Volumetric Performance Analysis and Rutting of PG76 Asphalt Mixture with Fly ash as Filler

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Abstract

Hot asphalt mixture is a type of pavement that is often used in a variety of traffic conditions and diverse environments. Permanent deformation in hot asphalt mixtures is damage caused by ambient temperature, aggregate quality and binding materials. This study shows the effect of using different types of binding materials, asphalt pen 60/70 and asphalt Pg76 with fly ash additives by analyzing the volumetric characteristics and rutting performance of asphalt mixtures. The results showed that the Pg76 mixture had a lower KAO value (6.5%) compared to the 60/70 pen mixture (6.6%). Based on volumetric analysis, the addition of fly ash as a filler has different effects depending on the type of asphalt used, which can be seen from the correlation values of VIM, VMA and VFB >0.7. The stability of the marshall in the PG76 FA mixture has a value of 1686.04 kg and the Pen 60/70 FA of 1407.58 kg. The addition of FA to hot asphalt mixtures can reduce moisture damage with an IRS value of more than 90%. The rutting performance of the PG76 FA mixture has better performance as evidenced by its higher dynamic stability values and lower deformation rate than the Pen 60/70 FA mixture. Temperature has a significant influence on the rutting performance of both mixtures especially in the Pen 60/70 FA mixture. The higher the test temperature indicates the greater the total deformation value, higher deformation rate, and lower dynamic stability in both mixtures.

Keywords: *Rutting, Volumetric, Zeolite, PG76, WTM*

I. INTRODUCTION

The development of road infrastructure is an important factor in economic development, hot asphalt mixtures as pavements are often used. Hot asphalt mixture is a type of pavement that is used in various traffic and environmental conditions so that the material used must meet specific technical requirements. One of the important components in a hot asphalt mixture is filler. Fillers have an important role in asphalt mixtures that significantly affect the performance of pavement. Fillers can make the asphalt mixture stiffer thereby increasing its resistance to groove deformation. Fillers can also affect the amount of asphalt content the use of fillers can increase resistance to water damage and freezing. The physical and chemical properties of the filler determine how the filler can interact with the asphalt which will ultimately affect the durability of the mixture. Fly ash (Fa) is one of the materials that can be used as fillers. Based on previous research, it was found that Fa has some of the same content as that in bitumen. The alumina contained in the Fa can improve the stability of the mixture at high temperatures, resistance to water and increase resistance to fatigue (fatigue)[1-4].

The use of Fa as a filler material in hot asphalt mixtures has been shown to provide many advantages such as increased stability, resistance to moisture, and permanent deformation [5]. The FA in hot asphalt mixtures not only meets existing standards but shows superior quality i.e. more resistant to shape change. Fly ash has the characteristics of a rounded shape, *self-commenting*, which can be self-hardened or pozolanic, and light weight [5]. The properties of Fa are advantages that can be used in various fields, one of which is asphalt concrete. With its ability as a [6] *stiffening* and *void-filling material*, Fa effectively improves the performance of asphalt-aggregate mixtures. This is evidenced by the fatigue life of specimens, especially those that use Fa with a high

Al2O3 content, which far exceeds the control specimen, while demonstrating its potential as a bitumen-saving material. Fa has been proven to make asphalt mixtures stiffer and stronger so that they are more resistant to permanent deformation that often occurs at high temperatures [8]. [7]

Based on the characterization that has been carried out, it was identified that the addition of polymers to PG76 asphalt has an impact on increasing viscosity and hardness. This phenomenon explains why *the Performance Grade* (PG) value of PG76 modified asphalt is higher than that of Pen 60/70 asphalt. Meanwhile, from the analysis of Marshall parameters, it was found that the performance improvement reflected from the stability value and the higher Marshall Immersion Index, was achieved with the consequence of using a higher optimum asphalt grade. Technically, [8] the PG76 binder is the best based on the results of all the tests. However, 60-70 penetration binders, which rank second, are more commonly accepted for a wide range of applications because they are cheaper and easier to find. [9]

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The use of polymer binders such as Pg-70 has proven to be consistently superior to Pen 60/70 binders. This advantage can be seen from mechanical properties such as much higher stability, as well as better durability (durability). This evidence of durability is confirmed by the higher Residual Strength Index values of the Pg-70 polymer mixture. On the other hand, the addition of Fa (fly ash) also plays a positive role by increasing the viscosity and cohesion of asphalt, thereby strengthening its stability against water disturbances [12].

Although polymer modified asphalt such as PG76 has been theoretically proven and laboratory to have an advantage in resisting deformation, its actual performance in the field is faced with increasingly severe challenges. The two main factors that are serious threats are the increase in pavement surface temperatures as a result of global climate change, as well as the increasing traffic load and congestion. The combination of these two factors creates extreme service conditions that can exceed the limits of the initial design, leading to a significant reduction in stiffness even on high-performance asphalt mixtures. This condition ultimately triggers *rutting* faster than expected. In-depth research is needed to precisely map how these high-temperature variations affect the *rutting* performance of these specific material combinations.

This study was conducted to analyze the performance of mixed rutting of Asphalt Concrete-Wearing Course (AC-WC) using PG76 asphalt with conventional filler substitution using fly ash. Fly ash, as a by-product of coal combustion, has the potential to improve the mechanical properties of the mixture while also being a more environmentally friendly material solution. This study will focus on evaluating the permanent deformation resistance of the mixture at various temperature levels (25, 45 and 60o) to provide empirical data on its performance in anticipating high temperature conditions and heavy loads.

II. MATERIALS AND METHODS

This study was conducted to evaluate the rutting performance of hot asphalt mixture of the Asphalt Concrete-Wearing Course (AC-WC) type using PG76 modified asphalt with conventional filler substitution by fly ash. This research method was designed experimentally in the laboratory using a performance test approach, with the main focus on testing permanent deformation (rutting) at various service temperatures. Determination of the characteristics of the mixture includes preparation of Marshall specimens, volumetric parameter testing, and rutting performance test with the Wheel Tracking Test tool.

The standard *Marshall* test is a test to estimate the performance of a mixture based on the volumetric of the mixture. The test was carried out by providing a load of 50.8 mm/min. Marshall test loading is applied until the mixture fails. The marshall test is carried out by immersing the test specimen in a water bath for 30 – 40 minutes at a temperature of 60°C [13]. Mixed stability indicates the ability of the mixture to accept and withstand traffic loads without suffering damage. *Flow* marshall is a value that indicates the vertical deformation received by the test that occurs due to loading until the condition of the sample collapses which indicates maximum stability. The marshall immersion test is a marshall test with a 24-hour immersion. The test was carried out to obtain the *value of the Index of Retained Strength* which is used to evaluate the compressive strength of the asphalt mixture under the influence of moisture. The IRS value aims to assess the resistance of asphalt mixtures to moisture damage. Moisture can damage the asphalt mixture, namely by means of the loss of the bond between the asphalt and the coarse and fine aggregates.

Rutting on road pavement can be predicted by *Wheel Tracking Machine* testing, which is by conducting tests with repeated loading. The test with the WTM tool was carried out at a temperature of 60oC with a loading speed of 42 times per minute and a given pressure of 0.7 MPa. The stability value obtained is the amount of load of the tracking wheel which results in a total deformation of 1 mm in the test time range of 45 minutes to 60 minutes [14] .

III. Results and Discussions

Based on the results of the test the KAO value on the mixture of test specimens using 60/70 asphalt pen is 6.6%. The KAO value in the mixture of test specimens using PG76 asphalt is 6.5%. The difference in KAO values in the two test product mixtures with different asphalt shows that the use of PG76 asphalt with a lower KAO value means that the mixture can be more efficient in terms of the use of binding materials.

A. Effect of Fly Ash (Fa) on Volumetric Mixtures

The air cavity between the aggregate particles covered by asphalt (VIM) in Figure 5 with the addition of good Fa in the mixture with Pg76 asphalt and 60/70 asphalt pen increased with the increase in Fa levels. Pg76 asphalt mixture experienced an increase in VIM value from standard mixtures. The VIM value in the 60/70 pen asphalt mixture increased until the addition of Fa at 50% then decreased, which indicates an increase in density due to the addition of Fa so as to reduce the air cavity in the asphalt mixture.

The void in mineral aggregate or VMA shown in figure 6 is increased by the addition of Fa to the mixture of Pg76 asphalt and 60/70 pen asphalt. Fa as an additive result in the mixture having enough free space between the aggregate particles that have been compacted. The addition of Fa resulted in a decrease in the VFB value in the mixture and an increase in VMA. The VMA values on both mixtures have not much different values which means that both mixtures have the total volume of aggregate and the cavities of the mixture filled by the asphalt are relatively similar. Higher VMA values in asphalt mixtures lead to smaller permanent deformation. [15] The addition of Fa to the asphalt mixture gives a volumetric effect of the asphalt mixture, namely reducing air cavities as occurs in the Pen 60/70 asphalt mixture. In contrast to Pg76 asphalt mixtures, the addition of Fa as a filler can cause an increase in the porosity of the mixture, this can occur due to the distribution of Fa fillers that are not optimal in the asphalt mixture.

The addition of fly ash has a strong correlation and a significant effect on the volumetric characteristics (VIM, VMA, and VFB) of the Pen 60/70 and PG76 asphalt mixtures. Especially in the PG76 mixture, the addition of fly ash can increase the air cavity (VIM), but as a result it decreases the asphalt-filled cavity (VFB) and the cohesion value of the mixture. Fa has been shown to improve stability in both types of mixtures. This increase occurs because the silica and alumina content in the Fa react chemically with bitumen, thereby strengthening the bonds in the mixture. Statistical analysis (ANOVA) also confirmed that the change in volumetric characteristics in both mixtures was significant, with the F-value greater than the F-crit and the P-value less than 0.05.

Table 1. Correlation Values *Pearson*

Mix Type	Density	VIM	VMA	VFB	Stability	Flow
Pen 60/70 fly ash	-0,89	0,89	0,89	-0,89	0,85	-0,38
Pg76 Fly ash	-0,97	0,97	0,97	-0,97	0,91	0,00

Table 2. F and P Values on Both Mixtures

Volumetric Characteristics		PG76	Pen 60/70
VIM	*F-Value*	55,15	38,59
	F-Crit	3,48	3,48
	P-Value	0,0000009	0,0000048
VMA	*F-Value*	76,27	38,69
	F-Crit	3,48	3,48
	P-Value	0,00000019	0,00000469
VFB	*F-Value*	52,38	39,11
	F-Crit	3,48	3,48
	P-Value	0,000001132	0,000004460

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B. Typefaces and the Effect of Fly Ash (Fa) on the Value of the Retained Strength Index (IRS)

The strength and stability of the asphalt mixture is reduced after being submerged in water. Moisture is one of the factors that cause damage to road pavement that causes loss of adhesion between aggregates and asphalt binding materials. In addition, the loss of cohesion and strength of the asphalt bond causes various other damages such as decomposing, striping and cracking.

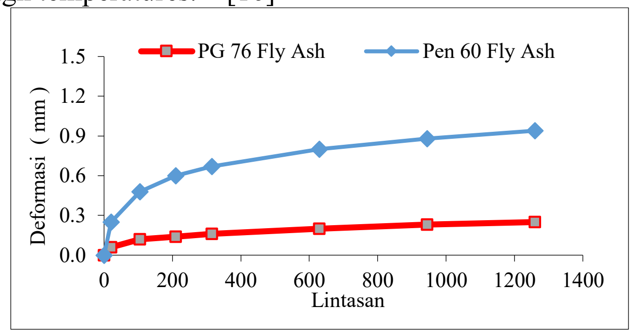
The IRS value or *Index of Retained Strength* is used to evaluate the strength of the asphalt mixture under the influence of moisture. The IRS aims to assess the resistance of asphalt mixtures to moisture damage. The IRS value is the percentage comparison between the stability value of the mixture affected by humidity or 24-hour immersion and the 0.5-hour control or immersion mixture. The figure shows the IRS value on a mixture of PG76 asphalt and 60/70 asphalt pen with the addition of Fa. The IRS value of the two mixtures is above the minimum value of the IRS value of hot asphalt mixture, which is 90%. The IRS of PG76 asphalt mixture is greater than the IRS value of 60/70 pen asphalt mixture, which indicates the ability of Pg76 asphalt with the addition of Fa to maintain the performance of the mixture from moisture damage. The addition of Fa to both mixtures showed an increase in the IRS value compared to the mixture without the addition of Fa. This shows that the addition of Fa can reduce moisture damage to asphalt mixtures.

C. Rutting Test Results Analysis

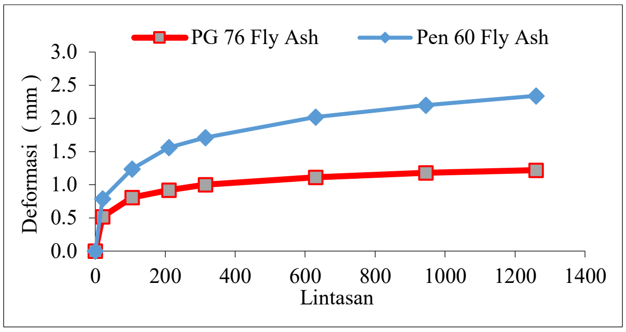
Permanent deformation testing using Wheel Tracking Machine (WTM) was carried out on PG76 and Pen 60/70 asphalt mixtures with the addition of fly ash at three temperature variations, namely 25 °C, 45 °C, and 60 °C. The results showed that PG76 asphalt mixtures consistently produced lower permanent deformation and higher dynamic stability compared to Pen 60/70 mixtures across all temperature variations.

At 25 °C, the deformation of the PG76 mixture is only 0.25 mm with a dynamic stability of 31,500 passes/minute, while the Pen 60/70 mix shows a deformation of 0.94 mm and a dynamic stability of 10,500 passes/minute. At 45 °C, the deformation increases to 1.22 mm for the PG76 and 2.34 mm for the Pen 60/70, with dynamic stability of 15,750 and 4,500 passes/mm, respectively. Testing at 60 °C showed a deformation of 2.49 mm for PG76 and a deformation rate (RD) of 0.1040 mm/min on the Pen 60/70, with dynamic stability of 2,863.6 and 1,431.8 passes/mm, respectively.

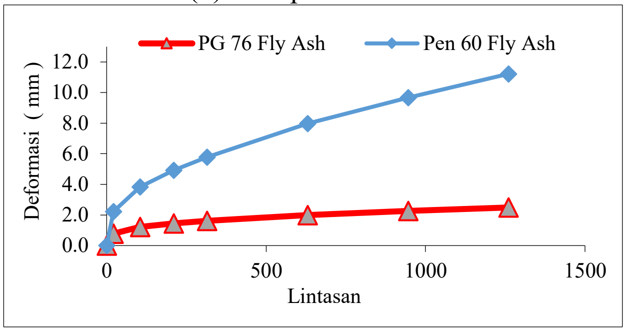
Overall, the test results showed that the temperature increase was directly proportional to the increase in permanent deformation, and that PG76 asphalt mixture with fly ash had better resistance to permanent deformation than Pen 60/70 asphalt mixture. The higher dynamic stability of the PG76 mixture confirms its superiority in withstanding repetitive loads especially at high temperatures. [16]



(a) Temperature 25°



(b) Temperature 45°



(c) Temperature 60°

Figure 1. Groove Depth with Temperature Influence

IV. CONCLUSIONS

Based on the test results, the KAO value in PG76 asphalt mixture is 6.5% and slightly lower than 60/70 pen asphalt of 6.6%. This shows that the use of PG76 asphalt is more efficient in the use of binding materials. The addition of fly ash has a noticeable effect on the volumetric properties of the mixture (VIM, VMA, and VFB). The greater the fly ash content, the VIM and VMA values tend to increase, while the VFB values decrease. The results of statistical analysis also show that these changes are significant to the characteristics of the mixture.

The addition of fly ash has been shown to increase the resistance of the mixture to the influence of water, which is shown by the increased value of the Index of Retained Strength (IRS) in both types of mixtures. The IRS value of PG76 asphalt mixture is higher than that of 60/70 asphalt pens, meaning that PG76 mixture with additional fly ash is better able to maintain its strength and stability after being submerged in water. Thus, fly ash can function as an additional material that helps reduce moisture damage.

From the results of the rutting test, PG76 asphalt mixture showed better resistance to permanent deformation than the 60/70 pen asphalt mixture at all temperature variations (25°C, 45°C, and 60°C). PG76 mixtures have a smaller groove depth and higher dynamic stability values. This indicates that the use of PG76 asphalt with the addition of fly ash is able to improve the ability of the mixture to withstand repeated loads, especially at high temperatures.

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