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Durability Performance Analysis of Mixture Asphalt Concrete - Base Course (AC-Base) Using Coal Fly Ash as A Filler Substitute

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ABSTRACT

Highways are land transportation infrastructure whose needs in Indonesia continue to increase, along with the increasing number of vehicle. The top Laston or base coarse (AC-Base) is a pavement foundation consisting of a mixture of asphalt aggregates with a certain ratio mixed and compacted in a hotmix. This coarse is at under binder coarse (AC-BC), not directly related to the weather, but it needs to have stability to withstand the traffic load spread through the vehicle wheels. Base coarse (AC-Base) serves to provide support the surface coarse, reduce strain and stress, spread and continue the load of road construction to the layer below (subgrade). Filler as one of the materials forming the AC-Base layer usually obtained from stone ash whose availability is increasingly difficult to feel in the field implementation. Therefore, a substitute material or substitute material is needed for the filler. One possible substitute material is fly ash. This research will analyze the performance of AC-Base coarse that make use of filler substitution material using fly ash with variation FA-0%, FA-5%, FA-7.5%, FA-10%, FA-12.5% and FA-15%. The samples made by Marshall Method will give the Optimum Asphalt Content (OAC) value on each mix variation. While the performance of this AC-Base mixture in increasing density, durability, and stability in the pavement mixture using the Marshall Immersion method (MI). The analysis result shows that the OAC value at 0% fly ash variation is 6,82%, at 5% fly ash variation is 6,87%, at 7.5% fly ash variation is 6,85%, at 10% fly ash variation is 6,84%, at 12.5% fly ash variation is 6,82%, and at 15% fly ash variation is 6.79%. While the performance of AC-Base mixture indicated by the MI value meets the specifications, and the MI value obtained tends to increase along with the increase in the percentage of fly ash. The mixture with 15% fly ash shows the better durability performance (99,75%) compared to other variations 0%, 5%, 7,5%, 10% and 12,5% (96,44%, 97,51%, 97,71%, 98,36% and 99,54%).

1. Introduction

Highways are land transportation infrastructure whose needs in Indonesia continue to increase, along with the increasing number of vehicles. Highways construction is a construction that accepts traffic loads, therefore it is expected that a road pavement layer must have a strong pavement construction and be able to accept the load from traffic users.[1].

Base Coarse (AC-Base) are pavement foundation consisting of a mixture of asphalt aggregates with a certain ratio mixed and compacted in a hot conditions. This coarse is located below the binder coarse (AC-BC), not directly related to the weather, but need to have stability to withstand traffic loads that are spread through the wheels of the vehicle. Base Coarse (AC-Base) serves to provide support for the surface coarse, reduce strain and stress, spread and transmit the burden of road construction underneath. (subgrade). The filler used in asphalt mixtures usually comes from rock ash whose availability is increasingly difficult to feel in field implementation. Therefore, in ensuring the smooth implementation in the field, various alternative materials have been investigated which have properties and sizes that are almost the same or even the same as stone ash. The one possible material is fly ash. Fly ash is a waste material in coal mines, the availability of which is quite a lot and has not been utilized.

Coal fly ash is included in the category of industrial waste which has a very high potential for use in road construction. Coal fly ash can be used as a filler because its particle size is very fine and has properties similar to rock ash, which is usually used as a filler in asphalt mixtures.[2].

This research is expected to be able to provide solutions to problems in the community, namely coal fly ash that has accumulated and has not been utilized optimally. The results of this study can be applied especially to roads in the Sawahlunto and surrounding areas and at the same time can save the environment.

2. Literature Review

2.1. Asphalt Concrete Coarse

Asphalt concrete coarse is a layer in road construction consisting of a mixture of hard asphalt and aggregate, mixed and spread hot and compacted at a certain temperature [3]. Asphalt concrete (AC) or commonly known as laston (asphalt concrete coarse) is a surface layer consisting of laston as a wear layer, where laston is made of coarse aggregate consisting of sand and a mixture of hard asphalt, then asphalted and compacted in a certain temperature hot conditions.[4]

Asphalt concrete (Kerbs and Walker, 1971), is a mixture commonly called asphaltic concrete, dense graded, bituminous mix which is processed by adding hot bitumen at a temperature not exceeding 275ºF (149ºC), then compacting at a minimum temperature of 225ºF (107ºC). Another feature according to the Highways of the Ministry of Public Works (2010) is that it has few voids, therefore asphalt concrete has high stability and is relatively stiff.

Flexible pavement construction consists of layers placed on the compacted subgrade surface. The arrangement of these layers plays an important role in receiving the traffic load and spreading it to the structure underneath. The arrangement of flexible pavement layers can be seen in Figure 1 below.

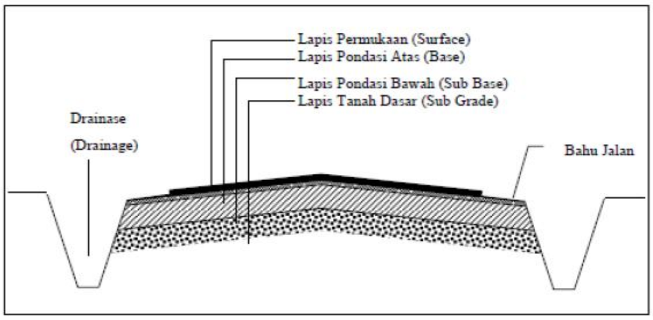

Figure 1. The Flexible Pavement Structural Components (silvia sukirman)

The surface course as the layer in contact with the wheels of the vehicle must be designed in such a way as not to be easily damaged and reach the design life so that large benefits can be achieved in accordance with the costs incurred. In accordance with its function Laston has three functions, namely:

- As a wearing course or AC-WC (Asphalt Concrete-Wearing Coure), with a minimum thickness of 4 cm,
- As a binder course or AC-BC (Asphalt Concrete-Binder Course), with a minimum thickness of 6 cm,
- As a foundation layer or AC-Base (Asphalt Concrete-Base), with a minimum thickness of 7.5 cm.

The properties of the hot asphalt mixture for coarse-graded AC according to the General Specifications (2018) are shown in Table 1.

Table 1. Requirements on the properties of Asphalt Concrete Mixture

Mixed Properties		LASTON Wearing Course	LASTON Binder Course	LASTON Base
The number of collisions per field		75		112(3)
The ratio of particles passing the 0.075 mm sieve to the effective asphalt content	Min.		0,6	
	Max		1,2	
Void in Mix (%) (4)	Min		3,0	
	Max.		5,0	
Void in Mineral Aggregate (VMA)	Min.	15	14	13
Void filled with Asphalt (%)	Min.	65	65	65
Marshall Stability (kg)	Min.	800		1800(3)
Flow	Min.	2		3
	Max.	4		6(3)
Residual of *Marshall* Stability (%) after immersion for 24 hours	Min.		90	
Void in Mix (%) at *Refusal density*	Min.		2	

Source: General Specifications 2018

2.2. Asphalt Concrete – Base Course (AC-Base)

AC-Base is a pavement foundation consisting of a mixture of aggregate and asphalt with a certain ratio mixed and compacted in a hot state. This layer is located under the binder course (AC-BC), is not directly related to the weather, but needs to have stabilization to withstand traffic loads that are spread through the vehicle wheels. AC-Base serves to provide surface layer support, reduce strain and stress, spread and transmit the road construction load to the layer below (subgrade).

2.3. Characteristics of Asphalt Mixture

Asphalt mixture design includes the selection and determination of material proportions to achieve the desired final properties of the asphalt mixture. The objective of the asphalt mix design is to obtain an effective mix of aggregate and asphalt gradations which will have the following properties and asphalt mix requirements [5]:

1) Stability
2) Flexibility
3) Durability
4) Impermeability
5) Workability
6) Skid Resistance

7) Compression
8) Temperature

2.4. Aggregate

Aggregate is a collection of crushed stone, gravel, sand or other minerals, both natural and artificial. Aggregate is the main component of the road pavement structure, which is 90%-95% aggregate based on weight percentage or 75%-85% aggregate based on volume percentage. Thus it can be concluded that the quality of road pavement is determined by the nature of the aggregate and the result of mixing the aggregate with other materials. The aggregate used in this study is an aggregate originating from PT. Anugrah Tripa Raya which is available in the Civil Engineering Laboratory of the Padang State Polytechnic.

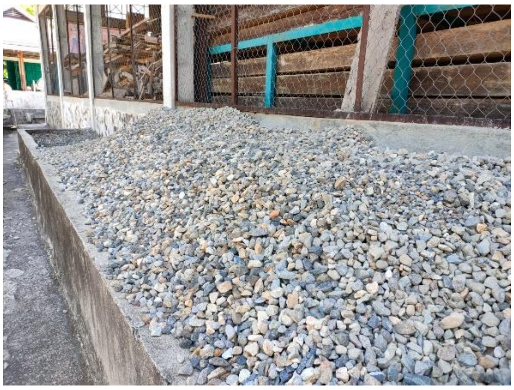

Figure 3. Aggregate used for research

Aggregate is divided into 3 types, namely coarse aggregate, fine aggregate and filler material. Provisions for coarse aggregate and fine aggregate are shown in Table 2 and Table 3[6] .

Table 2. Requirements of Coarse Aggregate

Test Type	Standard	Requirements
Preservation of aggregate form in sodium and magnesium sulfate solutions	SNI 3407:2008	Max.12 % or 18 %
Abrasion with Los Angeles machine	SNI 2417-2008	Max. 40 %
Aggregate adhesion to asphalt	SNI 2439-2011	Min. 95 %
The grains are broken on the coarse aggregate	SNI 7619:2012	95/90
Flat particles	ASTM D4791-10	Max. 10 %
Elongated particles	ASTM D4791-10	Max. 10 %
Material passes Sieve No.200	SNI ASTM C117:2012	Max. 1 %

Source: General Specifications 2018

Table 3. Requirements of Fine Aggregate

Test Type	Standard	Requirements
Sand Equivalent Value	SNI 03-4428-1997	Min 50 %
Uncompacted Void Content Test	SNI 03-6877-2002	Min 45
Material passes Sieve No.200	SNI ASTM C117: 2012	Max. 10 %

Source: General Specifications 2018

In designing pavements, aggregate gradation is planned according to the provisions shown in Table 4.[6]

Table 4. Combined Aggregate Gradation for Asphalt Mixture

Sieve Size		% Weight Passed to Total Aggregate Laston(AC)		
ASTM	(mm)	WC	BC	Base
1½”	37,5			100
1”	25		100	90 – 100
¾”	19	100	90 – 100	76 – 90
½”	12,5	90 – 100	75 – 90	60 – 78
3/8”	9,5	77 – 90	66 – 82	52 – 71
No.4	4,75	53 – 69	46 – 64	35 – 54
No.8	2,36	33 – 53	30 – 49	23 – 41
No.16	1,18	21 – 40	18 – 38	13 – 30
No.30	0,6	14 – 30	12-28	10-22
No.50	0,3	9-22	7-20	6 – 15
No.100	0,15	6-15	5-13	4 – 10
No.200	0,0075	4-9	4-8	3 – 7

Source: General Specifications 2018

2.5. Filler

Filler is part of the fine aggregate that passes a minimum of 75% sieve No. 200 (0.075mm [6]. Filler can be in the form of: stone dust, lime, Portland Cement or other materials [7]. The function of the filler in the mixture is to modify the fine aggregate gradation and together with the asphalt it forms a mixture as a lubricant and binds the fine aggregate to the mixture. Filler particles fill the space between fine aggregate and coarse aggregate thereby contributing to increase in density. This results in more contact area between the grains, reducing asphalt requirements, increasing stability and resistance to deformation

2.5.1 Fly Ash

Coal ash is part of the remaining coal combustion in the form of amorphous fine particles and the ash is an inorganic material formed from changes in mineral materials due to the combustion process [8]. The fly ash used in this test is the residue from the Sijantang PLTU coal. In this reserach, fly ash was chosen as the object of utilization with several considerations, including the amount of fly ash being more (± 80% of the total remaining coal combustion ash), the fly ash grains being much smaller (≤ 200 mm) so that they have more potential to cause air pollution, on the other hand fly ash still has a calorific value so it can still be reused as fuel.

Figure 4. Coal fly ash of PLTU Sijantang, Ombilin, Sawahlunto

2.5.2 Rock Ash

Rock ash is fine aggregate that passes through a 4.75 mm sieve and is retained on a 0.075 mm sieve [6]. Rock ash comes from the waste of the stone crushing industry. At present there are so many stone wastes that it would be nice to try to handle them optimally so that they are useful for construction materials [9]. However, in some locations, rock ash is quite difficult to obtain, so a replacement material with the same or nearly the same properties as the rock ash is needed.

2.6. Asphalt

Asphalt is a material that is solid to slightly dense at room temperature and is thermoplastic. Thus asphalt can melt if heated to a certain temperature and re-freeze if the temperature decreases [10]. Asphalt serves as an aggregate binder in road construction. Asphalt is used for road construction because it has consistency, resistance to weathering (durability), degree of hardening and resistance to water. The asphalt that will be used in this mixture is petroleum refined asphalt produced by PT. Pertamina with a penetration type of 60/70 must meet the requirements in Table 5.

Table 5. Requirements of Asphalt Pen 60/70

No.	Test Type	Method	Requirements
1	Penetration, 25°C (0,1 mm)	SNI 2456 2011	60 – 70
2	Kinematic Viscosity	ASTM D2170-10	≤ 300
3	Softening Point ; °C	SNI 2434 2011	≥ 48
4	Ductility at 25ºC (cm)	SNI 2432 2011	≥ 100
5	Flash point ; °C	SNI 2433 2011	≥ 232
6	Solubility in *Trichlor Ethylen*; %	AASHTO T44-14	≥ 99
7	Specific Gravity	SNI 2441 2011	≥ 1,0
8	Wax Paraffin Content (%)	SNI 03-3639-2002	≤ 2
9	Lost Weight (%)	SNI 06-2441-1991	≤ 0,8
10	Penetration on 25°C (% beginning)	SNI 2456 2011	≥ 54
11	Ductility on 25°C (cm)	SNI 2432 2011	≥ 50

Source: General Specifications 2018

In a pavement mixture, asphalt is required around 4% -10% by weight of the mixture or 10% -15% by volume of the mixture. Asphalt must also have good adhesion and cohesion and provide flexible properties to the mixture. In addition, asphalt also makes the pavement surface impermeable.

2.7. Asphalt Mix Planning with the Marshall Method

The Marshall test is a mandatory test for asphalt concrete, to find out and fulfill the properties of asphalt concrete as we expect. From the Marshall test it will be known what percentage of asphalt content is required for the planned rock gradation, which will produce optimum compressive strength (referred to as Marshall stability, or also referred to as statistical stability test, expressed in kg) of asphalt concrete cylinders (samples) , which has been soaked for one hour at 60ºC. [11] . The final result of the marshall planning is to determine the Optimum Asphalt Content (AOC) which will provide results/conclusions from all the properties of the asphalt mixture.

2.8. Durability

Durability is an assessment of the resistance of a road in receiving vehicle traffic loads through the friction of vehicle wheels and the road surface, as well as withstanding wear and tear from the effects of weather and climate, such as air, water, or changes in temperature [5]. In addition, the compaction factor also has a very important role in the performance of asphalt concrete. When compaction is carried out, the voids between the grains or mixture become small and dense so that a watertight layer is obtained. Optimal compaction results can be achieved if the compaction is carried out at a certain temperature and according to specifications. Compaction is usually still carried out even though the temperature of the mixture has not met the specifications so that optimal density is not obtained. This is because the voids between the grains or the mixture are less dense and dense and there are still cavities (pores). If the voids between the grains and the voids between the mixture are less dense, then the pores in the mixture can easily be entered by water so that the coating becomes brittle quickly (its durability decreases). To get good durability, high bitumen content is usually required. Even though using a high asphalt content, if the road is always submerged in water, gradually the road will quickly become damaged (brittle) before it reaches the design life limit. Road conditions that are always submerged by water will reduce the durability properties of the asphalt pavement layer. This is even worse if compaction is not carried out at a standard compaction temperature. As a result, it can reduce the performance of asphalt concrete such as low stability values, voids between grains or less dense mixture and poor durability properties [12]. The durability of the mix is greatly influenced by the quality of the asphalt, aggregates and mix properties. The durability of the pavement mixture is determined based on the selection of good stacking materials and in accordance with the requirements, the composition of the stacking materials according to the requirements, the strength according to the plan, good job execution, and maintenance [13]. The durability test of the mixture was carried out by the Marshall stability test on the immersed test object [6].

2.9. Marshall Immersion / MI

Marshall immersion is a test to determine the durability of asphalt mixtures. In this test, the resistance performance of the mixture was measured in hot water with a temperature of 60°C for 24 hours and 48 hours so that the mixture's susceptibility to the effects of water and temperature was identified. The mixture which is a hydrocarbon and organic compound will undergo oxidation when it meets water so that the adhesive properties of asphalt will decrease. This is characterized by the release of a thin film of bitumen on the surface of the aggregate. As a result of this process, the mixture will experience a decrease in quality. A decrease in quality which is characterized by a loss of stability based on immersion is measured as resistance to the effects of water. The immersion index should not be less than 90%.

3. Method

3.1. Study of literature

Literature discussion activities from this study include the design of flexible pavement materials where the author collects data and studies relevant basic theories from various sources such as books, the internet, informants and research that has been carried out related to the research that will be carried out by the author.

In this study fly ash is used as a substitute for filler in asphalt mixtures with various variations. Asphalt and aggregate properties testing carried out refers to the 2018 Bina Marga Specifications Revision 2.

3.2. Design

3.2.1. Design

The design of this study starts from the selection of gradations and types of mixtures. Based on the gradation design, an estimate of the middle bitumen content will be obtained. Middle asphalt content is a benchmark in determining the asphalt content to be used in the manufacture of mixtures. The samples were made with 5 variations of asphalt content, where 2 asphalt content differed each 0.5% below the middle asphalt content value and 2 asphalt content differed each 0.5% above the middle asphalt content value. For each asphalt content, 3 samples were made. The marshall analysis produces the optimum asphalt content value (OAC). At this OAC value, samples were made for the Immersion test, with variations in asphalt content of 0.5% below and above the OAC value for 2 immersion conditions.

The stages used include:

1) Preparation Phase: This stage includes the procurement of materials that will be used in research.

2) Material Properties Test: Materials used in this research (coarse aggregate, fine aggregate, rock ash filler, fly ash filler, and asphalt) must be tested for their properties.

3) Job Mix: Planned fly ash filler variations are 0%, 5%, 7,5%, 10%, 12,5% and 15%. Asphalt content variation is determined based on the estimated value of the middle asphalt content.

4) Sample Making: At this stage, Marshall samples and immersion samples were prepared in hot conditions (150°C). The mixture (Marshall sample) was put into the mold, then pounded for 2 x 112 collisions. While the mixture (immersion sample) was made based on the OAC value, with the same mold size as the Marshall sample.

5) Sample Testing: The tests carried out on the samples were the Marshall test and the Immersion test. Immersion samples were made at 2 immersion conditions, 24 hours and 48 hours for each variation of filler substitution.

3.2.2. Workflow

The stages of this study are depicted in a flowchart or workflow as shown in Figure 5:

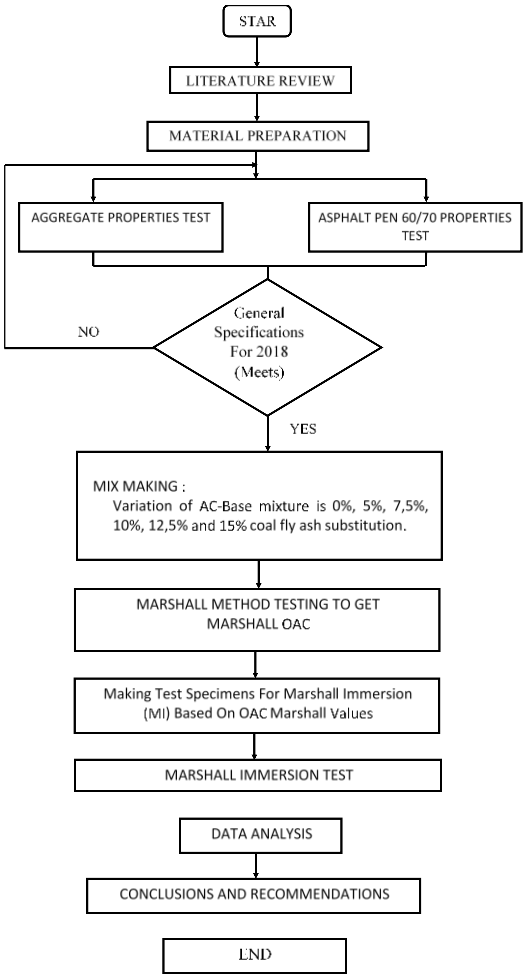

Figure 5. Workflow

3.3. Testing and Measurement

Tests are carried out on the materials that make up the mixture (asphalt and aggregate) and also on the mixture itself. There are 2 tests on the mixture, namely the Marshall test and the immersion test. The Marshall testing includes volumetric testing and stability testing. While the immersion test was carried out in 2 conditions, 24 hours and 48 hours.

The Marshall test equipment consists of a press tool equipped with a proving ring which is used to measure the stability value and a flow meter which is used to measure fatigue (flow).

3.4. Analysis, Drawing Conclusions, and Making Reports

The final stage in the research process is data analysis so that conclusions are obtained as a research report. In this reserach, data analysis was performed on aggregate test properties data, asphalt properties test data, Marshall immersion test data, and Marshall immersion test data. The data analysis is related to one another. After the data analysis stage, the next stage is the conclusion of the research conducted, which will then be made a report.

3.5. Research Materials and Tools

The materials used in this research include coarse aggregate, fine aggregate, rock ash filler, fly ash filler, and asphalt. Coarse and fine aggregates, and rock ash filler are from PT. Anugrah Tripa Raya (PT. ATR) bypass Padang. While Fly Ash Coal comes from PLTU Sijantang, Sawahlunto. The tools used are a set of sieves, aggregate inspection test equipment, asphalt inspection test equipment and asphalt mixture characteristic test equipment.

4. Result

4.1. Aggregate Properties Test Result

The results of the aggregate properties test are shown in Table 6 and Table 7:

Table 6. Coarse Aggregate Properties Test Results

NO	CHARACTERISTICS	RESULT	SPECIFICATION
1.	Bulk Specific gravity; t/m3	2,51	2,5 – 2,7
2.	SSD Specific gravity; t/m3	2,58	2,5 – 2,7
3.	Apparent Specific gravity; t/m3	2,70	2,5 – 2,7
4.	Los Angeles; (%)	27,29	Max 30%
5.	AIV (Aggregate Impact Value); (%)	23	Max 30%
6.	ACV (Aggregate Crushing Value); (%)	12,85	Max 30%
7.	Flakiness Index; (%)	8,55	Max 10%
8.	Alongated Index ; (%)	5,91	Max 10%
9.	Soundness; (%)	4,15	Max 10%

Table 7. Fine Aggregate Properties Test Results

NO	CHARACTERISTICS	RESULT	SPECIFICATION
1.	Bulk Specific gravity; t/m3	2,5	2,5 – 2,7
2.	SSD Specific gravity; t/m3	2,55	2,5 – 2,7
3.	Apparent Specific gravity; t/m3	2,61	2,5 – 2,7

4.2. Asphalt Properties Test Result

The test results for asphalt properties are shown in Table 8 below:

Table 8. Asphalt Properties Test Results

NO.	CHARACTERISTICS	RESULT	SPECIFICATION
1.	Specific gravity; t/m3	1,061	Min 1,0
2.	Flash point and Burn point; °C	344 & 354	Min 232
3.	Softening point; °C	48	Min 48
4.	Viscosity; cm2/detik	150 & 160	160 – 240
5.	Penetration; mm	65,2	60-70
6.	Ductility; cm	150	Min 100
7.	Losing weight TFOT; %	0,3106	Max 0,8
8.	Adhesion of asphalt to aggregate; %	95%	Min 95%

4.3. Optimum Asphalt Content Results

Marshall analysis of the samples with various variations give the optimum asphalt content (OAC) of the mixture. In the variation of 0% Fly Ash coal, the OAC value is 6.82%; variation of 5% Fly Ash coal got the OAC value is 6,87%; variation of 7,5% Fly Ash coal got the OAC value is 6,85%; variation of 10% Fly Ash coal got the OAC value is 6,84%; variation of 12,5% Fly Ash coal got the OAC value is 6,82%; and variation of 15% Fly Ash coal got the OAC value is 6,79%. The comparison of Marshall OAC values can be seen in the Fig. 6:

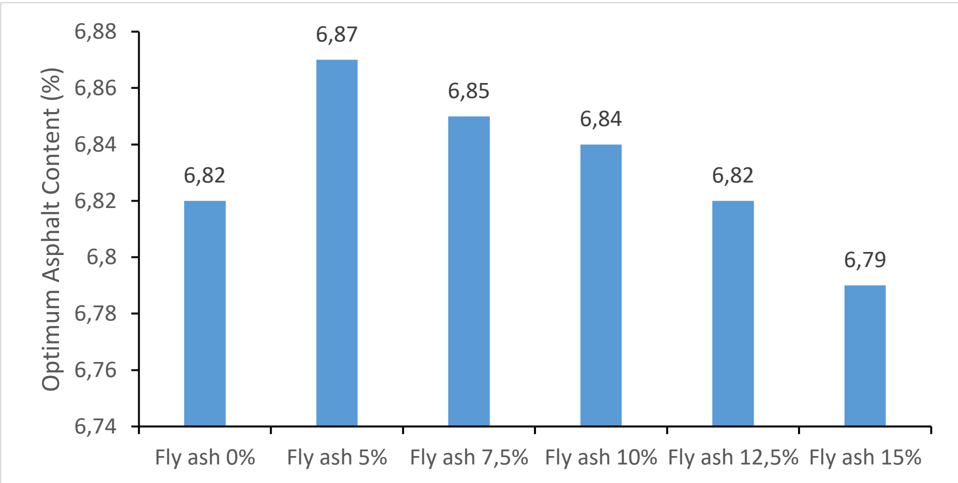

Figure 6. The OAC Marshall Comparison on Various Variations of Coal Fly Ash

4.4. Marshall Immersion Test Result

The Marshall Immersion test is a test to determine the durability of asphalt mixtures. In this test, the mixture was measured for its resistance performance at a temperature of 60˚C for 24 hours and 48 hours. The result of this test show on Fig 7.

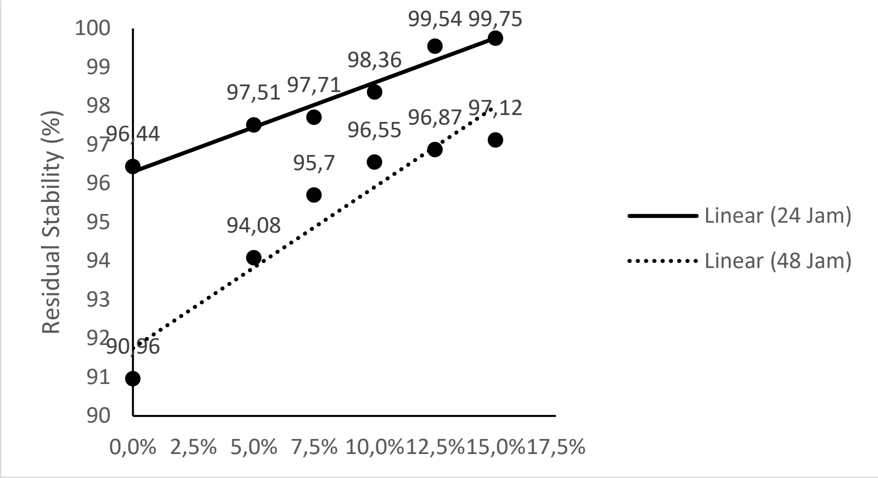

Figure 7. Marshall Immersion test results at 24 hours and 48 hours

Figure 7 shows the residual stability of samples for various variation filler substitution conditions at 24 hours and 48 hours.

4.5. Discussion

4.4.1 Discussion of Aggregate Properties Test

Testing of aggregate properties includes testing the specific gravity of coarse aggregate, fine aggregate and filler; aggregate impact value test; aggregates crushing value test; aggregate strength test with Los Angeles (LA) machine; soundness test; aggregate elongation and flakiness tests. The results of the properties test show that all test items meet the requirements.

Based on the results of the aggregate properties can be used in the manufacture of asphalt mixtures.

4.4.2 Discussion of Asphalt Properties Test

The asphalt properties testing consists of Specific gravity test, ductility testing, penetration testing, softening point test, flash and burn point testing, and weight loss test. The results of all asphalt properties tests meet the required specifications.

Based on the results of the asphalt properties can be used in the manufacture of asphalt mixtures.

4.4.3 Discussion of Marshall Test

In general, the Marshall test consists of volumetric testing and stability testing. The volumetric test includes sample thickness/height and sample weight. While the stability of the test includes the stability value and the value of flow. The results of the volumetric test using the equation will produce the values of Void in Mix (VIM), Void in Mineral Aggregate (VMA) and Void Filled Asphalt (VFA). The equation used is;

$$VMA = 100 - \left[\frac{SG\ theoretical - Aggregate\ content}{SG\ Bulk\ combination}\right]$$

$$VFA = \left[\frac{VMA - VIM}{VMA}\right] x\ 100$$

$$VIM = \left[\frac{SG\ Bulk - SG\ theoretical}{SG\ Bulk\ combination}\right] x\ 100$$

Description :

VMA = volume of aggregate voids in asphalt concrete, % of the bulk volume of asphalt concrete
VIM = volume of voids in asphalt concrete, % of the bulk volume of asphalt concrete
VFA = volume of voids between aggregates filled with asphalt, % of VMA

$$\text{SG Bulk combination} = \frac{100}{\frac{\%\,Coarse\ Aggregate}{SG\ Bulk\ Coarse\ Aggregate}+\frac{\%\,Fine\ Aggregate}{SG\ Bulk\ Fine\ Aggregate}+\frac{\%\,Filler}{SG\ Filler}}$$

$$\text{SG theoretical} = \frac{100}{\frac{\%\,Aggregate\ Content}{SG\ Efektif\ combination}+\frac{\%\,Aspal\ Content}{SG\ Aspal}}$$

$$\text{SG Effective combination} = \frac{100}{\frac{\%\,Coarse\ Aggregate}{SG\ Efektif\ Coarse\ Aggregate}+\frac{\%\,Fine\ Aggregate}{SG\ Efektif\ Fine\ Aggregate}+\frac{\%\,Filler}{SG\ Efektif\ Filler}}$$

Graphical analysis of the Marshall test results gives the OAC value for each filler substitution variation. The variables that are taken into account in the graphic analysis are VIM, VMA, VFA, Stability, Flow, and Marshall Quotient. The use of coal fly ash filler substitution as much as 5% causes an increase in OAC compared to without using coal fly ash substitution. However, the increase in the use of coal fly ash filler as a substitute material for rock ash filler up to 15% with an increase every 2.5% causes a decrease in Marshall OAC values (Fig.1). The OAC of Marshall is a benchmark for making marshall immersion samples.

4.4.4 Research Discussion on Marshall Immersion Test

The Marshall immersion test was carried out to review the durability of the asphalt mixture after immersion for 24 hours and 48 hours. This test was also carried out on all variations of the mixture. The test results as shown in Fig 7. The graph on Fig 7 shows that at 24-hour and 48-hour immersion, the durability of the mixture tends to increase along with the increase in the percentage of coal fly ash usage. The increase in residual strength index (RSI) was due to the presence of silica in coal fly ash. This causes the voids between the aggregates to be closed so that the higher the percentage of coal fly ash, the higher the residual strength index in the mixture. It can be seen that the highest residual stability value is found in the coal fly ash mixture of 15% with a RSI value is 99.75% for 24-hour immersion and the lowest value is in the 0% coal fly ash mixture with a RSI value is 96.44% for 24-hour immersion. While the RSI value for 48 hours of immersion gives a lower value than 24-hour immersion. These results as a whole show that by increasing the percentage of coal fly ash use, it can increase the value of the Residual Strength Index of the asphalt mixture and still meet the minimum requirement of 90%.

5. Conclusion

From the research that has been carried out on AC-Base asphalt mixtures with coal fly ash filler substitution with various percentage variations, the following conclusions can be drawn:.

1. The results of volumetric testing and marshall characteristics of the AC-Base mixture using coal fly ash as a filler substitution, in accordance with the 2018 technical specifications revision 2 division 6.
2. The KAO value of the AC-Base mixture using coal fly ash as a filler substitution decreased as the percentage of use of coal fly ash in the mixture increased.
3. Marshall immersion value tends to increase along with the increase in the percentage of use of coal fly ash in the AC-Base mixture. The mixture with 15 % coal fly ash gave better performance than the other variations (0%, 5%, 7.5%, 10% and 12.5%). This is indicated by the results of higher residual strength index both at 24 hours immersion (99.75%) and 48 hours immersion (97.12%).

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