The performance of asphalt-concrete wearing-course (AC-WC) mixture by using rice husk ash as filler with the addition of asbuton in asphalt pen 60/70 as binder

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Abstract. The supply of stone dust as filler and asphalt as binder is limited, therefore it is necessary to use an alternative to filler and asphalt import. The problem is expected to be overcome by the presence of rice husk ash as a filler and natural asphalt of Buton Island (Asbuton) as a binder. This study aims to evaluate the performance of Asphalt Concrete-Wearing Course (AC-WC) mixture by using rice husk ash as a filler and asphalt penetration 60/70 as binder with the addition of Asbuton. The specimens were made into two major groups: (i) the specimens using stone dust and asphalt pen 60/70 (ABA), and (ii) the specimens using rice husk ash and asphalt pen 60/70 with the addition of asbuton (ASA). The last group was performed with four variations: 0% (ASA 0), 5% (ASA 5), 10% (ASA 10), and 15% (ASA 15) over the total weight of the mixture. Total specimens were 75, each has 15 specimens. Asphalt contents used were 4.5% to 6.5%. Specifications used the standards of the Departemen Permukiman dan Prasarana Wilayah (2005) by using Marshall method Optimum asphalt contents (OAC) for each mixture were 5.6% (ABA), 6.0% (ASA 0), 6.3% (ASA 5), 5.9% (ASA 10), and 5.8% (ASA 15). In sum, the asphalt concrete mixture using rice husk ash as filler was able to compete with the one using stone dust as filler, and therefore can be used as alternative materials to road pavement construction.

Key words: rice husk ash, asbuton, asphalt-concrete wearing course (AC-WC)

Introduction

The current emerging issue on road construction in Indonesia is the lack of filler supply. Stone dust and Portland cement are commonly used as filler in road pavement construction. However, due to limited supply, those materials become relatively expensive. Therefore, it is necessary to searching for new alternatives as filler. An alternative is to use rice husk ash. Rice husk is produced by the waste of paddy and normally used as poultry's foods. As agrarian countries, Indonesia has a considerable amount of rice husk. Since a few years ago, the use of rice husk ash has been exploited as a soil stabilization material on road construction. The nature of cementation in rice husk ash is considered assist able to binding aggregates. Asphalt concrete is a flexible pavement. This type of asphalt mixture is a mixture consisting of asphalt and dense graded aggregate, spread and compacted in a hot temperature.

Another emerging issue in road pavement construction is the use of imported asphalt materials, due to the inability of domestic suppliers to provide national asphalt. Domestic production can only supply half of approximately 1.2 million tons/year of petroleum asphalt to road projects (Kurniadji and Nono, 2008). Reducing the use of import asphalt by utilizing the natural asphalt in Buton Island (Southeast Sulawesi), known as Asbuton, is expected to solve the problem. The supply of natural Asbuton is about 677 million tons.

Asbuton is expected to replace the role of conventional bitumen as a binder. Asbuton can be used as additive as well as substitution. Hermadi and Sjahdanulirwan (2008) reported the Marshall stability of asphalt mixture using asbuton Lawele was 1030 kg, higher than the one using asphalt pen 60/70 (930 kg). Hermadi (2007) reported that the properties of asphalt concrete are stronger than others, when asphalt pen 60/70 added by extracted granular asbuton.

The objective of this study is to evaluate the performance of Asphalt Concrete - Wearing Course (AC -WC) by using rice husk ash as a filler and asphalt pen 60/70 with the addition of asbuton Lawele as bitumen. For such purposes, there are two kinds of things to be done:

a. To evaluate the AC-WC mixture using stone dust as filler with asphalt pen 60/70
b. To evaluate the AC-WC mixture using rice husk ash as a filler and asphalt pen 60/70 with asbuton Lawele variation at the percentage of 0%, 5%, 10%, and 15% of the total weight of the mixture.

Literature Reviews
Flexible Pavement
Flexible pavement is the pavement system with multi-layers using asphalt as binder. It is also known as asphalt concrete. Asphalt concrete with dense graded aggregate is commonly used for heavy traffic load road (Sukirman, 2003). According to Fannisa and Wahyudi (2010:13) the characteristics of asphalt concrete are stability, durability, flexibility, fatigue resistance, surface roughness or shear resistance, waterproof and workability. In terms of its function, asphalt concrete consists of three types: Asphalt Concrete-Wearing Course (AC-WC), Asphalt Concrete-Binder Course (AC-BC) and Asphalt Concrete-Base with the maximum size of aggregate were 19 mm, 25.4 mm, 37.5 mm, respectively. The specification of AC-WC mixture can be seen in Table 1.

Table 1. Specification of the AC-WC mixture

Properties		Asphalt Concrete (AC)		
		WC	BC	Base
Collision		75		112
VIM (%)	Min	3.5		
	Max	5.5		
VMA (%)	Min	15	14	13
VFA (%)	Min	65	63	60
Stability (kg)	Min	800		1500
	Max	-		-
Flow (mm)	Min	3		5
MQ (kg/mm)	Min	250		300

Source: Departemen Permukiman dan Prasarana Wilayah (2005)

Materials of Asphalt Mixture
The quality of asphalt mixtures depends considerably on the quality of aggregate and asphalt, as the major materials. Aggregate material consists of coarse aggregate, fine aggregate, and filler.

a. Aggregate
Aggregate is a major component in road pavement structure. The amount of aggregate in a mixture is about 90-95% of the total weight of the mixture, or 75-85% of the total volume of the mixture. Anonymous (2005: 6-23) indicates the specification of coarse aggregate properties and test standards is shown in Table 2.2.

Table 2. Specification of Coarse Aggregate for Hot Mix Asphalt

Test	Standard	Spec.
Bulk specific gravity	SNI 03-1969-1990	Min. 2.5
Water absorption	SNI 03-1969-1990	Max. 3 %
Abrasion by Los Angeles machine	SNI 03-2417-1991	Max. 40%
Asphalt viscosity	SNI 03-2439-1991	Min. 95 %
Flakiness and elongated index	RSNI T-01-2005	Max. 10 %

Source: Departemen Permukiman dan Prasarana Wilayah (2005)

b. Filler

Filler is a non-plastic material with minimum of 75% of the weight passes through the sieve No. 200 (0.075 mm). In pavement concrete mixture, filler fills the space between coarse and fine aggregates to reduce the void volumen, increasing density, as well as decreasing permeability value of asphalt mixtures (Salim, 2010). General materials used as filler are stone dust, portland cement, limestone dust, and fly ash.

Rice Husk Ash

Rice husk ash is a product of burnt rice husk waste. Rice husk ash has specific properties containing chemical compounds (pozzolan) and silica (SiO2). A compound mixed with cement and water can be utilized to improve the compressive strength and tensile strength of concrete (Puspita, 2010). Burnt rice husk reaches 80-90% SiO2 content (Rianto, 2007).

Rice husk ash is considered to have good properties as compactor filler because it has property of cementation and relatively small grain size (passing sieve No. 200). Its advantages are: clearly visible from the rice husk ash as a filler material; abundant deposits of rice husk potentials for the procurement of filler materials; relatively inexpensive compared to other materials; and easy to find.

c. Asphalt

Asphalt is a thermoplastic material, soft/liquid when heated and becomes solid/semi-solid in a cool temperature (Siswosoebrotho, 1999: 3). Asphalt can be divided into natural asphalt and petroleum asphalt. Natural asphalt is asphalt obtained in the earth and can be used with a simple processing, such as asphalt of Buton Island (Asbuton) and Trinidad lake asphalt. Petroleum asphalt is asphalt of refining petroleum residue.

A common type of petroleum asphalt in Indonesia is asphalt penetration 60/70 and asphalt penetration 80/100. The specification of asphalt pen 60/70 can be seen in Table 3.

Table 3. Specification of Asphalt Pen 60/70

Test	Method	Spec.
Penetration, 25° C, 100 gr, 5 seconds;0.1 mill	SNI 06-2456-1991	60-79
Softening point; ° C,	SNI 06-2434-1991	48-58
Ductility, 25 ° C; cm	SNI 06-2432-1991	Min.100
Specific gravity	SNI 06-2441-1991	Min.1.0

Source: Departemen Permukiman dan Prasarana Wilayah (2005)

Asbuton

Asbuton or Buton asphalt, available in the form of rock (rock asphalt) found in Southeast Sulawesi, is estimated to have deposit about 677 million tons, with bitumen content of 10-40% (Suaryana, 2008). Kurniadji and Nono (2008) indicates that the largest amount deposited in the Lawele is 30% or 210 million tons equivalent to 70 million tons of petroleum asphalt. Suaryana (2008) indicates, asbuton bitumen has higher nitrogen components and lower paraffin components compared to petroleum asphalt bitumen, thus, asbuton bitumen adhesion is relatively better. In addition to the advantages, asbuton also has the weaknesses, in particular in terms of homogenity. Asbuton has a lower level bitumen, because the bitumen consists of minerals and aggregates. In order to increase the asbuton bitumen level, it is necessary to treat it in fabrication and classify the types of asbuton, e.g: granular asbuton, asphalt modified with asbuton or bitumen extraction of asbuton (Kurniadji and Nono, 2008: 4).

Asphalt Concrete Mix Design

Bukhari, et al. (2007) indicates one factor determining the quality of asphalt concrete mixture is by mix design. Mix design consists of the selection of the type of aggregate gradation and the type of bitumen content. Asphalt mix design aims to obtain an effective mix of aggregate gradation and asphalt. A proper mixture of aggregate and optimum asphalt will produce the optimal pavement construction.

a. Aggregate gradation

Aggregate gradation is the distribution of aggregate particles by size filling in one another forming an interlocking bond, that affect the stability of the pavement (Bukhari, et al., 2007, Sukirman, 1999).

Aggregate gradation can be grouped into well graded aggregates and poorly graded aggregates. Well graded aggregate means size of the aggregate distributed evenly or in other words contain a balanced portion between coarse and fine aggregate. Well or continuous or dense graded will produce a layer of pavement with high stability, waterproof and heavy volume. Poorly graded aggregate is the composition of aggregate grain size does not fit evenly. Poorly graded aggregates known by several names of aggregate gradation, they are uniform, gap, and open graded aggregate.

Gradation type used in this research for asphalt concrete (AC-WC) is well graded. Gradations used guided by the new specification of asphalt pavement in 2005 by Badan Penelitian dan Pengembangan Departemen Permukiman dan Prasarana Wilayah. Salim (2010) mentions in the AC-WC mixture, besides the limit of gradation control there are some requirements we should consider, they are the Fuller curve and restrict zone.

Fuller gradation curve is a curve where the condition of the mixture has a maximum density and the void between the mineral aggregate (VMA) is the minimum. Bina Marga recommends avoiding the combination of aggregate in restrict zone. Anonymous (1999) states that generally composition of the mixture would be better if the gradation of aggregate on the right above the Fuller curve and then cut the curve then under the Fuller curve on the left.

b. Asphalt Content

In asphalt mixture design, asphalt content required for the initial value of planning before the optimum asphalt content obtained. The initial or estimate asphalt content is the ideal asphalt content (a%) that will be varied to be 5 variations of the initial asphalt content of planning, i.e. (a-1)%, (a-0, 5)%, a%, (a +0.5)%, and (a +1)%.

Anonymous (2005) indicates the formula to estimate the initial asphalt content, as follows:

$$Pb = 0.035\ (\%CA) + 0.045(\%FA) + 0.18\ (\%\mathit{Filler}) + \text{Constant}$$

where:

Pb = Estimation of asphalt content, percentage of mix's weight;
CA = Coarse aggregate, percentage of aggregate retained sieve no. 8;
FA = Fine aggregate, percentage of aggregate passing sieve No. 8 and retained no. 200;
Filler = Aggregate has minimum weight 75% passing sieve no. 200;
Constant value: 0.5 – 1.0 for AC and HRS.

c. Marshall Test

One methods for asphalt concrete mix design is Marshall test. According to Sukirman (2003) mix design method mostly used in Indonesia is based on empirical testing, using a Marshall test. Marshall test is to determine the characteristics of asphalt mixture. Characteristics of asphalt mixture are shown in Marshall parameters, i.e. stability, flow, density, Marshall quotient, voids in the mix (VIM), voids in mineral aggregate (VMA) and voids filled with asphalt (VFA).

d. Optimum Asphalt Content (OAC)

Optimum asphalt content (OAC) is the bitumen content that can produce the best properties of mix. OAC is obtained from the evaluation of Marshall parameters. Optimum means identical to the compromise, that is not possible to determine the asphalt content that gives the best results for each requirement. For example, if the high flexibility desired, then high asphalt content would the best. If high stiffness desired, then low asphalt content would the best. Asphalt content is compromised taken from each of the corridors that meet every requirement values (Bukhari, et al., 2007).

Methodology

This section describes the research methods, including the description of material preparation, the research procedure, and the design used. Materials consist of petroleum asphalt pen 60/70 produced by PT. Pertamina and natural rock asphalt of asbuton Lawele produced by PT. Buton Aspal Indonesia. Aggregate used was produced from the Stone crusher plant in Gampong Lampanah Indrapuri Subdistrict of Great Aceh District. Stone dust used as a filler was also the product of stone crusher plant. Rice husk ash used in this research also came from a plant nearby location. The research was conducted at the Laboratory of Transportation, Department of Civil Engineering, Faculty of Engineering, Syiah Kuala University Banda Aceh.

Aggregate gradation selection

Gradation curve used in this research was in accordance with the gradation curve control points for AC-WC mixture released by Badan Penelitian dan Pengembangan Departemen Permukiman dan Prasarana Wilayah (2005). Gradation curve should be in between the Fuller curve and avoids the restricted zone. The planned gradation can be seen in the Table 4.

Table 4. Planned Aggregate Gradation

Sieve Size		Planned Gradation	
Sieve	Size (mm)	% Passed Weight	% Retained Weight
$1^1/_2$"	37.5		
1"	25.0		
$^3/_4$"	19.0	100	
$^1/_2$"	12.5	90	10
3/8"	9.5	73	17
No. 4	4.75	53	20
No.8	2.36	38	15
No. 16	1.18	24	14
No. 30	0.600	18	6
No. 50	0.300	14	4
No. 200	0.075	7	7
Filler			7

Designing Specimens

Preparation of specimens was generally grouped into two types of mixtures: the mixture of AC-WC using stone dust as a filler with asphalt pen 60/70 and the mixture of AC-WC using rice husk ash as a filler with asphalt pen 60/70 with the addition of asbuton variation as binder. Each asphalt content was made by 3 specimens. Thus, in total there were 15 specimens for five variations of asphalt content. The types of mixture that were generally based on different types of filler and asphalt used can be seen in Table 5.

Table 5. Type of Mixtures

Type of Mixture	Type of Filler	Type of Binder
ABA	Stone Dust	Asphalt Pen 60/70
ASA	Rice Husk Ash	Asphalt Pen 60/70 with asbuton variations (0%, 5%, 10%, and 15%)

Specimen design of ABA mixture is a mixture using stone dust as a filler and asphalt pen 60/70 as a binder used five variations of asphalt contents; 4.5%, 5%, 5.5%, 6%, and 6, 5%. ASA mixture used rice husk ash as a filler and asphalt pen 60/70 as a binder with the addition of four asbuton variations; 0%, 5%, 10%, and 15%. Then, there were four new mixtures as a result of the addition, the mixtures were ASA 0, ASA 5, ASA 10 and ASA 15. In total, there were 75 speciments to estimate.

Results and Discussion
Rice Husk Ash
The examination performed on rice husk ash used is sieve analysis. Sieve analysis was conducted by using sieve no. 16, no. 30, no. 50, no. 100, and no. 200. The analysis was conducted to determine the percentage of each grain size distribution of rice husk ash. The result of sieve analysis of rice husk ash can be seen in Table 6.

Table 6. Sieve Analysis Result of Rice Husk Ash

Sieve Size		Retained Weight	Retained Percent
Sieve	Size (mm)	(g)	(%)
No. 16	1.18	-	-
No. 30	0.600	1.50	0.75
No. 50	0.300	8.50	4.25
N0.100	0.150	41.70	20.85
No. 200	0.075	77.60	38.80
Filler		70.70	35.35
Total		200.00	100.00

The result of sieve analysis showed that rice husk ash material pass sieve no. 200 by 35.35%. The condition does not meet the requirement of min. 75%. It means that rice husk ash cannot be used directly. Rice husk ash can be used after gradation adjustment. Rice husk ash used in this research was only the fraction that passed sieve no. 200 only, thus the percentage of rice husk ash that passed sieve no. 200 turned to be 100.

Marshall Test
Marshall parameters reviewed in this study were VMA, VIM, VFA, stability, flow, and Marshall quotient. Marshall test results of ABA, ASA 0, and ASA 5 in average can be seen in Table 7 Marshall test results of ASA 10 and ASA 15 at average can be seen in Table 8.

Table 7. Marshall Test Result of ABA, ASA 0, and ASA 5 in Average

Characteristic of Mixture	Value of Parameter		
	ABA	ASA 0	ASA 5
Stability (kg)	976.87	959.93	1062.70
Flow (mm)	4.1	3.7	3.1
MQ (kg/mm)	244.29	260.78	350.35
VMA (%)	16.68	16.52	18.60
VIM (%)	5.75	5.97	5.71
VFA (%)	65.38	63.72	69.24

Table 8. Marshall Test Result of ASA 10, and ASA 15 in Average

Characteristic of Mixture	Value of Parameter	
	ASA 10	ASA 15
Stability (kg)	1636.07	1399.48
Flow (mm)	3.7	4.3
MQ (kg/mm)	527.92	357.42
VMA (%)	20.52	22.40
VIM (%)	5.38	5.11
VFA (%)	73.76	77.20

Marshall test results of ABA, ASA 0, and ASA 5 at OAC can be seen in Table 10 and Marshall test results of the mixture of ASA 10 and ASA 15 at OAC can be seen in Table 11.

Table 10. Marshall Test Result of ABA, ASA 0, and ASA 5 at OAC

Characteristic of Mixture	Value of Parameter		
	ABA	ASA 0	ASA 5
OAC (%)	5.6	6.0	6.3
Stability (kg)	1006.42	1149.53	1170.66
Flow (mm)	4.0	4.0	3.1
MQ (kg/mm)	258.25	298.34	376.51
VMA (%)	16.39	16.55	18.88
VIM (%)	5.21	4.99	4.39
VFA (%)	68.14	70.05	76.62

Table 11. Marshall Test Result of ASA 10 and ASA 15 at OAC

Characteristic of Mixture	Value of Parameter	
	ASA 0	ASA 5
OAC (%)	5,9	5,8
Stability (kg)	1819,73	1206,40
Flow (mm)	3,9	4,1
MQ (kg/mm)	525,51	340,68
VMA (%)	20,34	22,14
VIM (%)	4,44	4,27
VFA (%)	78,12	80,53

Marshall test results showed that the mixture using stone dust as a filler was more powerful than the mixture of rice husk ash. The condition was indicated by higher average value of stability. Neverheless, the difference at stability value was insignificant. Asbuton addition to the mixture can lead to change Marshall's parameters, the two of the parameters were stability and VIM. Marshall test results showed that addition of asbuton into mixture resulted higher stability value and lower VIM value. The highest stability value was obtained on a mixture of ASA 10, while the mixture of ASA 15 began to decline in stability value due to a very high presence percentage of fine minerals and bitumen in the mix as a result of increasing percentage of asbuton as can be seen in Figure 1.

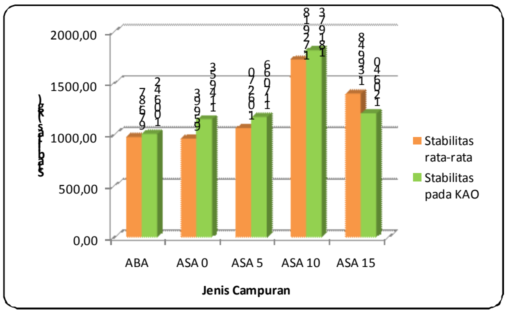

Figure 1. Stability value

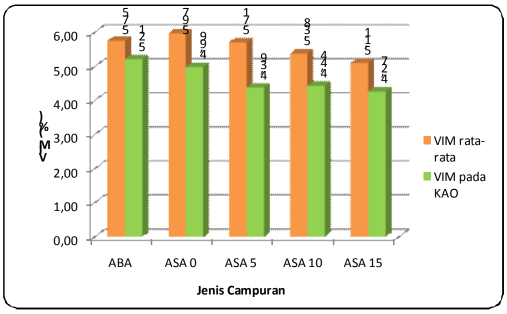

Figure 2. VIM value

In terms of VMA and VFA value, the higher the addition of asbuton increasing VMA and VFA value as can be seen in Figure 3 and Figure 4. It happened because of the increasing percentage of the presence of bitumen in the mix, increasing the volume of bitumen in the mixture. The volume of bitumen was composed by petroleum asphalt and bitumen of asbuton.

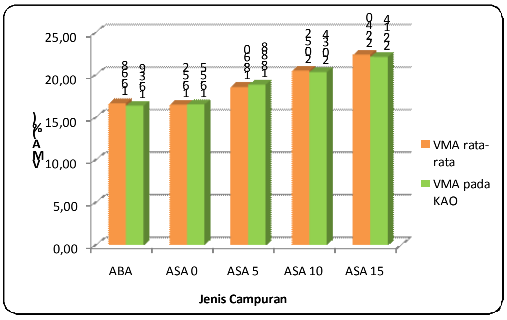

Figure 3. VMA value

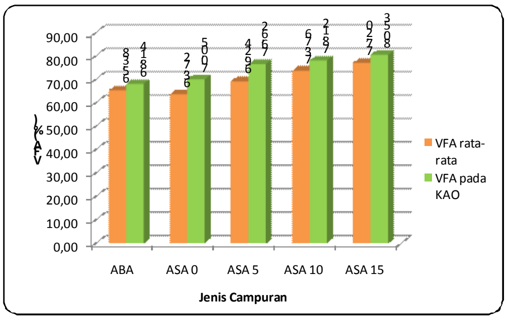

Figure 4. VFA value

Asbuton addition to the mix led to changes in flow and Marshall Quotient (MQ) value. At first flow decreased as a result of the increasing fraction of fine aggregates in the mix, but then continued to increase due to the increasing percentage of bitumen in the mix. While MQ value showed a rise up at ASA 10 due to high stability value of the mixture. Nevertheless, MQ value of ASA 15 declined due to decreased stability value of the mixture and increasing value of flow. The mixture had the highest MQ value at ASA 10, that mean the mixture was more rigid compared with the other mixture, as can be seen in Figure 5 dan Figure 6.

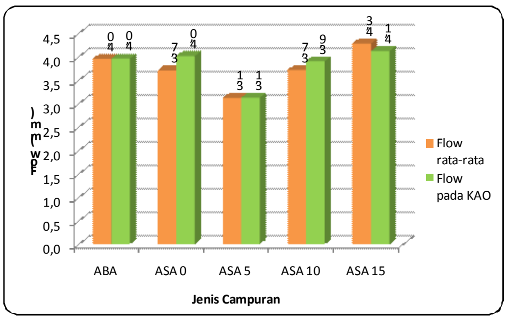

Figure 5. Flow value

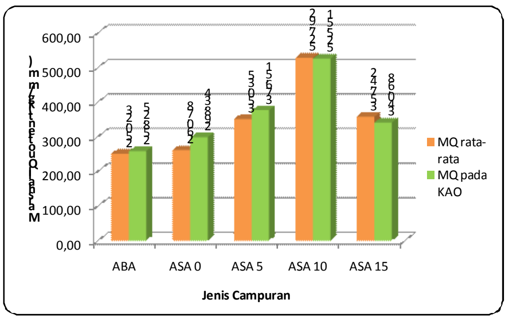

Figure 6. MQ value

Each mix has different optimum asphalt content (OAC). Mixture with the highest OAC value was ASA 5. It was caused the mixture contain high fine mineral fraction due to asbuton addition, therefore asphalt as a binder was needed. While OAC of ASA 10 and ASA 15 declined due to the influence of bitumen percentage in the mixture increased. Although the amount of fine fraction of ASA 10 and ASA 15 increased, nevertheless the increase was offset by an increase in the amount of bitumen asbuton, as can be seen in Figure 7.

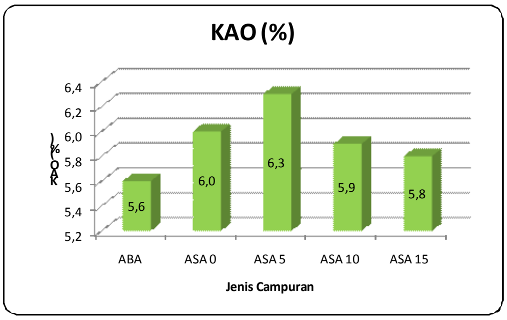

Figure 7. OAC value

Conclusions

a. Asbuton addition in the mix can increase the strength of stability value. The highest value was at ASA 10 with an average stability value of 1729.18 kg. Stability value at Optimum Asphalt Content was 1819.73 kg.
b. Capacity of stone dust (ABA) on the stability of the average was greater than rice husk ash (ASA 0) with the stability increased by 1.76%.
c. The mixtures used rice husk ash as a filler and with asbuton addition are able to compete with the mixture that use stone dust as a filler and without asbuton.

Recommendation

Research on rice husk ash as a filler and asbuton as a binder in asphalt concrete mixtures is promising and hence expected to expand to further research, such as:

a. In terms of binder, it is better to use bitumen asbuton after extraction. In that particular treatment, it will not increase the fine mineral of asbuton leading to changes in aggregate gradation.
b. In terms of research method, it is better to use substitution method in mixing asbuton into mixture. By doing so, it is probably has further clarify about the ability of asbuton in replacing the role of convensional asphalt. Such treatment can also avoid the occurrence of the changes in gradation or mineral percentage in the mixture.

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