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USAGE OF RECLAIMED ASPHALT PAVEMENT AS A MIXTURE MATERIAL OF ASPHALT CONCRETE - WEARING COURCE (ACWC)

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ABSTRACT

The objective of this research is to utilize Reclaimed Asphalt Pavement (RAP) as a mixture of hot asphalt AC-WC type. The new additional material is required such as an aggregate and asphalt to meet the technical performance which is based on Specification Bina Marga 2018 Revision 2. This research is started by analyzing the RAP. The result of RAP extraction process are aggregates and asphalt. Grading on aggregate were conducted for required grading envelope. If it failed to qualify for required grading envelope, new aggregate and new asphalt is needed. Therefore, the AC-WC mixture was composed by mixing with a variation of RAP which is 10%, 20% and 30%. From all of the mixing composition, only mixture with 30% of RAP and 70% of new materials is recommended for hot mixture which fulfilling the engineering criteria requirements.

Keywords: *Asphalt Concrete - Wearing Course (AC-WC), Reclaimed Asphalt Pavement (RAP), grading envelope*

1. Introduction

The East Java Province is responsible to maintain the condition of 1769 kilometers road, authorized as the road province [1]. The type of road is flexible pavement which needs the maintenance both potholes patching and overlaying annually. From all of road, only one third of the road reconstruction which had been scrapped resulting on the Reclaimed Asphalt Pavement (RAP). The volume of this RAP wasted material in East Java Province is approximately 50.000 m^3. The RAP wasted material can be used as the mixture of hot asphalt by adding the new material.

RAP contains the asphalt and aggregate which can be used as the substitute material for the new hot mix asphalt for the flexible pavement. The usage of RAP wasted material could save the natural resources such as the aggregate, sand and asphalt decreasing the natural disaster and damage caused by the mining process[2]. The RAP material can be used for simple purposes such as road shoulder material, road material for patching potholes, asphalt underlayer material as well as for purposes that require high technical specifications such as hot or cold mix[3]. In addition, some of the benefits of using RAP are: saving energy, maintaining environmental balance, reducing construction costs, and protecting aggregates and binders on old pavements. The Crack damage can be minimized by using this RAP mixture [4]. The use of RAP for the ACWC type still meets the requirements of the Technical specifications with certain materials and materials[5].

To optimize the usage of RAP material in East Java Province, this research is conducted as an effort to implement the RAP as the mixture material of Asphalt Concrete – Wearing Course (AC-WC) using asphalt Pen 60/70. So that the author wants to know about the characteristic of RAP (aggregate and asphalt) resulted from scrapping pavement material, and How to optimized the usage of RAP as the pavement material.

2. Material and Methods

2.1. Research Method

The steps of the research are shown below:

1. Analyzing the RAP to obtain the aggregate and asphalt characteristic as well as the grading of the material whether fulfilling the envelope required. If the grading of aggregate and asphalt is not meet the criteria, the new material is added.
2. Making the composition of mix design for Asphalt Concrete- Wearing Course (AC-WC) with adding of RAP variation.

2.2. Research Material

The material of the research is shown below:

1. The RAP material is obtained from scrapping one of the road in East Java Province
2. The new aggregate from the local Asphalt Mixing Plant (AMP).
3. The Asphalt Pen 60/70.

3. Result and Discussion

The result of test shows:

3.1. RAP and New Material (Aggregate and Asphalt)

Table 1. Result of RAP Material (Aggregate)

No	Type of test	Specification	Test Result
1.	Specific gravity gr/cm^3	-	2,6
2.	Water absorption (%)	-	1,42

Source: Test Results

Table 2 shows that the result of test had fulfilled the specification required.

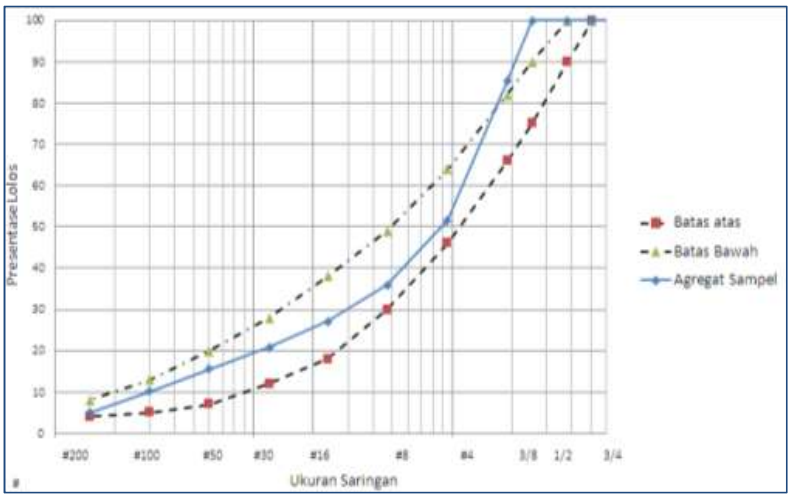

Figure 1. RAP Aggregate Grading

Figure 1 shows that the RAP aggregate grading is not fulfilled the specification required since the material passed sieve number ½ was not accepted on the grading envelope. To achieve the grading envelope, the new material is added.

Table 2. Result of RAP Material (Asphalt)

No	Type of test	Specification	Test Result
1.	Asphalt content in the mixture (%)	-	4%

Source: Test Results

Table 2 shows that the result of the test had fulfilled the requirement except the penetration test result with only 49 from 60-70 which required.

Table 3. Result of the New Material (Aggregate)

No	Type of test	Specification	Test Result
1.	Abrasion Test (%)	Maks 40%	30
2.	Aggregate Stickiness Test (%)	Min 95%	95
3.	Density Test (gr / cm3) and Water Absorption (%)	-	1.64

Source: Test Result

Table 3 shows that the result of the test had fulfilled the requirements.

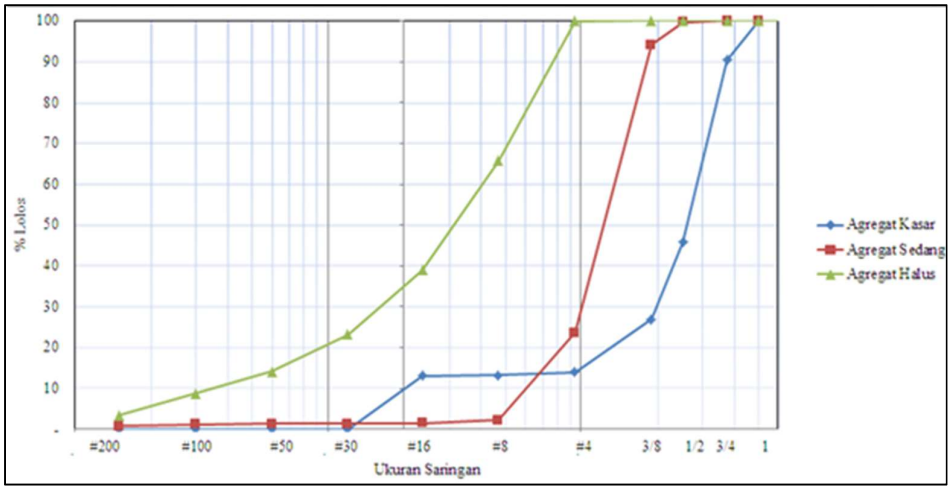

Figure 2. New Aggregate Gradations

Figure 2 shows that the course, medium and fine aggregate grading can be used as the added material for RAP so that the combined grading aggregate fulfills the specification required.

Table 4. Result of New Material (Asphalt)

No	Type of test	Requirement	Test Result
1.	Penetration at 25ºC (0.1 mm)	60-70	62
2.	Viscosity 135 ºC (cSt)	≥300	393
3.	Softening Point (ºC)	≥48	49,1
4.	Ductility at 25 ºC (cm)	≥100	> 140
5.	Flash Point ºC)	≥232	240
6.	Solubility of Trichlorethylene (%)	≥99	99,82
7.	Specific gravity	≥1,0	1,03
8	Weight Loss (%) (TFOT)	≤0.8	0,21%
9	Penetration at 25 ºC (%) (TFOT)	≥54	58%

No	Type of test	Requirement	Test Result
10	Ductility at 25 ºC (cm) (TFOT)	≥ 100	100

Source: Test Results

Table 4 shows that the result of the test using asphalt Pen 60/70 had fulfilled the requirement.

3.2. Mix Design Composition for AC-WC mixture.

To fulfill the grading envelope according to specifications, the new aggregates added consist of:

- Aggregate coarse (10-20)
- Aggregate medium (5-10)
- Fine aggregate (0-5)

Based on the gradation of RAP and the gradation of new materials, the composition of the AC-WC mixture is made as follows: (10% RAP; 90% new material), (20% RAP; 80% new material) and (30% RAP; 70% new material).

3.2.1. Gradient Aggregate Combined with RAP 10%, New Material 90%

Based on the RAP aggregate grading and the CA, MA, FA gradations, the compilation of the combined aggregate grading is carried out by trial and error of several compositions so that the combined aggregate gradations are included in the "grading envelope". As for the compilation of combined aggregate grading with RAP 10%, 90% new material is presented in Table 6 and Figure 3. 4.2 Mixture Design Composition for AC-WC

To fulfill the grading envelope as the specification the new aggregate which was added contains of as follows:

- Coarse aggregate (10-20)
- Medium aggregate (5-10)
- Fine aggregate (0-5)

Based on the RAP grading and new material aggregate, the mixture composition of AC-WC is made as follows: 10% RAP; 90% New Material), 20% RAP; 80% New Material and 30% RAP;70% New Material.

3.2.2. Combined Aggregate Grading with 10 % RAP, 90% New Material

The result of combined aggregate grading with 10 % RAP, 90% New Material is shown on Table 5 and Figure 3 below.

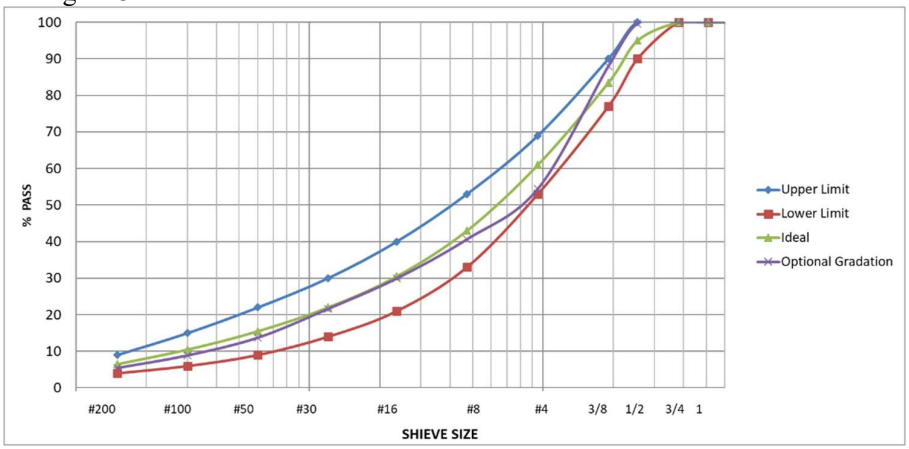

Figure 3. Combined Aggregate Gradation with RAP 10%, New Material 90%

Figure 3 shows that the combined grading had fulfilled the specification required.

Table 5. Gradient Aggregate Combined with RAP 10%, New Material 90%

Description	composition (%)	Shieve Size (% pass)									
Inch		3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Mm		19.0	12.5	9.5	4.75	2.36	1.18	0.600	0.300	0.150	0.075
Aggregate Gradient Data											
- RAP		100	100	81.58	45.25	28.67	22.76	18.27	14.31	11.43	8.00
- Coarse Aggregate (CA)		100.00	96.48	34.52	9.78	2.02	0.13	0.00	0.00	0.00	0.00
- Medium Aggregate (MA)		100	100.00	91.66	18.65	5.12	3.62	1.69	1.12	0.42	-
- Fine Aggregate (FA)		100	100	100	97.85	82.16	59.32	41.89	24.15	13.66	6.49
- Cement		100	100	100	100	100	100	100	100	100	100
Aggregate combination											
- RAP	10	10	10	8.16	4.53	2.87	2.28	1.83	1.43	1.14	0.80
- Coarse Aggregate (CA)	11	11.00	10.61	3.80	1.08	0.22	0.01	-	-	-	-
- Medium Aggregate (MA)	36	36.00	36.00	33.00	6.71	1.84	1.30	0.61	0.40	0.15	-
- Fine Aggregate (FA)	41	41.00	41.00	41.00	40.12	33.69	24.32	17.17	9.90	5.60	2.66
- Cement	2	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total Mix	**100**	**100.00**	**99.61**	**87.95**	**54.43**	**40.62**	**29.91**	**21.61**	**13.74**	**8.89**	**5.46**
Envelope Gradation Spec											
Maks.		100	100	90	69	53.0	40.0	30.0	22.0	15	9
Min		100	90	77	53	33	21	14	9	6	4
Ideal Gradation		**100.0**	**95.0**	**83.5**	**61.0**	**43.0**	**30.5**	**22.0**	**15.5**	**10.5**	**6.5**

Source: Test Results

Based on table 6 shows that the best composition to obtain the envelope combined grading consists of RAP 10%, course aggregate 11%, medium aggregate 36%, fine aggregate 41% and cement 2%.

3.2.3. Combined Aggregate Grading with 20 % RAP, 80% New Material

The result of combined Aggregate Grading with 20 % RAP, 80% New Material is shown on Table 6 and Figure 4 below.

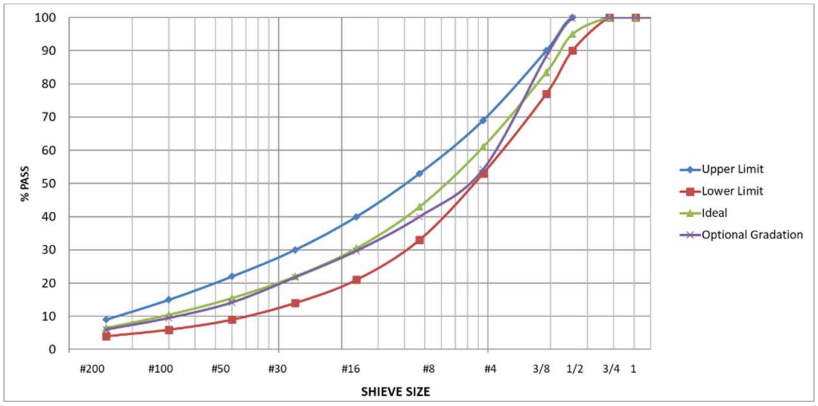

Figure 4 Combined Aggregate Gradation with 20% RAP, 80% New Material

Figure 4 shows that the combined grading had fulfilled the specification required.

Table 6. Combined Aggregate Grading with 20 % RAP, 80% New Material

Description	composition (%)	Shieve Size (% pass)									
Inch		3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Mm		19.0	12.5	9.5	4.75	2.36	1.18	0.600	0.300	0.150	0.075
Aggregate Gradient Data											
- RAP		100	100	81.58	45.25	28.67	22.76	18.27	14.31	11.43	8.00
- Coarse Aggregate (CA)		100.00	96.48	34.52	9.78	2.02	0.13	0.00	0.00	0.00	0.00
- Medium Aggregate (MA)		100	100.00	91.66	18.65	5.12	3.62	1.69	1.12	0.42	-
- Fine Aggregate (FA)		100	100	100	97.85	82.16	59.32	41.89	24.15	13.66	6.49
- Cement		100	100	100	100	100	100	100	100	100	100
Aggregate combination											
- RAP	20	20	20	16.32	9.05	5.73	4.55	3.65	2.86	2.29	1.60
- Coarse Aggregate (CA)	8	8.00	7.72	2.76	0.78	0.16	0.01	-	-	-	-
- Medium Aggregate (MA)	33	33.00	33.00	30.25	6.15	1.69	1.19	0.56	0.37	0.14	-
- Fine Aggregate (FA)	37	37.00	37.00	37.00	36.20	30.40	21.95	15.50	8.94	5.05	2.40
- Cement	2	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total Mix	**100**	**100.00**	**99.72**	**88.33**	**54.19**	**39.98**	**29.71**	**21.71**	**14.17**	**9.48**	**6.00**
Envelope Gradation Spec											
Maks.		100	100	90	69	53.0	40.0	30.0	22.0	15	9
Min		100	90	77	53	33	21	14	9	6	4
Ideal Gradation		**100.0**	**95.0**	**83.5**	**61.0**	**43.0**	**30.5**	**22.0**	**15.5**	**10.5**	**6.5**

Source: Test Results

Based on Table 6 shows that the best composition to obtain the envelope combined grading consists of RAP 20%, course aggregate 8%, medium aggregate 33%, fine aggregate 37% and cement 2%.

3.2.4. Combined Aggregate Grading with 30 % RAP, 70% New Material

The result of combined aggregate grading with 30 % RAP, 70% New Material is shown on Table 7 and Figure 5 below.

Table 7. Combined Grades with RAP 30%, 70% New Material

Description	composition (%)	Shieve Size (% pass)									
Inch		3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Mm		19.0	12.5	9.5	4.75	2.36	1.18	0.600	0.300	0.150	0.075
Aggregate Gradient Data											
- RAP		100	100	81.58	45.25	28.67	22.76	18.27	14.31	11.43	8.00
- Coarse Aggregate (CA)		100.00	96.48	34.52	9.78	2.02	0.13	0.00	0.00	0.00	0.00
- Medium Aggregate (MA)		100	100.00	91.66	18.65	5.12	3.62	1.69	1.12	0.42	-
- Fine Aggregate (FA)		100	100	100	97.85	82.16	59.32	41.89	24.15	13.66	6.49
- Cement		100	100	100	100	100	100	100	100	100	100
Aggregate combination											
- RAP	30	30	30	24.47	13.58	8.60	6.83	5.48	4.29	3.43	2.40
- Coarse Aggregate (CA)	8	8.00	7.72	2.76	0.78	0.16	0.01	-	-	-	-
- Medium Aggregate (MA)	25	25.00	25.00	22.92	4.66	1.28	0.91	0.42	0.28	0.11	-
- Fine Aggregate (FA)	35	35.00	35.00	35.00	34.25	28.76	20.76	14.66	8.45	4.78	2.27
- Cement	2	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total Mix	**100**	**100.00**	**99.72**	**87.15**	**55.27**	**40.80**	**30.51**	**22.57**	**15.03**	**10.32**	**6.67**
Envelope Gradation Spec											
Maks.		100	100	90	69	53.0	40.0	30.0	22.0	15	9
Min		100	90	77	53	33	21	14	9	6	4
Ideal Gradation		**100.0**	**95.0**	**83.5**	**61.0**	**43.0**	**30.5**	**22.0**	**15.5**	**10.5**	**6.5**

Source: Test Results

Based on table 8 shows that the best composition to obtain the envelope combined grading consists of RAP 30%, course aggregate 8%, medium aggregate 25%, fine aggregate 35% and cement 2%.

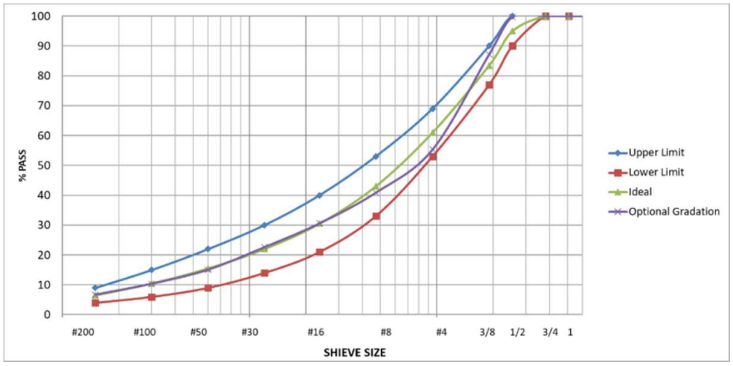

Figure 5. Combined Aggregate Gradation with RAP 30%, 70% New Material

Figure 5 shows that the combined grading had fulfilled the specification required.

3.2.5. New Asphalt Bitumen Content Added

Most of the asphalt bitumen content comes from the RAP, the calculation of the new asphalt Pen 60/70 which has to be added to fulfill the empirical asphalt bitumen content in mixture is shown on

Table 8 and Figure 6. Calculation of added bitumen content is based on NAPA Education Foundation, 1996[11].

Table 8. Asphalt Bitumen Content Added in Mixture

		10% rap mix					20% rap mix					30% rap mix				
AC-WC mix weight	(gr)	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Plan asphalt content	(%)	5	5.5	6	6.5	7	5.2	5.7	6.2	6.7	7.2	5.6	6.1	6.6	7.1	7.6
RAP bitumen content: 4%	(%)	0.4	0.4	0.4	0.4	0.4	0.8	0.8	0.8	0.8	0.8	1.2	1.2	1.2	1.2	1.2
New bitumen content	gr	4.6	5.1	5.6	6.1	6.6	4.4	4.9	5.4	5.9	6.4	4.4	4.9	5.4	5.9	6.4
Heavy asphalt rap	(gr)	4.8	4.8	4.8	4.8	4.8	9.6	9.6	9.6	9.6	9.6	14.4	14.4	14.4	14.4	14.4
New asphalt weight	(gr)	**55.1**	**61.1**	**67.1**	**73.1**	**79.1**	**52.9**	**58.9**	**64.9**	**70.9**	**76.9**	**52.3**	**58.3**	**64.3**	**70.3**	**76.3**
Aggregate Weight	(gr)	1140.1	1134.1	1128.1	1122.1	1116.1	1137.5	1131.5	1125.5	1119.5	1113.5	1133.3	1127.3	1121.3	1115.3	1109.3

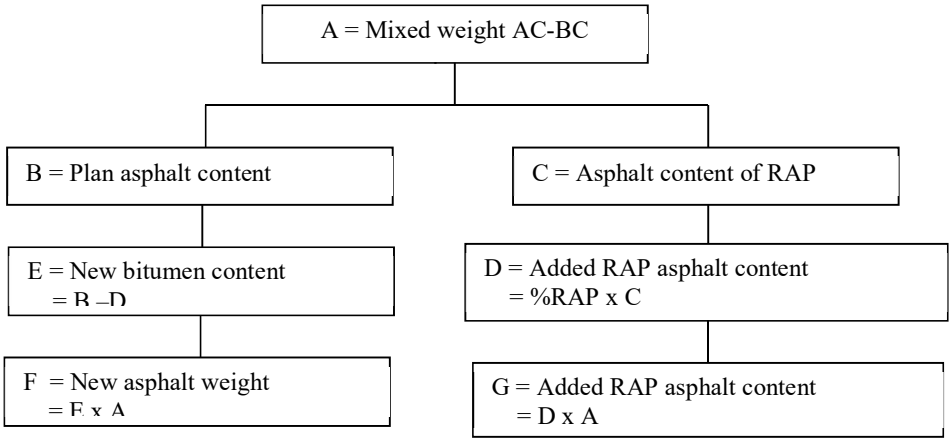

Figure 6. Calculation of Asphalt Bitumen Content Pen 60/70 added

3.3. Result of Mixture

3.3.1. Result of Mixture Using RAP 10%, Material 90%

The optimum asphalt bitumen content derived from the mixture properties is shown on figure

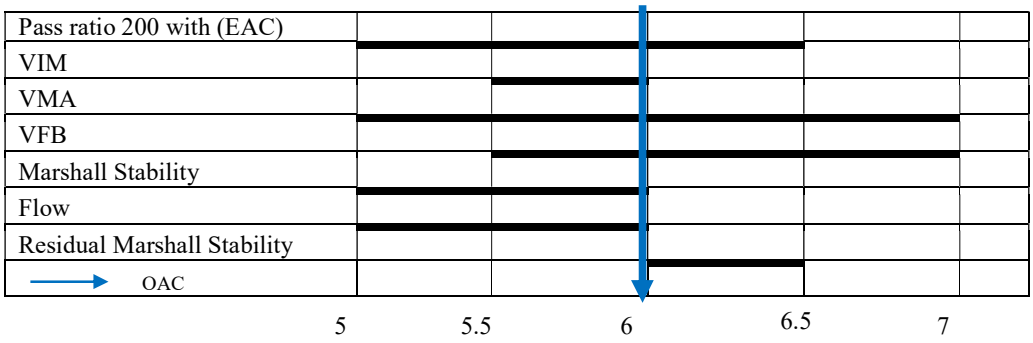

Figure 7. Optimum asphalt content (OAC) of Mixture Using RAP 10%, Material 90%

Figure 7 shows that the the mixture using RAP 10%, Material 90% had fulfilled the specification required which is 6%. The characteristic of the mixture is shown on Table 9.

Table 9. The characteristic of the mixture using RAP 10%, Material 90%

Characteristic of the mixture	Spec	Plan Asphalt Content (%)				
		4,6	5,1	5,6	6,1	6,6
Sieve passed particle ratio 0,075 mm with effective asphalt content	0,6 – 1,6	1.3	1.2	1.1	1	0.9
Void in Mix (VIM)(%)	3 – 5	6.972	5.177	3.238	1.965	0.756
Void In Mineral Agreggate (VMA) (%)	Min14	18.037	17.51	16.884	16.848	16.879
Void Filled With Bitument (VFB)(%)	Min 65	61.348	70.434	80.821	88.370	95.522
Stabilitas Marshall (kg)	Min 800	865.328	905.981	842.097	760.791	696.908
Flow (mm)	2 – 4	3.4	3.55	3.75	4.1	4.2
Residual Marshall Stability (%) after immersion for 24 hours, 60ºC	90	90,697	91,261	91,386	90,785	89,479

Source: Calculations

4.3.2 Result of Mixture Using RAP 20%, Material 80%

The optimum asphalt bitumen content derived from the mixture properties is shown on figure 8.

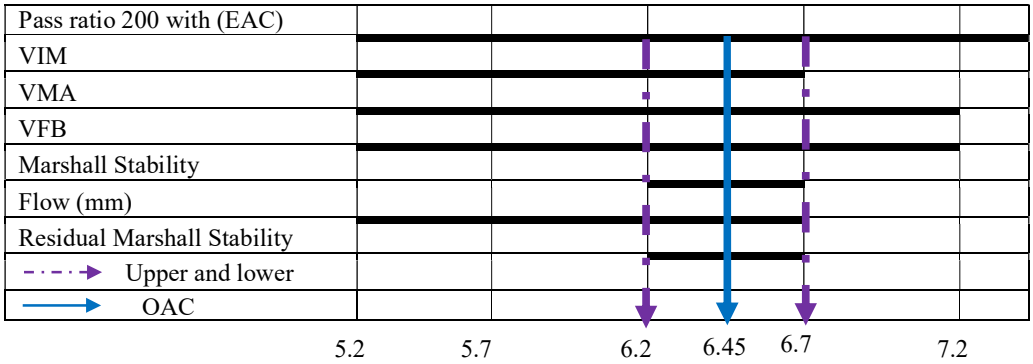

Figure 8. Optimum asphalt content (OAC) of Mixture Using RAP 20%, Material 80%

Figure 8 shows that the the mixture using RAP 10%, Material 90% had fulfilled the specification required which is 6.45%. The characteristic of the mixture is shown on Table 10.

Table 10. The characteristic of the mixture using RAP 20%, Material 80%

Characteristic of the mixture	Specification	Plan Asphalt Content (%) (%)				
		5.2	5.7	6.2	6.7	7.2
Sieve passed particle ratio 0,075 mm with effective asphalt content	0,6 – 1,6	1.4	1.2	1.1	1	0.9
Void in Mix (VIM)(%)	3 – 5	8.721	6.689	3.783	6.674	2.128
Void In Mineral Agreggate (VMA) (%)	Min14	17.595	16.851	16.541	16.364	16.114
Void Filled With Bitument (VFB)(%)	Min 65	50.721	60.322	77.133	77.548	86.8
Stabilitas Marshall (kg)	Min 800	754.984	772.407	842.097	824.675	778.214
Flow (mm)	2 – 4	3.2	3.4	3.5	3.7	4.3
Residual Marshall Stability (%) after immersion for 24 hours, 60ºC	90	90.500	91.330	90.400	91.320	90.290

Source: Calculations

4.3.3. Result of Mixture Using RAP 30%, Material 70%

The optimum asphalt bitumen content derived from the mixture properties is shown on figure 9.

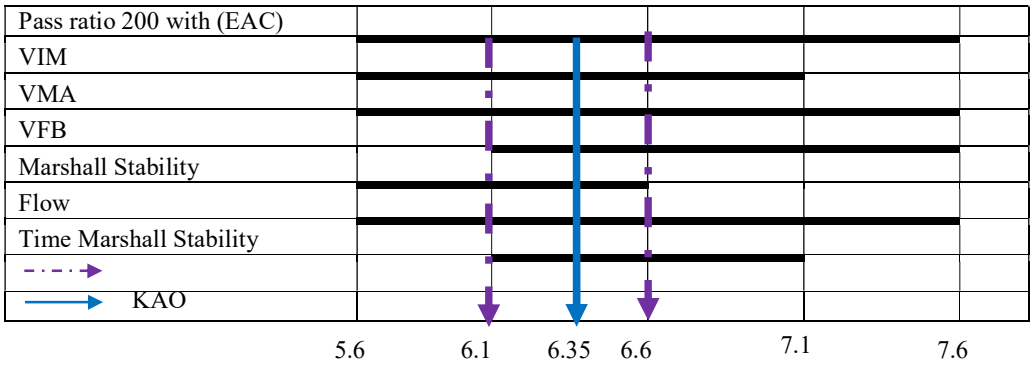

Figure 9. Optimum asphalt content (OAC) of Mixture Using RAP 30%, Material 70%

Figure 9 shows that the the mixture using RAP 10%, Material 90% had fulfilled the specification required which is 6.35%. The characteristic of the mixture is shown on Table 11.

Table 11. The characteristic of the mixture using RAP 30%, Material 70%

Characteristic of the mixture	Specification	Plan Asphalt Content (%) (%)				
		5.6	6.1	6.6	7.1	7.6
Sieve passed particle ratio 0,075 mm With effective asphalt content	0.6 – 1,6	1.4	1.3	1.2	1.1	1
Void in Mix (VIM)(%)	3 – 5	6.744	5.843	3.743	1.337	0.473
Void In Mineral Agreggate (VMA) (%)	Min14	18.666	18.917	17.035	17.164	17.488
Void Filled With Bitument (VFB)(%)	Min 65	63.868	69.114	78.040	92.209	97.296
Stabilitas Marshall (kg)	Min 800	807.252	836.290	853.712	766.599	691.101
Flow (mm)	2 – 4	3.3	3.40	6.35	3.7	4.0
Remaining Marshall stability (%) after immersion for 24 hours, 60ºC	90	89.20	91.67	90.48	91.65	89.92

Source: Calculations

4.4. Analysis of RAP Mixture

The RAP and new material composition are crusial affecting the mixture characteristic. The effect of RAP percentage in mixture for RAP 10%; New Material 90%, RAP 20%; New Material 80% dan RAP 30%; New Material 70% is shown on figure 10 to 16.

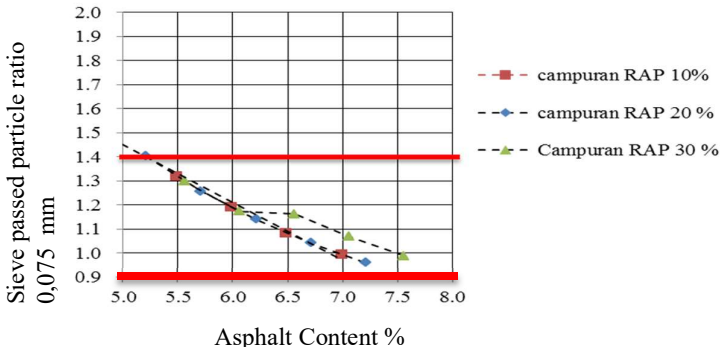

Figure10. Relationship Chart of RAP Mixture to Sieve passed particle ratio 0,075 mm with Optimum Asphalt Content

Figure 10 shows that the more RAP in mixture, the less Sieve passed particle ratio 0,075 and Optimum Asphalt Content.

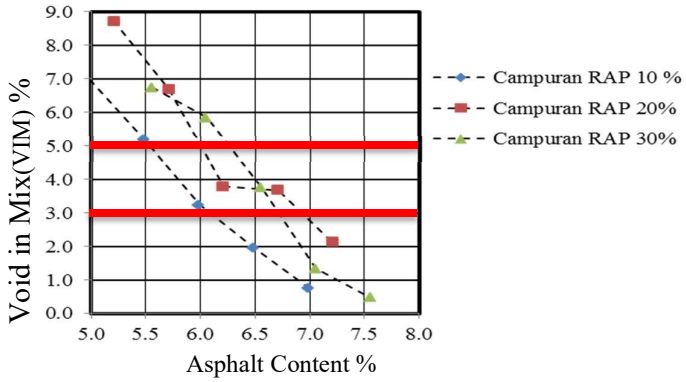

Figure 11. Relationship Chart of RAP Mixture to Void in Mixture (VIM).

Figure 11 shows that the RAP 10 % of mixture resulting the lowest Void in Mixture (VIM) compared to RAP 20% and 30%.

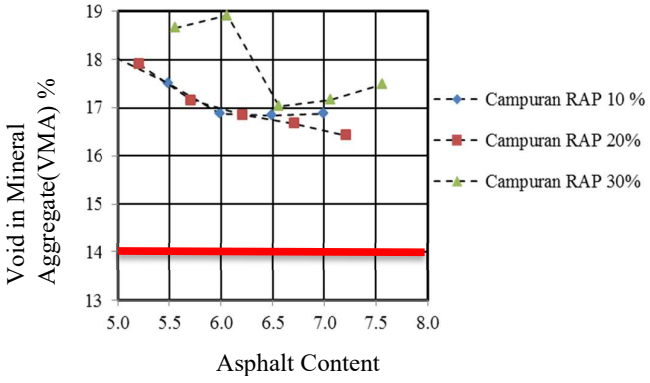

Figure 12. Relationship Chart of RAP Mixture to Void Mixture Aggregate (VMA).

Figure 12 shows that RAP 30 % of mixture resulting the highest Void Mixture Aggregate (VMA) compared to RAP 20% and 30%.

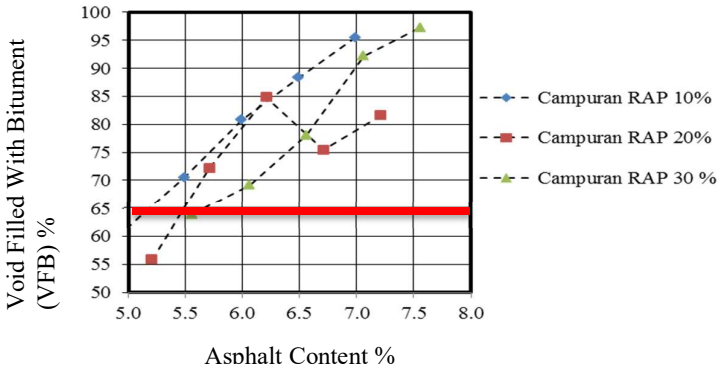

Figure 13. Relationship Chart of RAP Mixture to Void Filled Bitumen (VFB).

Figure 13 shows that RAP 20% of mixture did not fulfilled the bitumen content required for the lowest value.

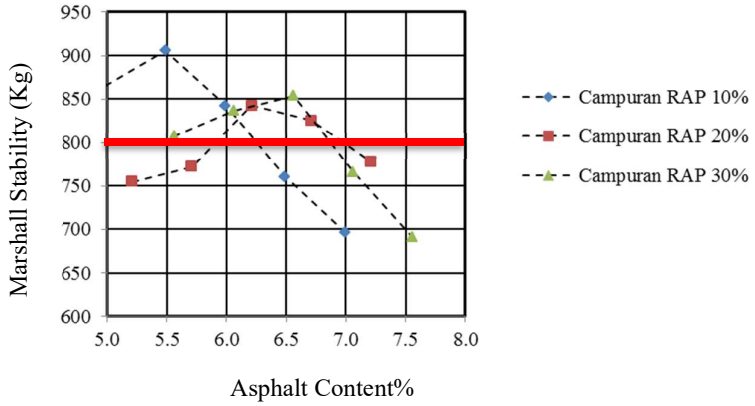

Figure 14. Relationship Chart of RAP Mixture to Marshall Stability.

Figure 14 shows that all of RAP mixture did not fulfilled the bitumen content required at the highest value.

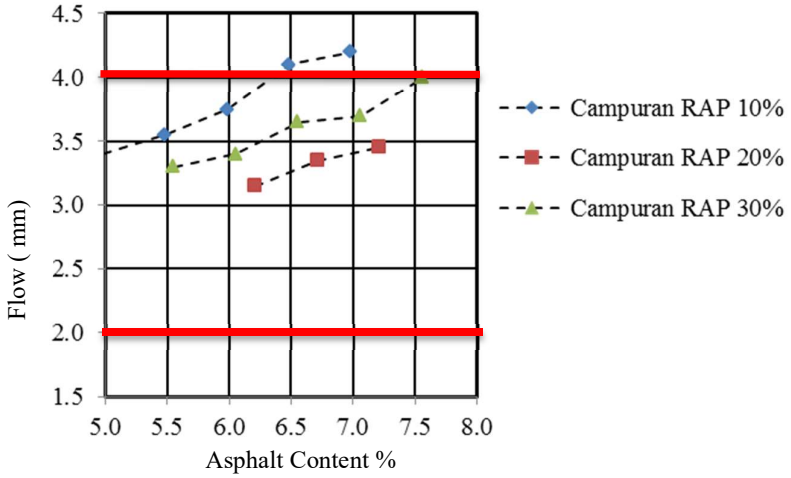

Figure 15. Relationship Chart of RAP Mixture to Flow.

Figure 15 shows that all of the RAP mixture had fulfilled the bitumen content required except for RAP 10% mixture at the highest bitumen content value.

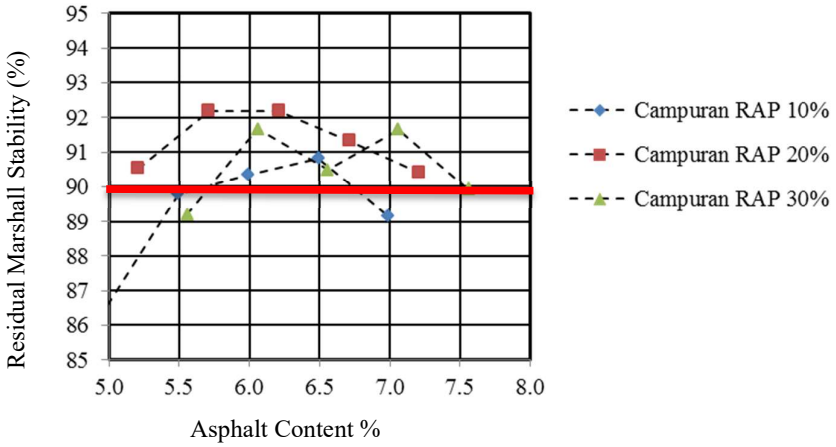

Figure 16. Relationship Chart of RAP Mixture to Residual Marshall Stability.

Figure 16 shows that all of RAP mixture had fulfilled the bitumen content required except for RAP 10% and RAP 30% mixture which did not fulfilled the bitumen content both at the highest and lowest value.

By comparing the characteristic of the result test of RAP 10%, RAP 20% and RAP 30% mixture, it can be concluded that:

a. The more RAP percentage of AC-WC mixture for three Sieve passed particle ratio 0,075, the less Effective Asphalt Content resulted. For VIM and VFB, most of the mixture using RAP 10% and RAP 30% had fulfilled the requirement. The VMA on all of RAP had fulfilled the requirement.
b. The more RAP percentage in AC-WC mixture, the flow value is decreasing significantly, but at RAP 30% mixture, the bitumen content had risen.

4. Conclusions and Suggestions

4.1. Conclusions

1. The RAP characteristic which fulfill the requirement of the specification is specific gravity test 2,6 gr/cm3 and water absorption 1,78 %, but RAP aggregate grading did not fulfill the grading envelope. The adding of new material aggregate is needed in order to fulfill the envelope grading required. The RAP characteristic for asphalt which fulfill the specification required is obtained from the extraction process of mixture with asphalt bitumen content 4%.
2. From all of the RAP mixture, the most optimum result and fulfill the specification required is RAP 30%; new material aggregate 70%.

4.2. Suggestions

The further research is needed to study RAP usage in ACWC mixture in the field. By the direct field testing and observing for the certain time frame, the real condition of the pavement loaded with the traffic is obtained.

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