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Characteristics Comparison of Refinery Asphalt, Rubberized Asphalt, and Buton Asphalt in Stone Matrix Asphalt Pavement with Marshall and Cantabro Method

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Abstract. The most common flexible pavement used in Indonesia were asphalt concrete and hot rolled sheet, with the most frequently problem caused by the extremely high traffic load. Because of that, an alternative type of pavement needed. Stone matrix asphalt (SMA) is a mixture with gap gradation which contains a large portion of coarse aggregates and forms a skeleton that efficiently spreads the load due to passing vehicles. SMA mixture consists of three types, that is thin SMA, fine SMA and rough SMA. The utilization of several types of asphalt also can be an alternative. In this research will be made a comparison about SMA mixture with buton asphalt, rubberized asphalt, and refinery asphalt based on Marshall properties, followed with Marshall immersion and cantabro test based on the optimum asphalt content. Overall based on the test result, the combination of SMA mixture with rubberized asphalt was the best. It had the highest stability with the lowest optimum asphalt content. While for the marshall immersion test, the stability of all sample after 24 hours soaked in waterbath were decreased. Also based on cantabro test result, the best index of retained strength value were for SMA mixture with rubberized asphalt.

1. Introducion

Road pavement is one of the important factors supporting the development of road transport infrastructure that is environmentally friendly, durable, and economical. The number of vehicles continues to increase every year resulting in road services must be improved. One way to prevent damage to the road pavement due to cargo loads from public transportation is to improve the quality and stability. Stone Matrix Asphalt mixture is an alternative pavement that can be used. The Directorate General of Bina Marga, in September 2018, has issued the latest general specifications to replace the previous specifications namely the 2010 general specification revision 3.

Along with the development of asphalt mixtures, asphalt is also widely developed, in addition to refinery asphalt there are several alternative asphalt that can be used as a binding agent in asphalt mixtures, for example, Buton Asphalt and rubberized asphalt.

Stone Matrix Asphalt or can be called SMA is a mixture with gap gradation that contains most of the coarse aggregates, Coarse aggregates are bound together with fillers, fibers and polymers with a thick asphalt layer [2]. According to the 2018 Bina Marga specification, Stone Matrix Asphalt consists of three kinds of mixtures, thin SMA, fine SMA, and rough SMA with aggregate size limits of 12.5mm, 19mm, and 25mm.

2. Literature Review

2.1. Stone Matrix Asphalt

Stone Matrix (SMA) contained coarse aggregate, fine aggregate, filler, asphalt, and admixture [6]. SMA also known as a mixture that mostly contains with coarse aggregates and form a skeleton that efficiently spreads the burden caused by a passing vehicle. SMA consists of high amount of coarse aggregate, then for the mastic its consist of mix of fine aggregate, filler and high percentage of asphalt [6]. The disadvantages of this SMA mixture are the low skid resistance value, higher manufacturing costs compared to traditional mixes due to the higher bitumen and filler content (however, longer life can reduce the reduction in life cycle cost), and the risk of having a fat point spots that appear on the asphalt surface due to an error in the design of the SMA mixture.

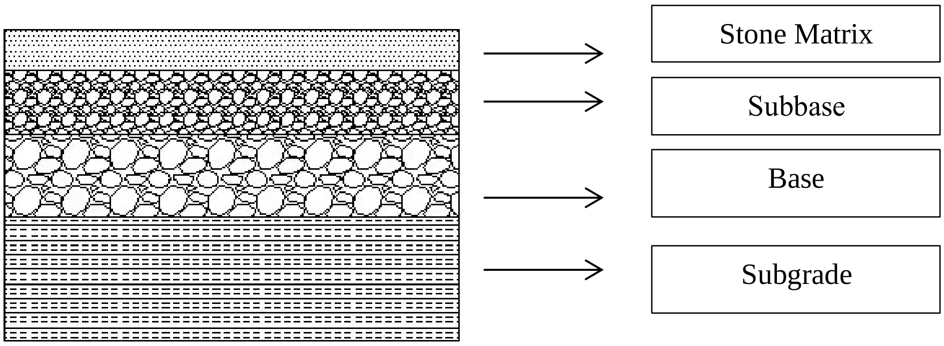

Figure 1. Stone Matrix Asphalt

2.2. Refinery Asphalt

Refinery asphalt is asphalt that obtained from petroleum refining [4]. Refinery asphalt originated from crude oil, the crude oil will be put in the distillation coloumn and heated up in temperature 500^{O}C to separate the oil fraction based on the boiling point. Fraction with boiling point under 500^{O}C will evaporate up to the distillation tower and will be heated again. At the same time for oil with boiling point above 500^{O}C will collected into residues and made into asphalt.

2.3. Rubberized Asphalt

Rubberized asphalt is a modification asphalt with rubber additives added. With the rubber additives added into the asphalt, it could increase the elasticity and adhesiveness. Rubberized asphalt characteristics were hard, strong against cracks, high adhesion and more flexible also the rubberized asphalt were more stable, not easily broken, not easily corrugated or eroded when exposed to sunlight. Stability, Marshall Quotient, Voids In Mixture and Voids in Mineral Aggregate value of SMA mixture that added with rubber was decreased. While flow and Voids Filled with Asphalt value increased [1].

There are three rubber asphalt technologies, namely, latex-based rubber asphalt technology, Masterbatch-based solid rubber asphalt, and rubber powder-based asphalt. Latex-based rubber asphalt technology uses two types of latex, ordinary concentrated latex, and pre-vulcanized concentrated latex. Rubberized asphalt used in this research is modified elastomer JAP-57.

2.4. Buton Asphalt

Buton asphalt is a natural asphalt contained in rock deposits found in Buton Island and its surroundings. One example of buton asphalt is Jaya Buton Modified Asphalt also called JBMA-50. This type of this asphalt is modification buton asphalt with refinery asphalt which contains asphalt content of ± 90% and minerals or fillers ± 10%. JBMA-50 asphalt consists of a composition of asphalt pen 60 or pen 80 with processed products from buton asphalt with other ingredients and anti-oxidants which are made in Manufacturing [5].

2.5. Marshall standard and marshall immersion test

Marshall test done for determine the stability and flow from the asphalt mixture. Marshall test done with marshall machine. Before marshall test, the sample for marshall standard must be soaked in waterbath with temperature 60ºC for 30 minutes. Marshall immersion test intend to determine the endurance or stability and flow from the mixture. Durability needed in pavement surface layer so that the layer could defend from the effects of weather, water and temperature or the damage due the vehicle friction [3]. In marshall immersion, will be compared the stability from soaking for 24 hours and stability from soaking for 30 minutes. From that, will be obtained retained strength index (RSI) for each mixtures. The result is the comparison between marshall stability at 60ºC for 24 hours with Marshall stability at 60ºC for 30 minutes. The higher the RSI value means durability potency from the mixture would be even better [3].

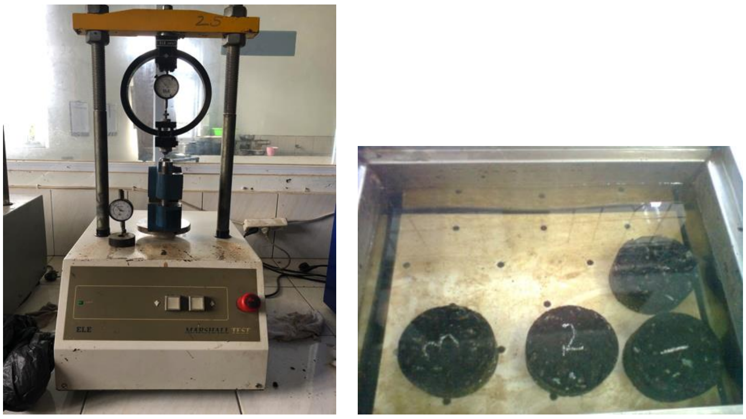

Figure 2. Marshall machine and Sample soaked in waterbath

2.6. Cantabro test

Cantabro test is a test for determine the pavement resistance to abrasion with los angeles machine without using the steel balls. This abrasion is stated by the ratio between the weight of sample after 300 spin towards the originally weight before it put in the machine. The cantabro test value describe the sample's endurance towards abrasion with los angeles machine [7].

figure 3. Cantrabro test with Los Angeles machine

3. Results of research

3.1. Marshall standard test result

From marshall test can be obtained the stability and flow. Then Marshall Quotionent (MQ) value, *Void in Mixture* (VIM), *Void Filled with Asphalt* (VFA), and *Void in mineral aggregate* (VMA) will be counted and being recapitulated into tables. Each data of the marshall test result should be made into chart. Also for SMA mixture, there were only 4 parameters that should be fulfilled.

Void in mineral aggregate (VMA) are the voids between the mineral aggregate, while Void in mixture (VIM) or voids in the mixture that already compacted. Based on Bina Marga 2018 specification, minimum value of VMA was 17% and VIM from 4-5%. Stability can be interpreted as the ability of the pavement to resist the deformation. The stability value can be obtained from machine dial along with the flow value. While flow was show the flexibility of the mixture or pavement. The flow value should be from 2 mm and maximum 4,5 mm. Marshall quotionent was the quotient of stability and flow. For SMA mixture there is no requirement for MQ value. The Marshall standard test result for each SMA mixture can be seen in these following tables.

Table 1. Marshall standard test result for thin SMA mixture.

No	Parameters	Requirement	Thin SMA with Rubberized Asphalt					Thin SMA with Buton Asphalt					Requirement	Thin SMA with Refinery Asphalt				
			Asphalt content					Asphalt content						Asphalt content				
			6%	6,5%	7%	7,5%	8%	6%	6,5%	7%	7,5%	8%		6%	6,5%	7%	7,5%	8%
1			17,06	17,38	17,57	18,08	18,60	17,29	17,48	17,20	18,80	18,39		18,19	16,89	17,75	17,71	18,09
2	VMA	Min. 17	17,29	17,34	17,59	18,04	18,72	18,04	17,09	18,28	18,26	18,62	Min. 17	17,97	17,26	17,70	17,79	18,75
3			17,57	17,75	17,92	17,66	18,68	18,46	17,67	17,99	17,48	18,85		17,84	16,86	18,15	17,85	18,43
	Average		**17,31**	**17,49**	**17,69**	**17,93**	**18,67**	**17,93**	**17,41**	**17,82**	**18,18**	**18,62**		**18,00**	**17,00**	**17,87**	**17,79**	**18,42**
1			65,69	71,12	77,02	81,05	84,81	64,43	70,38	78,77	77,02	85,73		60,64	73,44	75,89	82,93	87,57
2	VFA		64,66	71,29	76,92	81,29	84,15	61,21	72,32	73,15	79,81	84,46		61,54	71,55	76,19	82,49	83,83
3			63,42	69,31	75,21	83,41	84,38	59,50	69,46	74,62	84,18	83,18		62,09	73,58	73,87	82,14	85,58
	Average		**64,59**	**70,57**	**76,39**	**81,91**	**84,45**	**61,72**	**70,72**	**75,51**	**80,34**	**84,45**		**61,42**	**72,85**	**75,32**	**82,52**	**85,66**
1			5,86	5,02	4,04	3,43	2,83	6,15	5,18	3,65	4,32	2,63		7,16	4,49	4,28	3,02	2,25
2	VIM	4-5	6,11	4,98	4,06	3,38	2,97	7,00	4,73	4,91	3,69	2,89	4-5	6,91	4,91	4,21	3,12	3,03
3			6,43	5,45	4,44	2,93	2,92	7,48	5,40	4,57	2,77	3,17		6,76	4,46	4,74	3,19	2,66
	Average		**6,13**	**5,15**	**4,18**	**3,24**	**2,90**	**6,87**	**5,10**	**4,38**	**3,59**	**2,90**		**6,95**	**4,62**	**4,41**	**3,11**	**2,65**
1			1009,38	1246,88	1325,25	1121,00	1016,50	902,50	1128,13	1237,38	1099,63	904,88		985,63	1009,38	1016,50	1009,38	902,50
2	Stability	Min. 750	992,75	1235,00	1332,38	1140,00	1009,38	957,13	1156,63	1306,25	1073,50	916,75	Min. 600	950,00	985,63	1021,25	978,50	938,13
3			985,63	1230,25	1311,00	1151,88	978,50	976,13	1189,88	1334,75	1087,75	885,88		945,25	997,50	1009,38	969,00	950,00
	Average		**995,92**	**1237,38**	**1322,88**	**1137,63**	**1001,46**	**945,25**	**1158,21**	**1292,79**	**1086,96**	**902,50**		**960,29**	**997,50**	**1015,71**	**985,63**	**930,21**
1		Min. 2	3,35	3,62	3,70	3,85	4,1	3,64	3,74	3,72	3,65	3,81	Min. 2	3,35	3,62	3,75	3,85	4,15
2	Flow		3,10	3,5	3,92	3,7	4,18	3,53	3,62	3,70	3,80	4,00		3,40	3,52	3,82	3,75	3,90
3		Max. 4,5	3,25	3,75	3,50	3,68	4,15	3,41	3,54	3,65	3,92	0,19	Max. 4,5	3,65	3,65	3,63	3,82	3,85
	Average		**3,23**	**3,62**	**3,71**	**3,74**	**4,14**	**3,53**	**3,63**	**3,69**	**3,79**	**2,67**		**3,47**	**3,60**	**3,73**	**3,81**	**3,97**
1			301,31	336,99	344,22	309,67	247,93	247,94	301,64	332,63	301,27	237,50		294,22	278,83	271,07	262,18	217,47
2	MQ		320,24	315,05	360,10	325,71	241,48	271,14	319,51	353,04	282,50	229,19		279,41	280,01	267,34	260,93	240,55
3			303,27	351,50	356,25	307,17	235,78	286,25	336,12	365,69	277,49	225,99		258,97	273,29	278,07	253,67	246,75
	Average		**308,27**	**334,51**	**353,52**	**314,18**	**241,73**	**268,44**	**319,09**	**350,45**	**287,08**	**230,89**		**277,53**	**277,38**	**272,16**	**258,92**	**234,92**

From the table 1 above, can be conclude that the amount of asphalt content increased VMA and VFA value, while VIM decreased. The stability also increased and back decreased when it reach the optimum point. Mostly the optimum stability value of the mixture was in 7% asphalt content. Based on the Bina Marga 2018 spesification, SMA mixture's stability with refinery asphalt should be over 600 kg, while SMA mixture's stability with rubberized and buton asphalt (also know as modified asphalt) should be over 750 kg. The higher asphalt content, then the higher the flow. Flow requirement value was minimal 2 mm and maximum 4,5 mm. While for MQ, if the MQ value was high means the mixture had a rigid characteristic.

Table 2. Marshall standard test result for fine SMA mixture.

No	Parameters	Requirement	Fine SMA with Rubberized Asphalt					Fine SMA with Buton Asphalt					Requirement	Fine SMA with Refinery Asphalt				
			Asphalt content					Asphalt content						Asphalt content				
			6%	6,5%	7%	7,5%	8%	6%	6,5%	7%	7,5%	8%		6%	6,5%	7%	7,5%	8%
1	VMA	Min. 17	18,47	19,24	20,01	20,45	20,74	17,56	18,30	18,67	19,73	20,00	Min. 17	17,46	18,31	19,26	19,25	20,02
2			18,49	18,90	19,85	20,80	20,41	17,10	18,11	19,03	19,25	20,18		17,66	17,99	18,96	19,61	19,99
3			18,32	19,15	19,51	20,28	20,57	17,53	18,28	19,02	19,64	20,31		17,77	18,10	18,81	19,48	20,06
	Average		**18,42**	**19,10**	**19,79**	**20,51**	**20,57**	**17,40**	**18,23**	**18,90**	**19,54**	**20,17**		**17,63**	**18,13**	**19,01**	**19,45**	**20,02**
1	VFA		71,29	73,83	76,13	79,79	84,09	75,52	78,25	82,68	83,17	87,67		76,04	78,17	79,53	85,73	87,59
2			71,18	75,44	76,86	78,09	85,77	78,00	79,23	80,75	85,71	86,68		75,02	79,89	81,08	83,76	87,75
3			72,01	74,27	78,55	80,63	84,93	75,69	78,33	80,78	83,64	85,99		74,47	79,32	81,91	84,48	87,37
	Average		**71,49**	**74,51**	**77,18**	**79,51**	**84,93**	**76,40**	**78,61**	**81,40**	**84,18**	**86,78**		**75,18**	**79,13**	**80,84**	**84,66**	**87,57**
1	VIM	4-5	5,30	5,03	4,78	4,13	3,30	5,57	5,24	4,49	4,56	3,70	4-5	5,45	5,25	5,18	3,98	3,71
2			5,33	4,64	4,59	4,56	2,90	5,05	5,03	4,91	4,00	3,92		5,67	4,88	4,83	4,42	3,68
3			5,13	4,93	4,19	3,93	3,10	5,54	5,23	4,91	4,46	4,08		5,80	5,00	4,65	4,26	3,76
	Average		**5,25**	**4,87**	**4,52**	**4,21**	**3,10**	**5,39**	**5,17**	**4,77**	**4,34**	**3,90**		**5,64**	**5,04**	**4,89**	**4,22**	**3,72**
1	Stability	Min. 750	996,45	991,69	999,03	1019,20	939,58	1060,88	1021,48	1132,48	1069,25	1056,16	Min. 600	976,03	1003,22	1025,51	940,64	853,42
2			987,80	1028,30	1077,02	999,03	998,61	1037,40	1095,47	1130,06	1086,58	1053,96		968,63	978,25	1026,28	907,64	846,34
3			985,56	1032,07	1088,55	1010,25	966,58	1037,81	1092,00	1102,39	1028,21	1042,43		964,01	1037,30	1007,83	880,99	823,33
	Average		**989,94**	**1017,35**	**1054,86**	**1009,49**	**968,25**	**1045,36**	**1069,65**	**1121,64**	**1061,35**	**1050,85**		**969,56**	**1006,26**	**1019,88**	**909,76**	**841,03**
1	Flow	Min. 2	3,55	3,65	3,76	4,20	4,02	3,35	3,30	3,42	3,44	3,52	Min. 2	3,25	3,30	3,67	3,93	4,15
2			3,59	3,57	3,64	4,23	4,41	3,08	3,28	3,35	3,60	3,60		3,42	3,47	3,45	4,02	4,08
3		Max. 4,5	3,53	3,60	3,65	4,15	4,38	3,20	3,16	3,37	3,39	3,45	Max. 4,5	3,45	3,68	3,42	3,88	3,81
	Average		**3,56**	**3,61**	**3,68**	**4,19**	**4,27**	**3,21**	**3,25**	**3,38**	**3,48**	**3,52**		**3,37**	**3,48**	**3,51**	**3,94**	**4,01**
1	MQ		280,69	271,70	265,70	242,67	233,73	316,68	309,54	331,13	310,83	300,05		300,32	304,01	279,43	239,35	205,64
2			275,15	288,04	295,88	236,18	226,44	336,82	333,98	337,33	301,83	292,77		283,22	281,92	297,47	225,78	207,44
3			279,19	286,69	298,23	243,43	220,68	324,32	345,57	327,12	303,31	302,15		279,42	281,88	294,69	227,06	216,10
	Average		**278,35**	**282,14**	**286,61**	**240,76**	**226,95**	**325,94**	**329,70**	**331,86**	**305,32**	**298,32**		**287,65**	**289,27**	**290,53**	**230,73**	**209,73**

From the table 2 above, can be conclude that the amount of asphalt content increased VMA and VFA value, while VIM value decreased. The stability also increased and back decreased when it reach the optimum point. Mostly the optimum stability value of the mixture was in 7% asphalt content. Based on the Bina Marga 2018 spesification, SMA mixture's stability with refinery asphalt should be over 600 kg, while SMA mixture's stability with rubberized and buton asphalt (also known as modified asphalt) should be over 750 kg. The higher asphalt content, then the higher the flow. Flow requirement value was minimal 2 mm and maximum 4,5 mm. While for MQ, if the MQ value was high means the mixture had a rigid characteristic.

Table 3. Marshall standard test result for rough SMA mixture.

No	Parameters	Requirement	Rough SMA with Rubberized Asphalt					Rough SMA with Buton Asphalt					Requirement	Rough SMA with Refinery Asphalt				
			Asphalt content					Asphalt content						Asphalt content				
			5%	5,5%	6%	6,5%	7%	5%	5,5%	6%	6,5%	7%		5%	5,5%	6%	6,5%	7%
1	VMA	Min. 17	17,09	17,98	18,00	18,74	18,97	15,88	16,68	17,08	18,06	18,25	Min. 17	17,09	17,29	17,39	17,62	18,36
2			17,08	17,91	18,05	18,63	18,87	14,88	16,50	17,75	17,68	18,42		17,22	17,30	17,49	17,74	18,32
3			17,16	17,45	17,90	18,53	19,40	15,85	16,79	17,58	18,09	18,79		17,28	17,36	17,54	17,77	18,33
	Average		**17,11**	**17,78**	**17,98**	**18,65**	**19,08**	**15,54**	**16,65**	**17,47**	**17,94**	**18,49**		**17,20**	**17,32**	**17,47**	**17,71**	**18,34**
1	VFA		64,60	67,15	73,56	76,25	81,33	70,28	73,31	78,10	79,54	84,97		64,36	70,17	76,45	81,94	84,36
2			64,64	67,47	73,32	76,82	81,89	75,87	74,25	74,59	81,59	84,01		63,78	70,13	75,93	81,27	84,62
3			64,28	69,63	74,04	77,07	79,10	70,44	72,73	75,42	79,37	81,98		63,53	69,86	75,64	81,09	84,54
	Average		**64,51**	**68,08**	**73,64**	**76,71**	**80,77**	**72,19**	**73,42**	**76,04**	**80,17**	**83,65**		**63,89**	**70,05**	**76,01**	**81,43**	**84,51**
1	VIM	4-5	6,05	5,91	4,76	4,45	3,54	6,02	5,74	5,02	4,96	4,01	4-5	7,36	6,43	5,36	4,45	4,12
2			6,04	5,83	4,82	4,32	3,42	4,91	5,54	5,78	4,53	4,21		7,51	6,44	5,47	4,59	4,07
3			6,13	5,30	4,65	4,26	4,06	5,99	5,87	5,60	5,00	4,64		7,57	6,50	5,54	4,62	4,09
	Average		**6,07**	**5,68**	**4,74**	**4,34**	**3,67**	**5,64**	**5,71**	**5,47**	**4,83**	**4,29**		**7,48**	**6,45**	**5,49**	**4,55**	**4,09**
1	Stability	Min. 750	1037,50	1117,50	1145,00	1052,50	1002,50	900,00	970,00	1002,50	980,00	927,50	Min. 600	900,00	925,00	977,50	950,00	900,00
2			1050,00	1112,50	1152,50	1045,00	1012,50	910,00	975,00	1020,00	972,50	945,00		910,00	937,50	970,00	937,50	895,00
3			1045,00	1105,00	1142,50	1060,00	1022,50	925,00	985,00	1030,00	962,50	937,50		905,00	942,50	972,50	945,00	892,50
	Average		**1044,18**	**1111,68**	**1146,67**	**1052,50**	**1012,50**	**911,67**	**976,66**	**1017,50**	**971,67**	**936,67**		**905,00**	**935,00**	**973,33**	**944,17**	**895,83**
1	Flow	Min. 2	3,03	3,12	3,21	3,32	3,38	3,91	4,18	4,28	4,38	4,52	Min. 2	2,87	2,94	3,07	3,15	3,23
2			3,02	3,10	3,19	3,28	3,39	3,95	4,20	4,30	4,40	4,50		2,89	2,95	3,05	3,14	3,25
3		Max. 4,5	3,05	3,13	3,23	3,30	3,40	3,98	4,16	4,32	4,41	4,54	Max. 4,5	2,90	2,96	3,04	3,14	3,27
	Average		**3,03**	**3,12**	**3,21**	**3,30**	**3,39**	**3,95**	**4,18**	**4,30**	**4,40**	**4,52**		**2,89**	**2,95**	**3,05**	**3,14**	**3,25**
1	MQ		342,41	358,17	356,70	317,02	296,60	230,18	232,06	234,23	223,74	205,20		313,59	314,63	318,40	301,59	278,64
2			347,63	358,87	361,29	318,60	298,67	230,38	232,14	237,21	221,02	210,00		314,88	317,80	318,03	298,57	275,39
3			342,62	353,04	353,72	321,21	300,74	232,41	236,78	238,43	218,25	206,50		312,07	318,41	319,90	300,96	272,94
	Average		**344,24**	**356,69**	**357,22**	**318,94**	**298,67**	**230,99**	**233,66**	**236,62**	**221,01**	**207,23**		**313,51**	**316,95**	**318,78**	**300,37**	**275,65**

Based on Bina Marga 2018 specification, minimal value of VMA was 17%, while VMA value was from 4 to 5%. From the table 1 to 3 above, can be conclude that the amount of asphalt content increased VMA and VFA value, while VIM decreased. The stability also increased and back decreased when it has reach the optimum point. Mostly the optimum stability value of the mixture was in 6% asphalt content. Based on the Bina Marga 2018 spesification, SMA mixture's stability with refinery asphalt should be over 600 kg, while SMA mixture's stability with rubberized and buton asphalt (also know as modified asphalt) should be over 750 kg. The higher asphalt content, then the higher the flow. Flow requirement value was minimal 2 mm and maximum 4,5 mm. While for MQ, if the MQ value was high means the mixture had a rigid characteristic.

After marshall test result recapitulated into table and graphs, optimum asphalt content can be determined based on data that fulfill the requirement in Spesification of Bina Marga 2018 for each parameters.

3.2. Optimum asphalt content

From the marshall standard test result, the value of optimum asphalt content can be obtained. Optimum asphalt content can be seen in table 10. After that, the optimum asphalt content will be used as a reference to obtained the marshall parameters towards the optimum asphalt content.

Table 4. Optimum Asphalt Content

	Refinery Asphalt	Rubberized Asphalt	Buton Asphalt
Thin SMA mixture	6,81%	6,80%	6,90%
Fine SMA mixture	7,15%	6,95%	7,25%

Rough SMA mixture	6,7%	6,55%	6,7%

After the value of optimum asphalt content obtained, those optimum asphalt content will be used as a reference to obtain the marhall parameters towards optimum asphalt content for each mixture. Marshall parameters toward optimum asphalt content can be seen on these following tables.

Table 5. Marshall parameters towards optimum asphalt content for thin, fine and rough SMA

No.	Parameters	Thin SMA			Fine SMA			Rough SMA		
		Buton asphalt	Rubberized asphalt	Refinery asphalt	Buton asphalt	Rubberized asphalt	Refinery asphalt	Buton asphalt	Rubberized asphalt	Refinery asphalt
1.	KAO (%)	6,9	6,8	6,805	7,25	6,95	7,15	6,7	6,55	6,7
2.	VMA (%)	4,46	4,47	4,48	19,25	19,79	19,08	18,21	18,2	18
3.	VFA (%)	74,8	74,54	74,7	82,69	76,99	82,38	81,7	76,9	82,4
4.	VIM (%)	17,7	17,53	17,5	4,44	4,64	4,6	4,69	4,61	4,71
5.	Stability (Kg)	1239	1278,26	1011,5	1092,64	1040,42	984,65	970	1080	927
6.	Flow (mm)	3,68	3,77	3,66	3,41	3,77	3,67	4,45	3,31	3,2
7.	MQ (Kg/mm)	336,5	340	275	320,55	276,604	269,64	217,5	327	292

3.3. Marshall immersion test result

Summary of marhsall immersion test result based on the samples' stability can be seen on this following table.

Table 6. Marshall immersion test summary

No.	Mixture Type	Stability(kg)		*Index of Retained Strenght* (%)	Spesification
		30 menit	24 jam		
1	Thin SMA with buton asphalt	1294,375	1215,208	93,883	
2	Thin SMA with rubberized asphalt	1318,917	1270,625	96,338	≥ 90%
3	Thin SMA with refinery asphalt	1014,125	933,375	92,037	
1	Fine SMA with buton asphalt	1124,678	1056,847	93,968	
2	Fine SMA with rubberized asphalt	1065,096	1019,523	95,721	≥ 90%
3	Fine SMA with fefineryd asphalt	1022,198	936,1838	91,585	
1	Rough SMA with buton asphalt	942,5	881,667	93,545	
2	Rough SMA with rubberized asphalt	1055,833	993,333	94,08	≥ 90%
3	Rough SMA with fefineryd asphalt	939,1667	855,833	91,126	

Based on the table 15 above, index of retained strength value for thin SMA mixture with buton asphalt was 93,883%, rubberized asphalt was 96,338%, and refinery asphalt was 92, 037%. While for fine SMA mixture with buton asphalt was 93,968%, rubberized asphalt 95,721%, refinery asphalt was 91,585%. Also for the rough SMA mixture with buton asphalt was 93,545%, rubberized asphalt was 94,080%, and refinery asphalt was 91, 126%. SMA mixture that use rubberized asphalt has the highest index of retained strength value among three of themFrom Table 14 above, can be concluded that all the retained strength index from marshall immersion test were all fulfil the requirements which is above 90%.

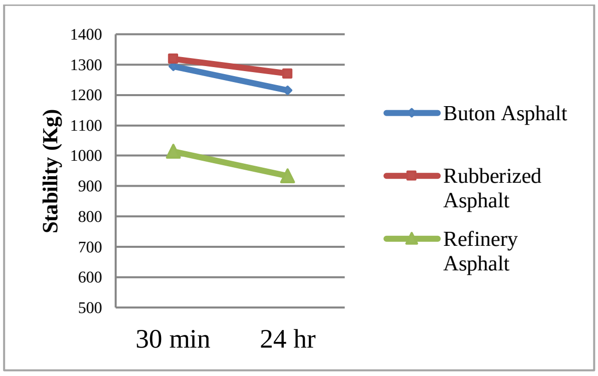

Figure 4. Retained strength index for thin SMA

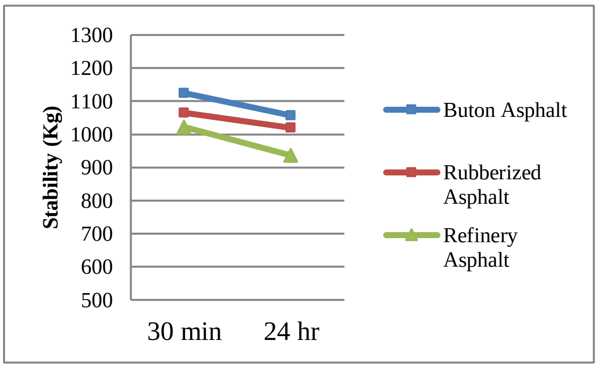

Figure 5. Retained strength index for fine SMA

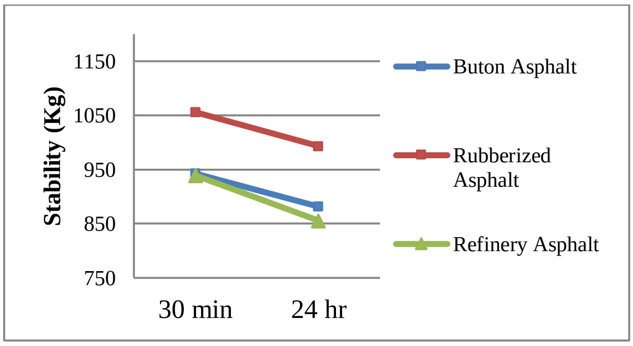

Figure 6. Retained strength index for rough SMA

3.4. Cantabro test result

Summary of cantabro test result can be seen in Table 15.

Table 7. Cantabro test result summary

No.	Sample	Optimum asphalt content	Original weight (gram)	Final weight (gram)	Weight loss (%)	Average (%)	Spesification
1	Thin SMA with buton asphalt	6,90%	1137,3	1109,4	2,45	2,39	
			1134,2	1107,6	2,35		
			1136,2	1109,2	2,38		
2	Thin SMA with rubberized asphalt	6,80%	1128,8	1104,7	2,14	2,14	<20%
			1126,4	1101,9	2,18		
			1125,6	1101,9	2,11		
3	Thin SMA with refinery asphalt	6,81%	1127,5	1097,1	2,7	2,69	
			1130,2	1100,3	2,65		
			1129,4	1098,5	2,74		
1	Fine SMA with buton asphalt	7,25%	1132,7	1097,5	3,11	3,14	
			1134,1	1098,1	3,17		
			1129,3	1093,9	3,13		
2	Fine SMA with rubberized asphalt	6,95%	1125,9	1099,6	2,34	2,34	<20%
			1125,2	1099,2	2,31		
			1127,3	1100,7	2,36		
3	Fine SMA with fefineryd asphalt	7,15%	1133,9	1101,8	2,83	2,88	
			1135,2	1102,6	2,87		
			1131,6	1098,4	2,93		
1	Rough SMA with buton asphalt	6,70%	1138,8	1100,3	3,38	3,34	
			1136	1098,5	3,3		
			1135,4	1097,6	3,33		
2	Rough SMA with rubberized asphalt	6,55%	1127,7	1092,3	3,14	3,14	<20%
			1130,1	1094,9	3,11		
			1131,3	1095,5	3,16		
3	Rough SMA with fefineryd asphalt	6,70%	1137,1	1095,3	3,68	3,74	
			1135,8	1093,2	3,75		
			1136,4	1093,4	3,78		

In Bina Marga 2010 revision 3 specification, percentage requirement for weight loss from cantabro test result was within 20%. From table 12 above, can be concluded that all samples were fulfill the requirement that is under 20%. If we conclude from the average, SMA mixture with rubberized asphalt has the lowest weight loss percentage.

4. Conclusions

4.1. Based on marshall standard test

a. Optimum asphalt content for thin SMA mixture with refinery asphalt, rubberized asphalt, and buton asphalt in row were 6,805%, 6,8% and 6,9%.

b. Optimum asphalt content for fine SMA mixture with refinery asphalt, rubberized asphalt, and buton asphalt in row were 7,15%, 6,95% and 7,25%. Optimum asphalt content for rough SMA mixture with refinery asphalt, rubberized asphalt, and buton asphalt in row were 6,7%, 6,55%, and 6,7%. For rough SMA mixture, the highest stability and lowest asphalt percentage used were from the rubberized asphalt.

4.2. Based on marshall immersion test

From the retained strength index value, each sample have fulfill the requirement of Bina Marga 2018 with minimum percentage 90%. Retained strength index for thin SMA was 96,338%, for fine SMA 95,721% and for rough SMA about 94,080%.

4.3. Based on cantabro test

Based on cantabro test, each sample have fulfiil the requirement of Bina Marga 2018 with maximum percentage is 20%.

a. The abrasion's average value of thin SMA with buton asphalt was 2,392%, thin SMA with rubberized asphalt was 2,686% and thin SMA with refinery asphalt was 2,147%.

b. The abrasion's average value of fine SMA with buton asphalt was 3,145%, fine SMA with rubberized asphalt was 2,344%, and fine SMA with refinery asphalt was 2,881%.

c. The abrasion's average value of rough SMA with buton asphalt was 3,339%, rough SMA with rubberized asphalt was 3,142%, and rough SMA with refinery asphalt was 3,737%.

d. Overall, sample that using the rubberized asphalt has the best cantabro value.

References

[1] Abuseta A A S 2014 *The Design and Properties of Split Mastic Asphalt Modified with Crumb Rubber* (Surakarta: Universitas Sebelas Maret) p 5
[2] Affandi F 2010 *Pengaruh Asbuton Semi Ekstraksi pada Campuran Stone Mastic Asphalt* (Bandung: Puslitbang Jalan dan Jembatan)
[3] Mangiwa B A K, Ramli I M, and Basir A 2016 *Analysis Retained Stability Index of Asphalt Porous Based Buton Granular Asphalt (BSA)* (Makassar: Universitas Hasanudin)
[4] Raharjo N E 2008 *Pengaruh Penggunaan Aspal Buton sebagai Filler Campuran Split Mastic Asphalt terhadap Karakteristik Marshall* (Yogyakarta: Universitas Negeri Yogyakarta) p 44
[5] PT. Hasrat Tata Jaya. 2017. "Technical instructions for asphalt buton JBMA-50 in hot mix." Pekanbaru.
[6] Tahir A 2011 *Kinerja Campuran Split Mastic Asphalt (SMA) yang Menggunakan Serat Selulosa Alami Dedak Padi* (Palu: Universitas Tadulako)
[7] Winayati, Hendri R dan Alfian S 2018 *Analisis Penggunaan Abu Tandan Kelapa Sawit Sebagai Filler ditinjau dari Nilai Keausan Perkerasan (Cantabro Test)* (Riau: Universitas Islam Riau) p 9