WC); (2) Asphalt Concrete-Binder Course (AC-BC) intermediate surface layer Laston; and (3) Asphalt Concrete-Base (AC-Base) foundation layer.

Asphalt Concrete Wearing Course (AC-WC) is a layer of pavement that is directly related to vehicle tires, and is a layer that is waterproof, weather resistant, and has the required stiffness with a minimum nominal thickness of 4 cm. These layers function to receive traffic loads and spread them to the layers below in the form of vehicle loads (vertical forces), brake forces (Horizontal) and vehicle wheel blows (vibration) (Oemiati, 2017).

For the provisions of hard asphalt requirements must meet the requirements of the General Specifications of Bina Marga at table 1 (BINAMARGA, 2020).

Table 1. Specifications for Hard Asphalt

No	Test Type	Testing Method	Type I asphalt Pen. 60-70
1	Penetration at 25ºC (0,1 mm)	SNI 2456-2011	60-70
2	Kinematic Viscosity 135ºC (cSt)	SNI 06-6441-2000 or ASTM D2170-10	≥ 300
3	Softening Point (ºC)	SNI 2434-2011	≥48
4	Ductility at 25ºC (cm)	SNI 2432-2011	≥100
5	Flash Point (ºC)	SNI 2433-2011	≥232
6	Solubility in Tricholoroethylene	AASHTO T44-03	≥99
7	Specific Gravity	SNI 2441-2011	≥1,0
8	Paraffin Content of Wax (%)	SNI 03-3639-2002	≤2
Residue Testing of TFOT Results (SNI-06-2440-1991) or RTFOT (SNI-03-6835-2002)			
9	Weight Loss (%)	SNI 06-2441-1991	≤0,8
10	Penetration at 25ºC (0,1 mm)	SNI 06-2456-2011	≥54
11	Ductility at 25ºC (cm)	SNI 2432-2011	≥50

The combined aggregate gradation for AC-WC mixtures must meet the requirements given in table 2.

Table 2. Combined Aggregate Gradation for Paved Mixes

Sieve		Gradation
Sieve Number	Sieve Size (mm)	AC-WC
1 ½”	37,500	-
1/2”	12,500	90 - 100
3/8”	9,500	77 - 90
No. 4	4,750	53 - 69
No. 8	2,360	33 - 53
No. 16	1,180	21 - 40
No. 30	0,600	14 - 30
No. 50	0,300	9 - 22
No. 100	0,150	6 - 15
No. 200	0,075	4 - 9

Palm Bunch Ash

Flexural pavements that are often used are a mixture of several materials and fillers including cement, sand, lime and stone ash. These fillers are limited and non-renewable, one alternative that can be used as a filler is using palm bunch ash.

Palm bunch ash is a renewable natural resource. Palm bunches as the residue of palm oil mill processing in solid form are burned at a temperature of 800ºC to 1,000ºC, resulting in palm bunch ash which can be used as an alternative material for asphalt mixture (filler) (Sentosa et al., 2005). Palm bunch ash has a high silica content so that it can be used as a substitute for cement and can reduce waste from factory processing.

Crumb Rubber

Crumb rubber is rubber powder that is crushed. from the recycling process or the reconstruction of waste made from rubber tires of vehicles that are no longer used. Used tires are natural rubber that has passed the manufacturing process and has passed the addition of certain mixtures and then printed in the form of outer tires for motorized vehicles, waste itself is the residual result of a process that can no longer be used and does not dissolve in soil or water, if this waste is increasingly in the environment it will have an impact on environmental pollution and health for the surrounding community. The results of shredded used tires can reduce damage to flexible pavement caused by weather and traffic factors (Gosali et al., 2016) cited from (AASHTO, 1982).

Testing Asphalt Concrete Mixtures

Asphalt concrete mixtures are formed by aggregates, asphalt, fillers or additives that are mixed and compacted at certain temperatures. Tests for asphalt concrete mixtures include volumetric testing and Marshall testing.

Optimum Asphalt Content

Optimum Asphalt Content (OAC) is the asphalt content that produces the best pavement mixture properties and meets the existing requirements (Othman & Abdelwahab, 2021). Bina Marga sets 5 Marshall characteristics to determine OAC, namely, stability, meltability, VIM, VMA, VMA and MQ. Stability and yield values are obtained from Marshall testing in the laboratory, while VIM, VMA, VFA and MQ are obtained from the analysis of Marshall characteristics testing data.

Durability

Durability is the ability of asphalt to maintain its original properties due to weather influences or temperature changes during the road service period (Pan et al., 2018). Durability testing of this mixture aims to determine the adhesion of asphalt to aggregate by soaking asphalt concrete in water (Angius et al., 2018). The durability of asphalt concrete mixtures can be seen from the amount of stability value in the marshall test after soaking.

The standard durability testing procedure according to Bina Marga General Specifications 2018 Revision 2 (2020) is carried out by immersing the test specimen at a fixed temperature of ± 60° C for 30 minutes and 24 hours. Comparison of soaked stability with standard stability, expressed as a percent and called the Residual Strength Index with a minimum value of 90%. It can be calculated based on the following equation.

$$\text{RSI} = \frac{\text{MSi}}{\text{MSs}} \text{x } 100$$

with:
RSI : Residual Strength Index (%)
MSi :Marshall Stability, after 24 hours, soaking at ± 60°C.
MSs :Marshall Stability standard condition

The residual strength index value indicates the remaining strength of the pavement after soaking for a certain period of time.

Research Methodology

This research was conducted at the Highway Laboratory of the Faculty of Engineering, Riau University, with reference to the General Specifications of Bina Marga 2018 Revision 2 (2020) as a reference for determining the mixture of asphalt concrete (AC-WC) using the marshall testing method. As for the test implementation standards, the Indonesian National Standard (SNI) relating to laston testing is used.

Equipment and Materials

The equipment used in this research are.

1. Aggregate inspection test equipment
2. Asphalt inspection test equipment
3. A set of sieves with sizes: 1½", 1/2", 3/8", number 4, number 8, number 16, number 30, number 50, number 100, number 200
4. Tools for making test specimens
5. Tools for Marshall testing
6. Oven with temperature up to 200oC (± 1oC)
7. Soaking tub (water bath) equipped with temperature control 10-60oC.
8. Thermometer
9. Scales with an accuracy of 0.1 gram
10. Other equipment

The materials used in this research are.

1. Pertamina asphalt penetration 60/70 produced by PT Riau Mas Bersaudara.
2. Coarse and fine aggregates from the processing of crushed stone quarry from Pangkalan, West Sumatra Province obtained from PT Riau Mas Bersaudara.
3. Crumb rubber, obtained from PT Wira Vulcanisir Pekanbaru, Riau.
4. The filler used is palm bunch ash which is used from the Palm Oil Mill (PKS) of PT Perkebunan Nusantara V, Kampar Regency, Riau Province.

Asphalt Testing

Tests and test steps for asphalt are as follows.

Table 3. Types of Asphalt Tests

Test Type	Test Standard
Asphalt Penetration	SNI 2456-2011
Asphalt Soft Point	SNI 2434-2011
Flash Point and Burn Point of Asphalt	SNI 2433-2011
Asphalt Ductility	SNI 2432-2011
Specific Gravity of Asphalt	SNI 2441-2011
Asphalt Weight Loss	SNI 06-2440-1991
Asphalt Viscosity	SNI 7729-2011

Testing of Filler Materials

The filler consisting of palm bunch ash is tested as follows.

Table 4. Type of Aggregate Testing

Test Type	Test Standard
Sieve Analysis of Coarse Aggregates and Fine Aggregates	SNI 03-1968-1990
Specific Gravity of Coarse and Fine Aggregates	SNI 03-1969-2016 and SNI 03-1970-2016
Persistence of Coarse Aggregates	SNI 3407-2008
Wear Resistance of Coarse Aggregates with Los Angeles Machine	SNI 2417-2008
Adhesion of Coarse Aggregate to Asphalt	SNI 2439-2011
Percentage of Severe Grain of Coarse	SNI 7619-2012
Flat and Oblong Index of Coarse Aggregate	ASTM D4791

Test Type	Test Standard
Coarse Aggregate and Fine Aggregate that Passes Sieve Number 200	SNI 03-4142-1996 and ASTM C 117:2012
Fine Aggregate Sand Equivalent	SNI 03-4428-1997
Angularity	SNI 03-6877-2002
Clumps of Clay and Fine Aggregate Fragile Grains	SNI 03-4141-1996

Testing of Filler Materials

The filler consisting of palm bunch ash is tested by testing passes sieve number 200 (SNI 03-4142-1996 or ASTM C146-2012) and specific gravity testing (SNI 15-2531-1991).

Testing of Added Materials Crumb Rubber

In the added material crumb rubber is tested by testing passes sieve number 80 (SNI 03-4142-1996 or ASTM C146-2012).

Asphalt Concrete Mix Design

Determination of the proportion of AC-WC mixture is based on the results of sieve analysis testing for each aggregate used. The determination of the proportion for each fraction was carried out by trial-and-error method, while the percentage of additional fillers used in the mixture was determined based on the additional needs required.

Optimum asphalt content (OAC) was obtained from the calculation of estimated asphalt content (Pb) in Formula 2.1 page 18. To obtain the optimum asphalt content (OAC), five variations were made with a difference of 0.5% between the ranges of two asphalt levels below the planned asphalt content, namely (Pb-0.5)% and (Pb-1)%, and two asphalt levels above the planned asphalt content, namely (Pb+0.5)% and (Pb+1)%. Based on the variations in asphalt content, crumb rubber variations, and the types of tests carried out to obtain the OAC value, the number of test specimens required is 45 samples with a description in Table 5.

Table 5. Number of Test Objects to Determine the OAC

Asphalt Content (%)	**Variation of Crumb Rubber (%)**			**Number of Samples**
	0	**3**	**6**	
Pb-1	3	3	3	9
Pb-0.5	3	3	3	9
Pb	3	3	3	9
Pb+0.5	3	3	3	9
Pb+1	3	3	3	9
Total				**45**

After obtaining the optimum asphalt content for each mixture variation, the test was continued by making Marshall test specimens at the optimum asphalt content condition with standard Marshall testing, the number of samples required was 3 samples each for the filler variation, as can be seen in Table 6.

Table 6. Number of Test Object at Optimum Water Content (OAC) Condition

Asphalt Content (%)	**Variation of crumb rubber (%)**					**Number of Samples (Pieces)**
	0,5 hour	**3 hours**	**6 hours**	**12 hours**	**24 hours**	
0	3	3	3	3	3	15
3	3	3	3	3	3	15

Total	**30**

Based on the tests carried out in this study, initially the total number of samples to be studied was 90 samples with 45 samples used for OAC testing and 45 samples used for asphalt durability testing. However, after the OAC test was carried out, it was found that the 6% crumb rubber variation did not meet the standards of Bina Marga General Specifications 2018 Revision 2 (2020) so that durability testing for the 6% crumb rubber variation could not be carried out. Therefore, the total number of samples to be studied is 75 samples with 45 samples used for OAC testing and 30 samples used for durability testing.

Research Results and Discussion

Testing Results of Constituent Materials

The constituent materials used for thin layer asphalt concrete (Laston) mixtures are tested for their characteristics first. This material test aims to determine whether the material used is feasible or not to be used as a mixture of asphalt concrete layers (Laston) and meets the General Specifications of Bina Marga 2018 Revision 2 (2020).

Asphalt Testing Results

The asphalt used is asphalt with a penetration of 60/70 Pertamina production obtained from PT Riau Mas Bersaudara. Tests were carried out for each variation of crumb rubber addition. The results of testing asphalt with 0% crumb rubber (without crumb rubber) can be seen in Table 7.

Table 7. Results of Aggragate Test

Tested Material Properties	**Test Standard**	**Unit**	**Test Result**	**Spesifications**	
				Min	**Max**
Flash Point with Cleveland Open Cup	SNI 2433-2011	^{o}C	270.0	232	
Specific Gravity	SNI 2441-2011		1.148	1	
Weight Loss (TFOT)	SNI 06-2440-1991	% weight	0.560		0,8
Viscosity					
> Ideal Compaction Temperature (Viscositas= 280 CtS)	(1) AASHTO T 72-90	^{o}C	152.00		
Min Solidification Temperature (250)		^{o}C	150.00		
Max Solidification Temperature (310)		^{o}C	154.00		
> Ideal Mixing Temperature (Viscositas=170 CtS)	(2) AASHTO T 54-61	^{o}C	161.00		
Min Mixing Temperature (150)		^{o}C	159.00		
Max Mixing Temperature (190)		^{o}C	164.00		
Kinematic Viscosity 135 ^{o}C (cST)		^{o}C	475.00	300	

From the test results of 60/70 penetration asphalt in Table 7, it can be seen that the asphalt test has met the General Specifications of Bina Marga 2018 Revision 2 (2020). So it can be said that the asphalt used is suitable as a constituent material for the asphalt concrete layer (Laston) in this study.

Aggregate Testing Results

The aggregates tested in this study were aggregates 1-2, medium, stone ash obtained from RMB Beton, Riau. The aggregate test results can be seen in Table 8 and Table 9.

Table 8. Coarse Aggregate Test Results

Testing			Standard	Testing Result	Spesifications Min	Spesifications Max
Persistence of Aggregate Shape to Solution (%)		natrium sulfate	SNI 3407:2008	2.35		12.00
		magnesium sulfate		-		18.00
Abrasion with *Los Angeles* Machine (%)	Modified AC Mixture	100 rounds	SNI 2417:2008	-		6.00
		500 rounds		-		30.00
	All Other Graded AC Types	100 rounds		-		8.00
		500 rounds		15.51		40.00
Aggregate Adhesion to Asphalt (%)			SNI 2439:2011	98	95,00	
Broken Grains in Coarse Aggregate (%)			SNI 7619:2012	100.00	95/90	
Flat and Oval Particles (%)			ASTM D4791 Ratio 1 : 5	9.97 and 8.85		10.00
Aggregate 1-2 Passing Sieve Number 200%			SNI 03-4142-1996	0.73		2.00
Medium Aggregate Passed Through Sieve 200%			SNI 03-4142-1996	0.94		1

Table 9. Fine Aggregate Testing Results

Testing	Standard	Testing Results	Spesifications Min	Spesifications Max
Sand Equivalent Value (%)	SNI 03-4428-1997	67.39	50	
Angularity with Void Content Test (%)	SNI 03-6877-2002	47.00	45	
Clays and Friable Grains in Aggregate (%)	SNI 03-4141-1996	0.90		1
Fine Sieve Pass Number 200 (%)	ASTM C 117:2012	9.16		10

Filler Testing Results

The filler used in this research is palm bunch ash. The General Specifications of Bina Marga 2018 Revision 2 (2020) regulates several tests of filler materials, including in two ways, namely sieve number 200 testing and specific gravity testing as in Table 10 below.

Table 10. Filter Characteristic Test Result

Inception Type	Standard	Unit	Requirement	Result Palm Bunch Ash
Sieve Number 200	SNI ASTM C136:2012	%	75	88.92
Specific Gravity	SNI 15-2531-1991	-	-	2.41

Approximate Asphalt Content

Once the respective aggregate proportions are obtained, the approximate asphalt content value is found. According to the Ministry of Public Works and Public Housing in 2019, the following empirical formula is used to calculate the asphalt content:

$$Pb = 0.035 (CA) + 0.045 (FA) + 0.18 (FF) + C$$

With:

Pb: Estimated value of optimum asphalt content to the weight of the mixture (%)

CA: Aggregate from the largest sieve to the retained sieve number 4 (%)

FA: Aggregates that pass sieve number 4 up to retained sieve number 200 (%)

FF : Aggregates that pass sieve number 200 (%)
C : Coefficient for laston 0.5-1.0

From the aggregate fractions determined in Table 4 and 5, the content of each aggregate size is obtained, namely:

$$CA = (13 + 35) \text{ x } \frac{(100 - 8{,}16)}{100} \% = 44.13 \%$$

$$FA = 52 \text{ x } \frac{(100 - 8{,}16)}{100} \% = 47.81 \%$$

$$FF = 8.06 \%$$

C used 0.5

So that the approximate asphalt content value is obtained, namely:

Pb = 0.035 (44.13%) + 0.045 (47.81%) + 0.18 (8.06%) + 0.5
= 5.65% rounded up to 6%

Then another variation is made with a difference of 0.5% between the range of two asphalt levels below the estimated asphalt content and the range of two asphalt levels above the estimated asphalt content. Thus, the asphalt content variations used in this study are 5%, 5.5%, 6%, 6.5%, and 7%.

Determination of Optimum Asphalt Content of HRS-Base Lataston Mixture

In analyzing Marshall characteristics, several methods are used to find the OAC value based on SNI 06-2489-1991 by analyzing five Marshall characteristics as a standard for determining OAC. Each mixture composition consisting of variations in asphalt content is calculated for VMA, VIM, VFA, stability, flow and MQ. The values were described in a graph limited by the General Specifications of Bina Marga 2018 revision 2 (2020), then transferred into the Marshall performance table. The optimum asphalt content is obtained from the value that meets all the Marshall criteria. The asphalt variation used is based on the reference of the estimated asphalt content. The results of marshall testing with 3% crumb rubber additives are shown in Table 11.

Table 11. Marshall Test Results of Find OAC with Crumb Rubber Content

Asphalt Content (%)		VMA (%)	VIM (%)	VFA (%)	Stability (With T) (kg)	Flow (mm)	MQ (kg/mm)
5	1	18.82	8.47	54.99	70.00	2.80	344.54
	2	19.12	8.81	53.91	59.00	3.10	262.30
	3	18.70	8.40	55.20	67.00	4.10	225.21
5.5	1	20.26	8.95	55.84	77.00	3.90	272.10
	2	19.19	7.72	59.77	69.00	3.80	250.25
	3	17.92	6.28	64.98	53.00	3.60	211.35
6	1	18.90	6.21	67.17	73.00	3.40	308.23
	2	19.19	6.55	65.90	70.00	3.90	257.67
	3	19.11	6.45	66.26	71.00	3.60	283.13
6.5	1	18.93	5.04	73.38	69.00	3.00	330.19
	2	18.68	4.75	74.56	72.00	4.20	246.10
	3	18.50	4.54	75.44	78.00	4.30	260.41
7	1	19.12	4.06	78.77	73.00	4.00	262.00
	2	19.29	4.25	77.94	58.00	4.20	198.25
	3	19.12	4.06	78.78	72.00	3.80	272.01

Data from the test results of Marshall characteristics values at each asphalt content, an average of 3 test pieces for each asphalt content. Furthermore, the data is made in the form of a Marshall characteristic graph to obtain the Optimum Asphalt Content (OAC) value, as in Table 12. and Figure 1.

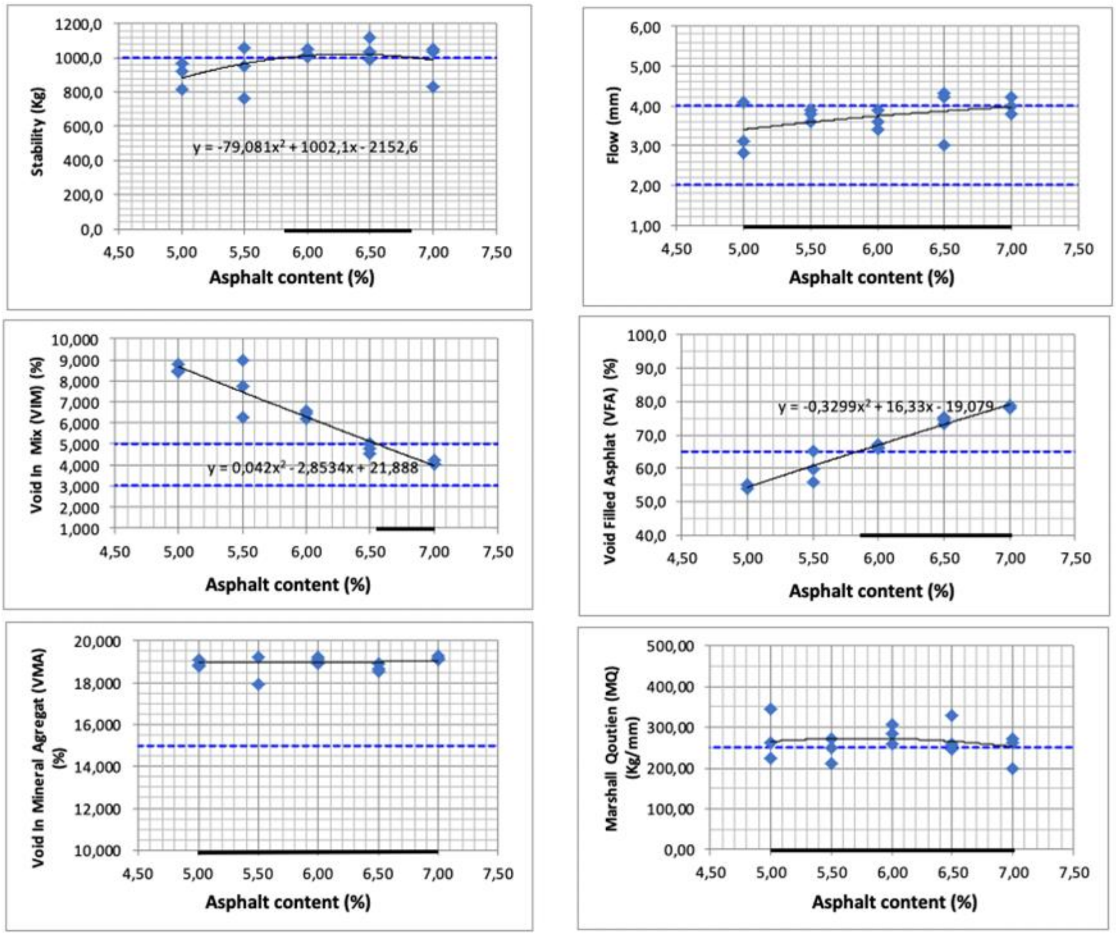
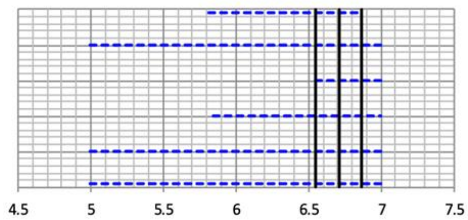


Figure 1. Graph of Marshall Characteristics Test Results of 3% Variation of Crumb Rubber Additives

Table 12. Determination of Optimum Asphalt Content (OAC) with 3% Crumb Rubber Additive

No	Criteria	Spesification	Specification
1	Stability (kg)	1000	
2	Flow (mm)	2 – 4	
3	VIM (%)	3 – 5	
4	VFA (%)	Min. 65	
5	VMA (%)	Min. 15	
6	MQ (kg/mm)	Min. 250	
OAC			$\frac{(6.55 + 6.87)}{2}$ 6.71%

From Figure 1 and Table 12 above, the Optimum Asphalt Content (OAC) value for asphalt mixtures with 3% crumb rubber additives and 4% palm bunch ash filler is 6.71%.

Marshall Immersion Test Disccusion and Analysis

Marshall soaking test analysis is to compare the stability value in soaking conditions of 0.5 hours, 3 hours, 6 hours, 12 hours and 24 hours. The mixture used in the condition of optimum asphalt content. From the comparison data, the durability value can be taken against the soaking time. The following are the stability results obtained from marshall soaking in variations of crumb rubber additives 3%.

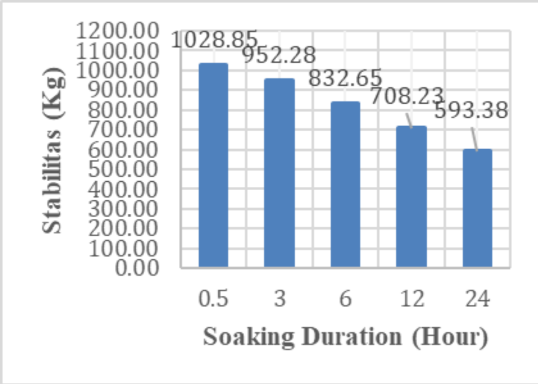


Figure 2. Relationship of OAC Stability Value with Soaking Time for 3% Crumb Rubber Variation

The asphalt mixture with 3% crumb rubber added material variation has a stability value that tends to decrease towards the addition of the immersion time. The standard value that has been set according to the General Specifications of Bina Marga 2018 Revision 2 (2020) for stability value is at least 1,000 kg. The stability value shown starts from a soaking time of 0.5 hours with a value of 1,028.85 kg until it decreases during the addition of soaking time up to 24 hours with a stability value of 593.38 kg. Therefore, the 0.5 hour soak time still meets the standard of the stability value and decreases so that the 3 hour, 6 hour, 12 hour, and 24 hour soak times do not meet the standard of the stability value.

The RSI value required by the General Specifications of Bina Marga 2018 revision 2 (2020) is at least 90%. In the results of the RSI value obtained, it can be seen that the soaking time of 0.5 hours and 3 hours is still able to withstand damage, while for the soaking time of 6 hours, 12 hours, and 24 hours the RSI value does not meet the predetermined requirements. RSI does not meet the predetermined requirements.

Relationship Between Stability and Soaking Time

Stability is a measure of the maximum ability of an asphalt mixture to resist deformation caused by the traffic load on it. The higher the stability value, the more the asphalt pavement will be able to withstand traffic loads without deforming, and vice versa. The relationship between OAC stability value and soaking time can be seen in Table 13, Figure 3 and Figure 4.

Table 13. Soaking OAC Stability Value

Soaking Time (Hour)	**Crumb Rubber Variation**	
	0%	**3%**
0.5	930.65	1,028.85
3	849.30	952.28
6	752.83	832.65
12	618.27	708.23
24	500.93	593.38

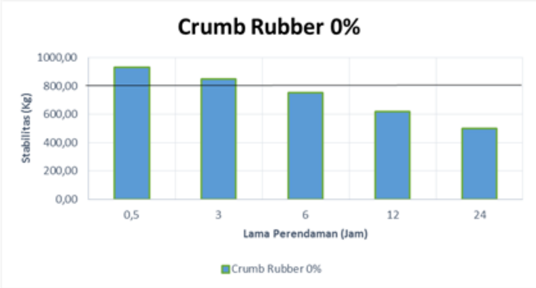


Figure 3. Soaking OAC Stability with Crumb Rubber 0% (Without Crumb Rubber Additives)

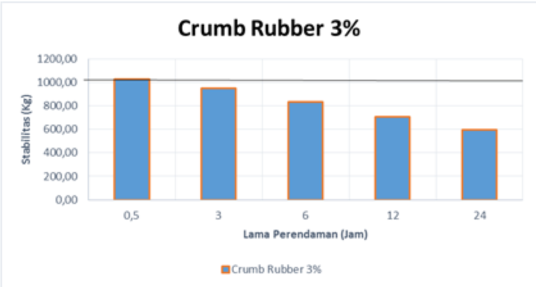


Figure 4. Soaking OAC Stability with 3% Crumb Rubber Additives

Table 13 and Figure 4 can be seen that the value of stability in the mixture of crumb rubber variations at each increase in soaking time decreased the value of stability. The highest value of stability is in the 3% crumb rubber mixture at a soaking time of 0.5 hours with stability reaching 1,028.85 kg. While the lowest stability value was in the 0% crumb rubber variation at a soaking time of 24 hours which amounted to 500.93 kg.

Relationship of Residual Strength Index (RSI) with Soaking Time

The RSI value is related to the ability of asphalt pavement to resist damage caused by water. The General Specifications of Bina Marga 2018 Revision 2 (2020) provides a limit for the stability value after soaking for 24 hours (1 day) with a temperature of 60±1° C is a minimum of 90% of the original stability. The values of the index of residual strength (RSI) of the mixture for all test results can be seen in Table 14 and Figure 5.

Table 14. Soaking OAC RSI Value

Soaking Time (Hour)	**Variation of Crumb Rubber**	
	0%	**3%**
0.5	100.00	100.00
3	92.51	92.56
6	81.82	80.93
12	67.38	68.84
24	54.55	57.67

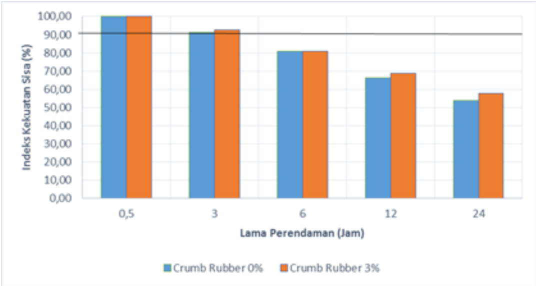


Figure 5. Graph of Soaking OAC RSI Value

Based on Table 14 and Figure 5, it can be seen in general that there is a significant decrease in strength in asphalt mixtures as the length of soaking increases. Soaking causes water to be absorbed into the mixture, water penetrates between the asphalt surface and the aggregate and its pores. The presence of water in the interface and pores eventually leads to the peeling of asphalt from the aggregate surface and causes a reduction in the strength of the mixture.

The test results show that RSI value with 0% and 3% crumb rubber variations meets the General Specifications of Bina Marga 2018 Revision 2 (2020) only at immersion times of 0.5 hours and 3 hours, which is a minimum of 90%, while for 0% and 3% crumb rubber variations for immersion times of 6 hours, 12 hours, and 24 hours on the entire mixture cannot meet the provisions set by the General Specifications of Bina Marga 2018 Revision 2 (2020) which is 90%.

Table 15. Asphalt Durability Test Results Under Optimum Conditions

Soaking Duration	OAC	Crumb Rubber Content	Palm Bunch Ash	Residual stability	Percentage of Durability
0.5	6.56%	0%	4%	930.65	100%
	6.71%	3%	4%	1028.85	100%
3	6.56%	0%	4%	849.3	92.51%
	6.71%	3%	4%	952.28	92.56%
6	6.56%	0%	4%	752.83	81.82%
	6.71%	3%	4%	832.65	80.93%
12	6.56%	0%	4%	618.27	67.38%
	6.71%	3%	4%	708.23	68.84%
24	6.56%	0%	4%	500.93	54.55%
	6.71%	3%	4%	593.38	57.67%

Conclusion

Based on the results of research on the durability of AC-WC asphalt concrete mixtures using crumb rubber waste as an additive and palm bunch ash as a filler, it can be concluded:

1. Marshall testing on crumb rubber variations of 0% and 3% has met the General Specifications of Bina Marga 2018 Revision 2 (2020). The maximum test results in the 3% crumb rubber combination produced the highest stability value of 1,028.85 kg, at 0.5-hours soaking.
2. Durability test results show that the RSI value with 0% and 3% crumb rubber variations only meets the requirements at 3 hours of immersion, namely 92.51% for 0% crumb rubber and 92.56% for 3% crumb rubber. So it is concluded that the AC-WC asphalt mixture with crumb rubber and palm bunch ash has not met the General Specifications of Bina Marga 2018 revision 2 (2020), which is a minimum of 90%, because for 24-hour immersion it is not fulfilled.

3. Based on the overall test results, the researcher's hypothesis is inversely proportional to the test results. Initially the researcher hypothesized that the asphalt mixture with crumb rubber additives and palm bunch ash filler was able to increase the durability of the asphalt, but the test results contradicted the researcher's hypothesis, because the results showed that there was a drastic decrease in the stability value which caused the RSI value not to meet the General Specifications of Bina Marga 2018 Revision 2 (2020) so it can be concluded that the hypothesis of the researcher was rejected.

For further improvement of the research results, it is recommended to conduct research by paying attention to the following matters:

1. Similar research can be carried out using various variations in the percentage of crumb rubber waste content, palm bunch ash filler and asphalt content used.
2. Research on the characteristics of more varied mixtures, for example comparing between AC, HRS, or ATB mixtures in order to obtain a comparison of the research.
3. It is hoped that further research will be carried out with variations in soaking water, and testing on the chemical properties used in crumb rubber additives and palm bunch ash fillers.

References

Angius, E., Ding, H., & Hesp, S. A. M. (2018). Durability assessment of asphalt binder. *Construction and Building Materials*, *165*, 264–271. https://doi.org/10.1016/j.conbuildmat.2018.01.037

Apriyadi, F. (2018). *Pengaruh Beban Berlebih Kendaraan Berat Terhadap Umur Rencana Perkerasan Kaku Pada Jalan Diponegoro, Cilacap (the Influence of Heavy Vehicle Overload on Rigid Pavement Design Life of Diponegoro Road, Cilacap)*.

Ardiansyah, F. I., Suryono, W., Rahmawati, V., Surabaya, P. P., & Jemur Andayani, J. (2021). Perencanaan Overlay Pada Landas Pacu Di Bandar Udara H.Hasan Aroeboesman Ende. *Seminar Nasionalinovasi Teknologi Penerbangan (Snitp) Tahun 2021*, 1–9.

Arshad, M., & Ahmed, M. F. (2017). Potential use of reclaimed asphalt pavement and recycled concrete aggregate in base/subbase layers of flexible pavements. *Construction and Building Materials*, *151*, 83–97. https://doi.org/10.1016/j.conbuildmat.2017.06.028

Badry, K., Malik, A., & Alwinda, Y. (2021). Pengaruh Air Gambut Terhadap Karakteristik Marshall Pada Campuran Asphalt Concrete - Binder Course (AC-BC) Yang Menggunakan Abu Tandan Sawit Sebagai Bahan Pengisi (Filler). *Jurnal Online Mahasisawa FT UNRI*, *8*.

Bancin, E. D. L., Lubis, K., & Mahda, N. (2021). Pengaruh Penggunaan Tanah Merah Sebagai Filler Pada Campuran Aspal Ac-Bc Terhadap Nilai Marshall. *Journal of Civil Engineering Building and Transportation*, *5*(1), 17–25. https://doi.org/10.31289/jcebt.v5i1.5072

BINAMARGA. (2020). *Spesifikasi Umum Bina Marga 2018 Revisi 2*. Kementerian PUPR.

BPS. (2023). *Statistik Kelapa Sawit Indonesia 2022*.

Dumyati, A. (2015). Analisis Penggunaan Pasir Pantai Paciran Sebagai Agregat Halus Terhadap Kuat Tekan Beton. *Jurnal Profil*, *2*(1), 8–17. https://doi.org/10.52166/dearsip.v2i1.3352

Erna Frida, G. P. D. (2017). ANALISIS KEKUATAN ASPHALT CONCRETE WEARING COURSE (AC-WC) DENGAN SERBUK BAN BEKAS SEBAGAI ZAT ADITIF. *Juitech Journal*, *01*(1), 473–482. https://doi.org/http://dx.doi.org/10.36764/ju.v1i1.6

Fahmi, A. M., Irwan, I., & Amsuardiman, A. (2021). Analisis Pengaruh Aspal Modifikasi Dengan Penambahan Abu Cangkang Sawit Terhadap Kinerja Perkerasan Aspal. *Journal of Civil Engineering Building and Transportation*, *5*(2), 64–68. https://doi.org/10.31289/jcebt.v5i2.5670

Farlin Rosyad, Niko Prastyo, M. K. (2017). Analisis Pengaruh Penambahan Limbah Karet Terhadap Durabilitas Dan Flexibilitas Aspal Beton (Ac-Wc). *Jurnal Tekno*, *14*(2), 23–31. https://doi.org/10.33322/forummekanika.v7i2.202

Fithra, H. (2017). Pengaruh Jumlah Tumbukan Pada Campuran Asphalt Concrete Wearing Course (Ac-Wc) Tambahan Lateks Terhadap Sifat Marshall. *Teras Jurnal*, *7*(1), 203–212.

Gosali, G., Jaya, H., Wulandari, P. S., & Patmadjaja, H. (2016). Pengaruh Penambahan Serbuk Ban Karet Mesh #80 Pada Campuran Laston Untuk Perkerasan Jalan Raya. *Jurnal Dimensii Pratama Teknik Sipil*, *5*(1), 1–8.

Gunawan, B. S. (2022). Pengaruh Aspal Campuran Limbah Ban Karet. *SLUMP TeS: Jurnal Teknik Sipil*, *1*(1), 10–20. https://doi.org/https://doi.org/10.52072/slumptes.v1i1.280

Halim, I. H., & Sepriyanna, I. (2022). PENGARUH SERBUK BAN BEKAS SEBAGAI BAHAN TAMBAH PADA CPHMA DENGAN VARIASI SUHU PEMADATAN TERHADAP KARATERISTIK MARSHALL. *Construction and Material Journal*, *4*(2), 83–89. https://doi.org/10.32722/cmj.v4i2.4593

Hamzah, M. O., Omranian, S. R., & Golchin, B. (2015). A Review on the Effects of Aging on Properties of Asphalt Binders and Mixtures. *Caspian Journal of Applied Sciences Research*, *4*(6), 15–34.

Hamzami. (2023). PENGARUH SUBSTITUSI TANAH DIATOME SEBAGAI FILLER TERHADAP KEGAGALAN RETAK BERDASARKAN NILAI TEGANGAN REGANGAN PERKERASAN BETON ASPAL. *Jurnal Teknologi Terapan & Sains 4.0*, *4*(3), 1–10. https://doi.org/https://doi.org/10.29103/tts.v4i3.15154

Haris, H. (2019). Analisis Pengujian Stabilitas dan Durabilitas Campuran Aspal dengan Tes Perendaman. *Jurnal Linears*, *2*(1), 33–47. https://doi.org/10.26618/j-linears.v2i1.3026

Laila, N., Dian Kurniasari, F., & Amin, A. (2022). *Pemanfaatan Abu Cangkang Sawit (ACS) Untuk Subtitusi Filler Pada Lapisan Asphalt Concrete Wearing Course (AC-WC)*. *1*(1), 1–10.

LaMonaca, S., & Ryan, L. (2022). The State of Play in Electric Vehicle Charging Services – A Review of Infrastructure Provision, Players, and Policies. *Renewable and Sustainable Energy Reviews*, *154*(September 2021), 111733. https://doi.org/10.1016/j.rser.2021.111733

Memon, S. A., Shah, S. F. A., Khushnood, R. A., & Baloch, W. L. (2019). Durability of sustainable concrete subjected to elevated temperature – A review. *Construction and Building Materials*, *199*, 435–455. https://doi.org/10.1016/j.conbuildmat.2018.12.040

Nugroho, M. S. (2019). Karakteristik Marshall Quotient Pada Hot Mix Asphalt Menggunakan Agregat Alam Sungai Opak. *INERSIA: LNformasi Dan Ekspose Hasil Riset Teknik SIpil Dan Arsitektur*, *15*(2), 84–91. https://doi.org/10.21831/inersia.v15i2.28627

Oemiati, N. (2017). Analisa Penggunaan Tanah Kerikil Terhadap Peningkatan Daya Dukung Tanah Untuk Lapisan Konstruksi Perkerasan Jalan Raya. *Jurnal Penelitian Dan Kajian Teknik Sipil*, *5*(1), 1–5. https://doi.org/https://doi.org/10.32502/jbearing.698201751

Othman, K. M. M., & Abdelwahab, H. (2021). Prediction of the optimum asphalt content using artificial neural networks. *Metallurgical and Materials Engineering*, *27*(2), 227–242. https://doi.org/10.30544/579

Pan, P., Kuang, Y., Hu, X., & Zhang, X. (2018). A comprehensive evaluation of rejuvenator on mechanical properties, durability, and dynamic characteristics of artificially aged asphalt mixture. *Materials*, *11*(9). https://doi.org/10.3390/ma11091554

Prapti, L., Suryawardana, & Triyani, E. (2015). Analisis Dampak Pembangunan Infrastruktur Jalan Terhadap Di Kota Semarang. *Jurnal Dinamika Sosbud*, *Vol 17*, *No*, 82–103.

Pratama, F. D., Bunyamin, & Kurniasari, F. D. (2021). ISSN 2407-9200 (Online) Universitas Abulyatama Jurnal Teknik Sipil Unaya. *Jurnal Teknik Sipil Unaya*, *7*(2), 123–134.

Purnomo, W., Evaldo, B., & Suparma, L. B. (2015). Pemanfaatan crumb rubber (serbuk karet roda). *Prosiding FSTPT*, *II*(2), 22–24.

Putri, L. R., Widiastuti, M., & Alkas, M. J. (2022). Pengaruh Penggunaan Crumb Rubber Dengan Material Senoni Dan Filler Batu Senoni Terhadap Nilai Karakteristik Marshall Asphalt Concrete – Binder Course (Ac-Bc). *Teknologi Sipil : Jurnal Ilmu Pengetahuan Dan Teknologi*, *6*(1), 21. https://doi.org/10.30872/ts.v6i1.7720

Rahman, F., & Fathurrahman, F. (2017). Pemanfaatan Hasil Pembakaran Limbah Cangkang Kelapa Sawit sebagai Bahan Pengganti Pasir pada Pembuatan Beton Normal. *Media Ilmiah Teknik Sipil*, *6*(1), 30–40. https://doi.org/10.33084/mits.v6i1.259

Ritonga, A. H., Ilmu, U., Sari, K., Indonesia, M., Ilmu, U., Sari, K., & Indonesia, M. (2019). Ikatan Kimia Antara Aspal Dengan Polimer. *Jurnal Kesehatan Masyarakat Dan Lingkungan Hidup*, *2*(2).

Saikia, N., & Brito, J. de. (2009). USE OF INDUSTRIAL WASTE AND MUNICIPALITY SOLID WASTE AS AGGREGATE, FILLER OR FIBER IN CEMENT MORTAR AND CONCRETE. In M. C. Wythers (Ed.), *Advances in Materials Science Research* (Vol. 3, Issue 2010, pp. 1–36). Nova Science Publishers, Inc.

Sari, K. N. I., Maliki, A., & Suharso, A. B. K. (2022). Pemanfaatan Campuran Limbah Karet Ban Dengan Filler Abu Kerang Simping Pada Aspal Beton. *Axial : Jurnal Rekayasa Dan Manajemen Konstruksi*, *10*(1), 025. https://doi.org/10.30742/axial.v10i1.2173

Sentosa, L., Putra, A. I., & Mufriadi. (2005). Karakteristik Laston Menggunakan Bahan Pengisi Abu Sawit. *Jurnal Transportasi*, *5*(1), 49.

Sukirman, S. (2010). Perencanaan Tebal Struktur Perkerasan. In *Nova* (1st ed., Vol. 1). Nova.

Suyuti, M. M., Program, M., Teknik, S., & Utara, G. (2014). Menggunakan Metode Bina Marga Pada Ruas Jalan Gorontalo-Limboto. *RADIAL JURNAL*, *2*(2), 135–154. https://doi.org/https://doi.org/10.37971/radial.v2i2.55

Tahir, A. (2019). KARAKTERISTIK CAMPURAN BETON ASPAL (AC-WC) DENGAN MENGGUNAKAN VARIASI KADAR FILLER ABU TERBANG BATU BARA. *Jurnal Smartek*, *7*(4), 77.

Winayati, W., Lubis, F., & Haris, V. T. (2017). Pengaruh Filler Abu Tandan Sawit Terhadap Karakteristik Marshal Pada Campuran Ac-Bc. *SIKLUS: Jurnal Teknik Sipil*, *3*(1), 19–26. https://doi.org/10.31849/siklus.v3i1.370

Wu, W., Jiang, W., Yuan, D., Lu, R., Shan, J., Xiao, J., & Ogbon, A. W. (2021). A review of asphalt-filler interaction: Mechanisms, evaluation methods, and influencing factors. *Construction and Building Materials*, *299*(13). https://doi.org/https://doi.org/10.1016/j.conbuildmat.2021.124279