DEVELOPMENT OF LABORATORY PERFORMANCE OF INDONESIAN ROCK ASPHALT (ASBUTON) IN HOT ROLLED ASPHALT MIX

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ABSTRACT

Rock asphalt exists in large quantities in Buton Island, Indonesia, and until late 1990s was used extensively in its natural state as a surfacing layer for existing road pavements. On the other hand, extensive maintenance of the Indonesian road network involves the use of very large quantities of bitumen-bound materials. Given the relatively high cost of refinery bitumen and the existence within the country of large resources of rock asphalt, the outcome of the research of natural rock asphalt becomes significant for those involved in implementing the highway maintenance programs.

This paper describes some laboratory performances of Hot Rolled Asphalt (HRA) mixes type C and F, using an ASBUTON (Indonesian Rock Asphalt) as filler. The laboratory works, conducted at Highway Engineering Laboratory, Civil Engineering Department, Institute of Technology Bandung (ITB), are: Marshall Standard Test, Marshall Immersion Test, Wheel Tracking Test and Dynamic Resilient Modulus Test. The factors affecting Asbuton performances are discussed as procedures under consideration for improving the usage of these materials.

In this research, Asbuton was used as a fine aggregate and filler in a Hot Rolled Asphalt (HRA) mixes type C and type F, according to the British Standard Specification : BS 594 part 1-1985. The results of Standard Marshall Test showed that the use of Asbuton filler will decrease the Optimum Bitumen Content and Marshall Stability, comparing to the use of “fly-ash” filler in HRA mixes. The results of Marshall Immersion test showed also the better performance of Asbuton filler (97.5% IRS), compared to “fly-ash” filler (82.5% IRS). The Wheel Tracking test gave also the same results as another test i.e. better performance of Asbuton filler (0.45 mm D_o), compared to “fly-ash” filler (1.38 mm D_o).

Finally, the Resilient Modulus of HRA mix using Asbuton filler has higher value (3108 MPa) than HRA mix using “fly-ash” filler (2399 MPa), at the temperature of 25^o C).

In General, almost all results showed that the use of Asbuton filler in HRA mix gives the better performance of mix, compared to the “standard” filler, such as “fly-ash” filler.

Key Words: Hot Rolled Asphalt, Asbuton filler, Marshall Test, Stifness, British Standard

1. INTRODUCTION

Rock asphalt deposits exist in large quantities in Buton Island, South-East Sulawesi, Indonesia, and it is named locally as Aspal Buton or ASBUTON. Since the deposits are widely variable in both composition and properties, then the production of a consistently uniform material , whose its performance can be predicted with reasonable confidence is really difficult (McElvaney, J., 1986).

When installed under carefully controlled conditions, pavement materials incorporating Asbuton, have performed well, but in general, its performance on a wider scale, has been disappointing. In particular, when used as a road surfacing material or overlay, the life of that material was not equal to that achieved by using conventional refinery bitumen, regardless the type of mix considered.

Until late 1990s Asbuton was used extensively in its natural state as a surfacing layer for existing road pavements in the highway maintenance and betterment programme in Indonesia. Use of these materials was then suspended by the Directorate General of Highways, due to "under estimated" performance of the mix, as mentioned above.

On the other hand, extensive maintenance and betterment of the Indonesian road network, involves the use of very large quantities of bitumen-bound materials. Given the relatively high cost of refinery bitumen, much of which is imported from another country, and the existence within the country of large resources of rock asphalt, the outcome of the research of natural rock asphalt becomes significantly important for those involved in the highway maintenance programs.

This paper describes some laboratory performances of Hot Rolled Asphalt (HRA) mixes type C and type F, according to the BS 594 part 1-1992 (British Standard, 1992), using Asbuton (Indonesian Rock Asphalt) as a fine aggregates and filler.

The laboratory works, conducted at Highway Engineering Laboratory, Civil Engineering Department, Institute of Technology Bandung (ITB), are: Marshall Standard Test, Marshall Immersion Test, Wheel Tracking Test and Dynamic Resilient Modulus Test. The factors affecting Asbuton performances were then discussed as a procedure under consideration for improving the usage of these materials.

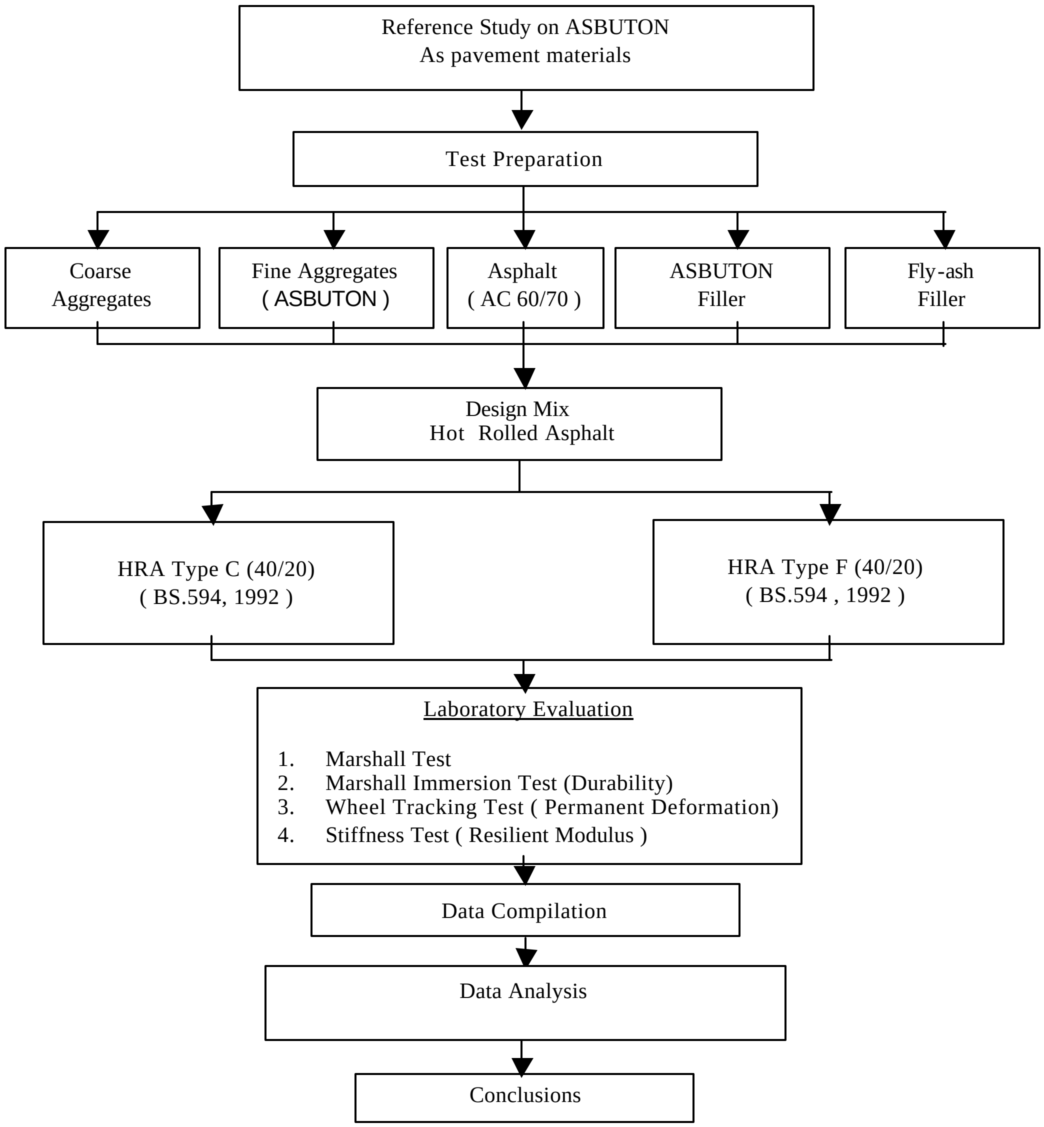


Figure1

Flow Chart of Research Activities

2. HOT ROLLED ASPHALT MIXTURES

The activities performed to fulfill the objectives of this research are shown in Figure1 (Subagio, B.S., et al., 2002). Almost the entire test methods used in this research was those specified by the British Standard method and the Indonesian method. Other standard methods, i.e.: ASTM and AASHTO were used when appropriate.

2.1 Bitumen Properties

Petroleum asphalt called "AC-20" (approximately equivalent to 60/70 pen), produced by PERTAMINA, was used in the HRA-Asbuton mixture. The laboratory tests performed to evaluate the bitumen properties were: Penetration, Softening Point, Ductility, Flash Point, Solubility, Specific Gravity and Viscosity. The results of these tests were presented in Table 1.

2.2 Aggregate Properties

The coarse and fine aggregates used were crushed rock imported from West Java, Indonesia and the filler used were Asbuton and "fly ash", as a comparison. The laboratory tests performed to evaluate the properties of coarse aggregates were: Aggregate Impact Value, Aggregate Crushing Value, Water Absorption, Specific Gravity, Flakiness, Elongation and Angularity. The tests for fine aggregates were: Specific Gravity and Water Absorption, while for filler was Specific Gravity only. The results of these laboratory tests are given in Table 2.

2.3 Mix design of Hot Rolled Asphalt

The objective of mix design is to procure an economical material, making full used of local resources that meet engineering requirements for optimal service and economic performance. The principle design of bituminous mixtures is to choose the aggregate type, aggregate grading, bitumen grade, bitumen modifier (if necessary), and to determine the bitumen content that will optimize its engineering properties in relation with the in-service behavior during pavement life (Asphalt Institute, 1993).

In this research, mix design were prepared for 4 (four) types of mixture i.e. HRA type C mixture with Asbuton as fine aggregates and fly ash as filler, HRA type C mixture with Asbuton as both fine aggregates and filler, HRA type F mixture with Asbuton as fine aggregate and fly ash as filler, and HRA type F mixture with Asbuton as both fine aggregate and filler.

According to the British Standard method (British Standard, 1992), the mixing temperature was 110^{o}C ± 3^{o}C above Softening Point and the tamping temperature was 92^{o}C ± 2^{o}C above Softening Point also. Referring to the result of Softening Point test i.e. 53^{o}C, then the mixing temperature was 159^{o}C~165^{o}C and the tamping temperature was 142^{o}C~146^{o}C.

3. LABORATORY TESTS PREPARATIONS

In order to determine the Optimum Binder Content (OBC) of HRA-Asbuton mixture, the Standard Marshall test was used, in conformed with the British Standard method (British Standard, 1992). This method required 3(three) experimental parameters to be considered i.e. Marshall Stability, Density of the mix and Density of compacted aggregates.

The specimens for Standard Marshall Test were prepared at asphalt content ranging from 4.0% to 7.0% by weight, at 1.0% increment. The weight of each specimen was 1030 grams in average, tamped by 2x75 blows, as suggested by Indonesian Specification for Heavy Traffic (Bina Marga,1997) and three specimens were tested for each asphalt-content. The total specimens prepared for this test were 4x4x3 = 48 samples.

The Marshall Immersion test was conducted for specimens prepared at optimum bitumen content. The objective of this test was to measure its durability or the water resistance of the mixture after immersion for 24 hours at 60^{o}C. The specimens prepared for this test were 4x3x1 = 12 samples.

The Resilient Modulus of specimens, at its optimum bitumen content, was measured by using UMATTA equipment (Wahyudi, M.P., 1996), in 2(two) temperature levels i.e. 25^{o}C and 60^{o}C for HRA-C specimens, and 25^{o}C and 45^{o}C for HRA-F specimens. The total specimens prepared for this test were 2x2x1 = 4 samples.

The purpose of Wheel Tracking test was to measure the resistance of HRA mixture on plastic deformation (SHELL, 1990). This test was conducted for specimens at its optimum bitumen content, in 2(two) temperature levels i.e. 25°C and 60°C, and 2(two) types of filler i.e. "fly ash" and Asbuton. Then the total specimens prepared were 2x2x1 = 4 samples.

4. TEST RESULTS AND DISCUSSIONS

4.1 Bitumen

The laboratory tests data for bitumen properties, used in HRA-Asbuton mixture, were shown in Table 1. The results on Penetration tests at 25°C showed that the Pen value i.e. 66.8 was in the range specified i.e. 60 to 79, for Pen 60/70. Another tests on Softening Point, Flash Point, Ductility, Solubility and Loss on Heating, gave the results which fall between the ranges; maximum, or minimum value specified by the Indonesian specification (Bina Marga, 1997). It means that this type of bitumen could be used in the HRA mix. The kinematic viscosity tests were also conducted not to determine mixing and compaction temperatures as mentioned above, but to complete the test-series for bitumen properties in the laboratory.

Table 1
Test results on Bitumen Properties

No	Laboratory Test	Unit	Result	Indonesian Specification	
				Minimum	Maximum
1	Penetration	0.1 mm	52.75	60.00	79.00
2	Softening Point	°C	51.75	48.00	58.00
3	Burning Point	°C	350	200	-
4	Ductility	cm	>100	100	-
5	Solubility	%	99.82	99.00	-
6	Specific Gravity	-	1.04	1.00	-
7	Loss on Heating (TFOT)	%	0.0036	-	0.80
8	Penetration after TFOT	0.1 mm	66.60	80.00	-
9	Viscosity (Saybolt Furol)				
	140°C	cSt	319.37	-	-
	160°C	cSt	201.39	-	-
	180°C	cSt	57.79	-	-

4.2 Aggregates

All of the laboratory tests results of aggregates used in this research, as shown in Table 2, meet the Indonesian specification (SNI M-09-1989-F) and British Standard specification (BS 812: Part 3 : 1975).

The aggregate gradation curve for HRA-Asbuton Mixture, i.e. HRA type C (40/20) and HRA type F (40/20), used in this research, was conformed to British Standard Specification (British Standard, 1992), as shown in Table 3 and Figure 2. The combined grading points were chosen at the mid-point between those two boundary lines, as shown also in Figure 2.

TABLE - 2
Test on Aggregate Properties

No	Laboratory Test	Unit	Results	Specification	
				Min	Max
Coarse Aggregates					
1	Bulk Specific Gravity	-	2.559	2.5	-
2	SSD Specific Gravity	-	2.639	-	-
3	Apparent Specific Gravity	-	2.781	-	-
4	Effective Specific Gravity	-	2.670	-	-
5	Water Absorption	%	3.11	-	3
6	Aggregate Impact Value	%	17.61	-	30
7	Aggregate Crushing Value	%	19.7	-	25
8	Flakiness Index	%	26.5	-	-
9	Elongation Index	%	25.6	-	40
Fine Aggregates (Asbuton)					
1	Specific Gravity (HRA-C)	-	2.536	-	-
2	Specific Gravity (HRA-F)	-	2.316	-	-
Filler					
1	Specific Gravity (fly-ash)	-	2.531	2.5	-
2	Specific Gravity (Asbuton)		2.092	-	-

4.3 Marshall Test

The results of Standard Marshall Test are: Stability, Flow, Marshall Quotient (MQ), Density, Voids in Mix (VIM), Voids in Mineral Aggregate (VMA) and Voids Filler with Binder (VFB), as presented in Table 4, for HRA type C and type F mixture. As mentioned previously, 2(two) types of mix were prepared for each type of HRA mix i.e. "fly-ash" filler and Asbuton filler.

TABLE - 3
Aggregate Grading for Hot Rolled Asphalt type C and type F

% coarse aggr./ nominal size	40/20	
Pavement thickness	50 mm	
	HRA type C	HRA type F
Sieve Diameter (mm)	Mid-point (%)	Mid-point (%)
28	100	100
20	97.5	97.5
14	67.5	67.5
10	67.5	67.5
6.3	67.5	67.5
2.36	56	56
0.6	30	48.5
0.212	17.5	25
0.075	8	8

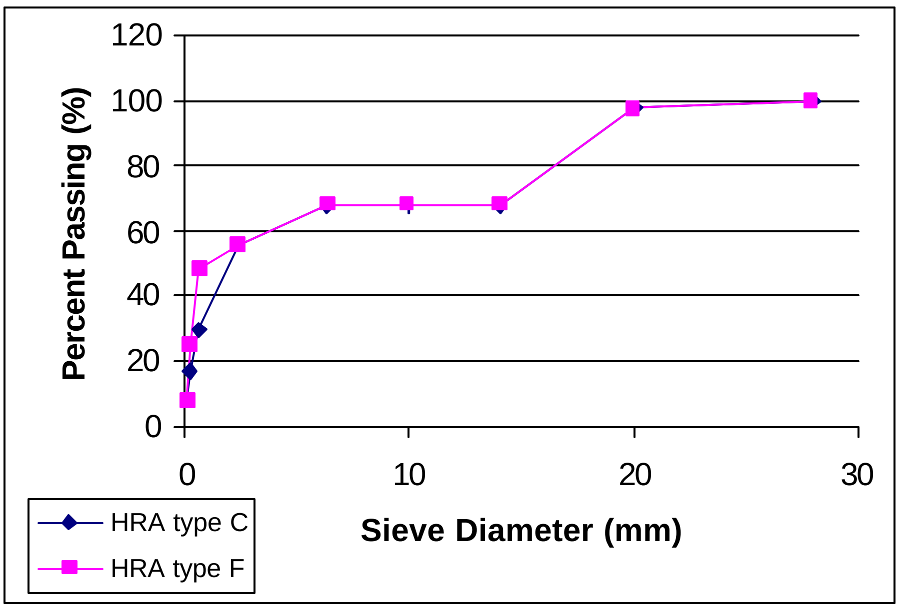


Figure - 2
The aggregate gradation curve for HRA-Asbuton Mixture

It is shown that: all Marshall Parameters of HRA mix type C and F using Asbuton filler were slightly “”under-value” compared to the same mixes using “fly-ash” filler. It is seen also that: the results of Marshall Stability at Optimum Bitumen Content for all mixes were higher than its minimum value for highest Density of Traffic, specified by the Indonesian Standards (Bina Marga, 1997). The same conditions obtained similarly for Marshall Flow value i.e. lower than the maximum value specified by the Indonesian Standards (Bina Marga, 1997).

TABLE - 4
Marshall Test of HRA type C and type F

No.	Asphalt Content (%)	VIM (%)	VMA (%)	VFB (%)	Stability (kg)	Flow (mm)	MQ (kg/mm)
Filler Fly - Ash							
1	5.0	19.33	25.42	23.95	1417.7	4.41	321.44
2	6.0	18.49	26.32	29.78	1717.0	3.52	564.06
3	7.0	16.87	26.49	36.32	880.6	5.24	170.11
Filler Asbuton							
1	5.0	19.23	25.32	24.08	1267.5	4.96	255.64
2	6.0	18.33	26.17	29.98	1781.0	5.21	344.80
3	7.0	17.25	26.83	35.69	1420.8	5.53	257.14

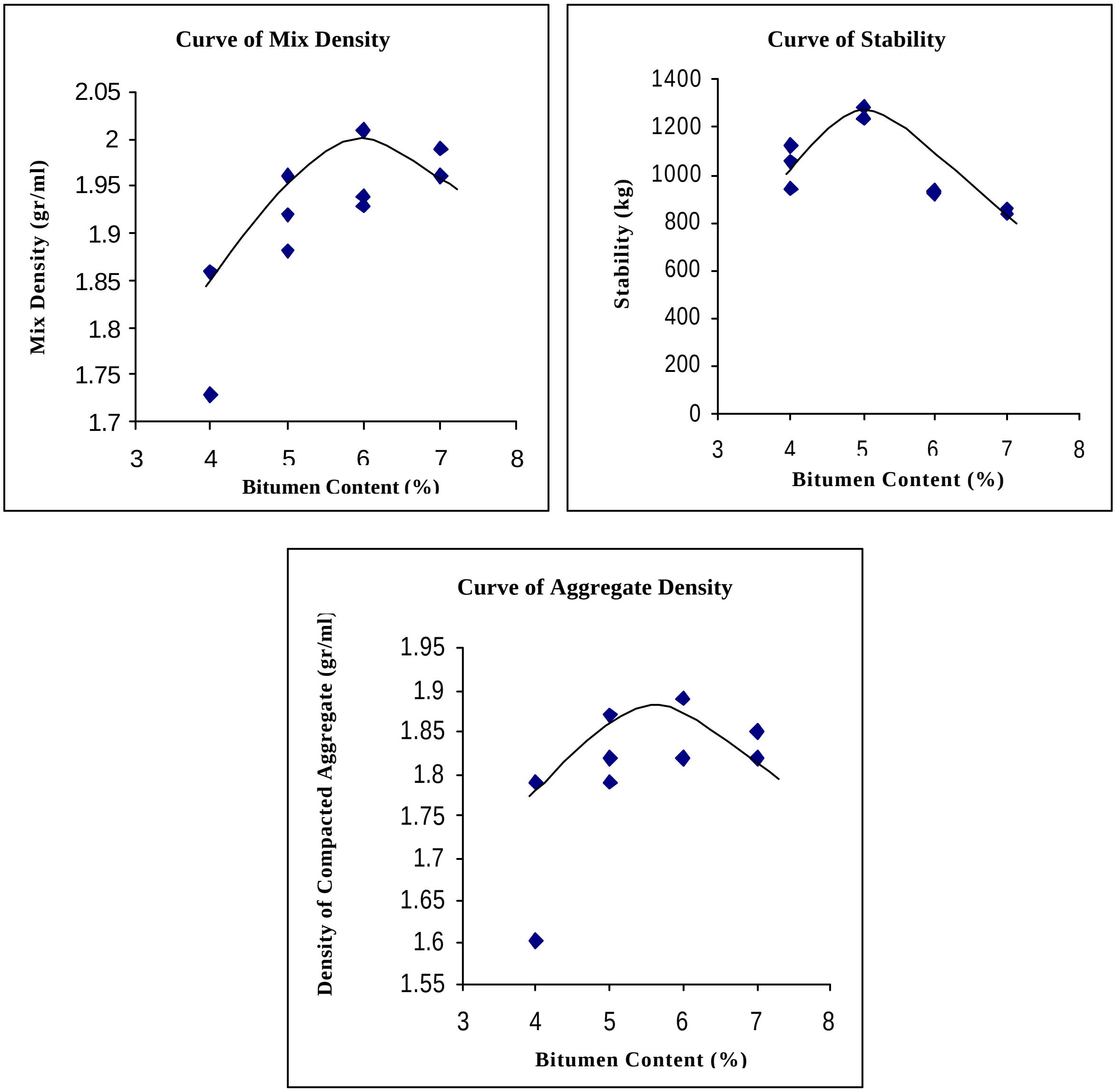
4.4 Optimum Bitumen Content

Referring to the British Standard Specification (British Standard, 1992), the optimum bitumen of HRA-Asbuton mix shall be determined using 3(three) parameters i.e. Marshall Stability, Density of mix and Density of compacted aggregate. The value of “optimum” bitumen content related to each parameter above should be taken, and the average value was then calculated. An example of this method was presented in Figure 3, i.e. for HRA-Asbuton mix type F using Asbuton filler.

It is shown that: the Optimum Bitumen Content of HRA mix type C and F using Asbuton filler was relatively lower than the same mixes using “fly-ash” filler. We can conclude then the Asbuton filler functioned effectively in the HRA mix type C and F.

4.5 Marshall Immersion Test

As mentioned previously, the objective of this test was to measure the water resistance of the mixture after immersion for 24 hours in the water at 60^{o}C. The results of calculated



Note :
OBC determined by Mix Density is 5.8%, OBC determined by Density of Compacted Aggregates is 5.5%, and OBC determined by Marshall Stability is 5.0%, then OBC in average is 5.43%.

Figure – 3
The Value of Optimum Bitumen Content
For HRA Type F using Asbuton Filler

IRS (Index of Retained Stability) were presented in Figure 4 and all values were higher than IRS minimum specified by the Indonesian Specifications (Bina Marga, 1997), i.e. 75%. It is shown that the **ratio** of Index of Retained Stability (IRS) for each type of HRA

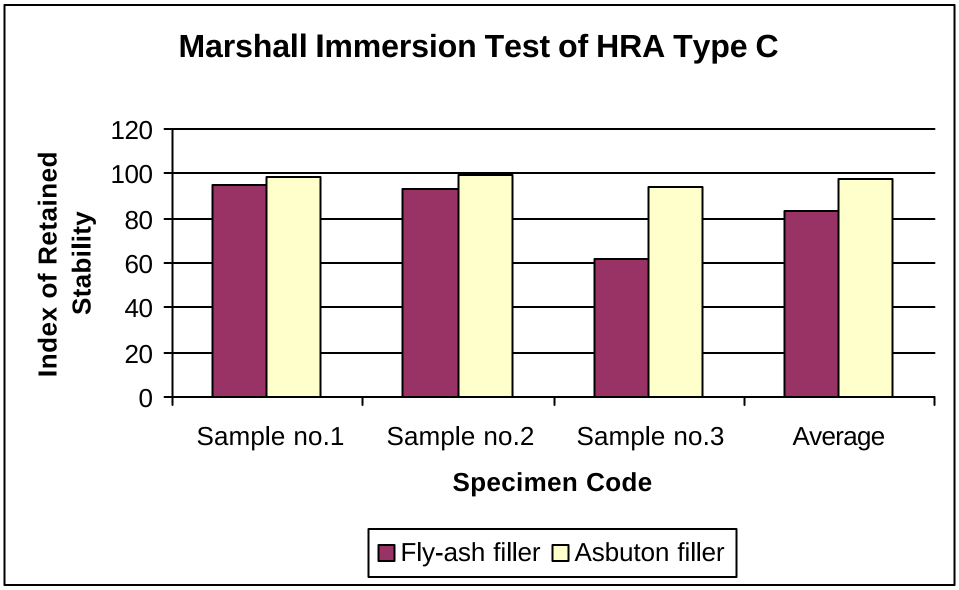


Figure – 4 a
Index of Retained Stability for HRA Type C

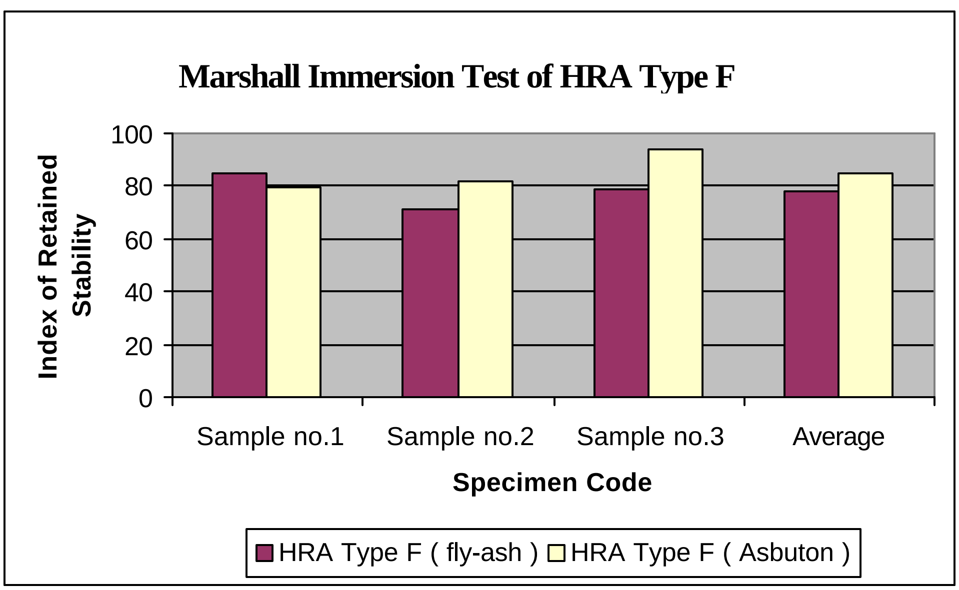


Figure – 4 b
Index of Retained Stability for HRA Type F

mix using Asbuton filler as reference, was relatively different i.e. 84.6% for HRA type C and 91.9% for HRA type F. Hence, it is concluded that the susceptibility of water damage of HRA mix using Asbuton filler is relatively higher than HRA mix using "standard" filler e.g. "fly-ash".

4.6 Resilient Modulus Test

The results of Resilient Modulus measurement using UMATTA were presented in Table 5a and 5b. It is shown that: the Resilient Modulus of HRA mix type C and F using Asbuton filler was relatively higher than the same mixes using "fly-ash" filler, for both temperatures i.e. 25^{o}C and 45^{o}C or 60^{o}C. It can be concluded that Asbuton filler will increase the "inter-granular" or "mortar" strength of HRA mix and increase also its Resilient Modulus.

TABLE - 5.a
Resilient Modulus Test of HRA Type C

No.	Temperature ^{o} C	Resilient Modulus (MPa)	
		Fly-ash filler	Asbuton filler
1	25	2399.0	3108.0
2	60	210.0	890.8

TABLE - 5.b
Resilient Modulus Test of HRA Type F

No.	Temperature ^{o} C	Resilient Modulus (MPa)	
		Fly-ash filler	Asbuton filler
1	25	7138.0	7876.0
2	45	1777.0	2721.0

4.7 Wheel Tracking Test

The resistance of plastic deformation in this test was represented by 3(three) parameters i.e. Dynamic Stability (DS), Total Deformation (D_o) and Rate of Deformation (RD). The results of this test for all mix specimens at 2(two) temperature levels, i.e. 25^{o}C and 45^{o}C for HRA type C, and 25^{o}C and 60^{o}C for HRA type F, were presented in Figure 6. It is shown that: the value of Dynamic Stability (DS) for two types of filler in HRA mix type C was relatively similar at 25^{o}C, but it was significantly different at 60^{o}C. This condition was not similar for HRA mix type F i.e. it's Dynamic Stability was significantly higher for HRA mix using Asbuton filler than the same mix using "fly-ash" filler. Hence, it can be concluded that the Asbuton filler gave better resistance of plastic deformation in HRA mix type F than in HRA mix type C.

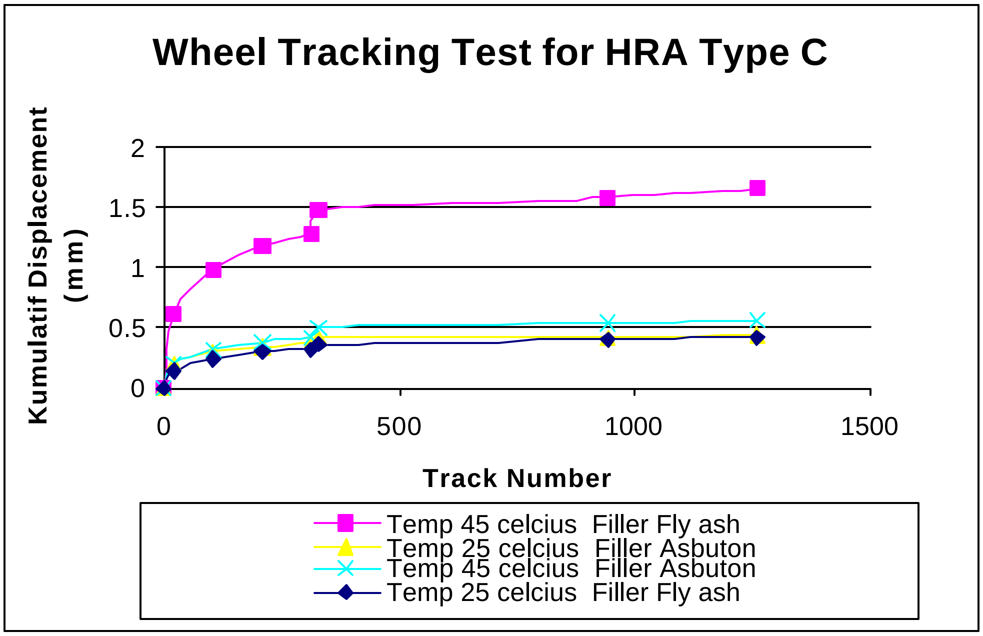


Figure – 6
Wheel Tracking Test of HRA Type C

5. CONCLUSIONS

Referring to the results of laboratory test and data analysis, some conclusions could be drawn:

a. In general, the use of Asbuton filler in Hot Rolled Asphalt (HRA) mix type C and type F could improve some laboratory performances of asphalt mix i.e. Optimum Bitumen Content of mix, Index of Retained Stability, Resilient Modulus and Resistance of Plastic Deformation.

b. All test conducted e.g. Marshall Test, Marshall Immersion test, etc., gave the results that could meet the criteria specified by the British Standard method and the Indonesian specification for Hot Rolled asphalt mix in Heaviest Traffic.

c. Considering all laboratory test results, the use of Asbuton filler could be recommended to replace the "standard" filler, such as : fly-ash or cement, in Hot Rolled Asphalt mix, for both type C and type F,
d. An Indonesian specification for Hot Rolled Asphalt using Asbuton as filler or fine aggregates should be proposed in the near future, in order to implement those types of mix in the pavement construction and maintenance in Indonesia.
e. Some development of research using Asbuton as filler or fine aggregates in Hot Rolled asphalt mix shall be prepared. This following research should be conducted i.e. Flexure Fatigue test, Indirect Tensile test, Creep test, etc.

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