COMPARISON OF THE STRENGTH OF ASPHALT CONCRETE-WEARING COURSE (AC-WC) REVIEWED TOWARDS THE USE OF PC, FLY ASH AND ZEOLITE AS A FILLER IN MIXTURES

Putri Arifin[1], Bambang Supriyanto[2] dan Pranoto[3]

[1]*Universitas Negeri Malang, email: putri.arifin.1705236@students.um.ac.id*
[2]*Universitas Negeri Malang, email: bambang.supriyanto.ft@um.ac.id*
[3]*Universitas Negeri Malang, email: pranoto.ft@um.ac.id*

Abstract: Asphalt Concrete-Wearing Course (AC-WC) is a pavement layer that is in direct contact with the vehicle's wheels. This layer is the largest in receiving traffic loads that work on the surface of the layer. Therefore, a mixture is needed to achieve high stability. For this reason, PC, fly ash, and zeolite as a filler are used in the hope of increasing the density of the mixture so as to produce high stability values. This research aims to (1) to describe the characteristics of marshall on a mixture of AC-WC with PC, fly ash and zeolite (2) to compare the strength of the AC-WC mixture in terms of the results of the Marshall parameters between PC, fly ash and zeolite. The characteristics and strengths are reviewed by marshall parameters that include stability values, flow, VIM, VMA, and VFA. The plan in this research begins with a laboratory test which include testing of aggregates, asphalt and filler. Then make the test object and continue with the Marshall test. The method of data analysis using descriptive quantitative and inferential statistics One Way Anova and the last is draw conclusions. The results showed: (1) as the asphalt content increases, the stability value tends to increase to 6% asphalt content and then decreases to 7% asphalt content where the highest average stability value is PC filler of 1299.69 kg, then zeolite filler of 1252.53 kg, followed by fly ash filler of 1005.68 kg, the flow value tends to increase with increasing asphalt content where the highest average flow value is fly ash filler of 3.89 mm, then zeolite filler of 3.59 mm, followed by PC filler of 3.06 mm, the VIM value tends to decrease with increasing asphalt content where the highest average VIM value is zeolite filler of 7.07%, then PC filler of 6.21%, followed by fly ash filler of 3.97%, VMA value tends to decrease with increasing asphalt content where the highest average VMA value is zeolite filler of 16.38%, then PC filler of 15.69%, followed by fly ash filler of 14.04%, the VFA value tends to increase with increasing the asphalt content where the highest average VFA value is fly ash filler of 72.30%, then PC filler of 61.77%, followed by zeolite filler of 57.30% (2) there is a significant difference in the average value of stability, flow, VMA between filler PC, fly ash and zeolite. The difference for the stability value is found in the fly ash filler with PC, while for flow is PC with fly ash and PC with zeolite, for VMA is fly ash with zeolite. There is no significant difference in the average VIM and VFA value between PC filler, fly ash and zeolite.

Keywords: AC-WC, PC, fly ash, zeolite, marshall parameters

1. PRELIMINARY

At this time, Fly Ash and Bottom Ash (FABA) have become a hot topic of discussion, especially for industry players (Info PJB, 2021). Power plants produce solid waste in the form of ash from coal combustion called FABA (Kinasti, 2017). On February 2, 2021, FABA has been officially removed from the list of Hazardous and Toxic Substances (B3) (Info PJB, 2021). The results of the characteristic test by the Ministry of Environment and Forestry in 2020 stated that FABA waste from PLTU did not meet the characteristics of B3 waste (Kementerian Lingkungan Hidup dan Kehutanan, 2021). Even though it is designated as non-B3 waste, there must still be efforts to utilize it in processing FABA waste. This utilization effort is carried out to reduce non-B3 waste, as well as to make FABA beneficial to the community and have economic value.

PLTU Paiton is one of the largest steam power plants in Indonesia, located in Bhinor Village, Paiton District, Probolinggo Regency. PLTU Paiton has an important role in supporting the supply of electricity in Java and Bali. Fueled by coal, the Paiton PLTU produces on average solid waste in the form of ash which can reach 350 tons a day (Nashrullah, 2022). The resulting ash is known as fly ash. The fly ash will continue to grow and accumulate if it is not used massively. One effort that is expected to reduce fly ash deposits so that they do not accumulate is to use fly ash as a filler in road base materials. Other countries such as India and the United States have used fly ash as a road base material (Kurniawan, 2010).

Indonesia, which is a volcanic area, produces volcanic eruption material in the form of zeolite minerals such as those found in Sumatra, Java, East Nusa Tenggara and Sulawesi (Kusdarto, 2008). Zeolites are minerals consisting of hydrated alumina silicate crystals containing alkaline or alkaline earth cations in a three-dimensional framework (Gustam, 2009). The number of zeolite deposits in Indonesia is not less than 250 million tons with a production level of 100-250 thousand tons per year, Indonesia's zeolite reserves do not run out in 1000 years (Suwardi, 2009). However, from a large number of existing zeolite deposits, only a small portion has been used for various purposes. Whereas zeolite in Indonesia is one of the natural resources with great potential if used properly. Therefore, it is necessary to make an effort to utilize zeolite whose deposits have millions of tons in nature so that it can be utilized optimally, one of which is as an alternative to filler in the AC-WC mixture.

In this research, the authors tried to maximize the use of fly ash waste and zeolite natural resources as a filler in the AC-WC mixture. The fly ash used comes from PLTU Paiton, Probolinggo Regency. The zeolite used came from Ngeni Village, Wonotirto District, Blitar Regency. The hope of this research is that it can provide an environmentally conscious attitude and can motivate people to utilize, manage and research coal ash waste from the PLTU that is around them. The community is also expected to be able to make natural zeolite as a natural potential that can be utilized and managed properly.

2. METHOD

This research is a type of experimental research conducted in a laboratory. This research begins with an examination of the material which includes testing of aggregates, asphalt and filler. The purpose of material inspection is to ensure that the materials to be used for asphalt-concrete mixtures meet the requirements and standards set. Then make the test object and continue with the Marshall test. Data analysis in this study used two methods, namely quantitative descriptive and inferential statistics One Way Anova using the SPSS program.

Descriptive quantitative research method serves to analyze the data by describing the data that has been obtained as it is. The use of quantitative descriptive in this research wants to examine the relationship between asphalt content and the results of Marshall parameters which include stability, flow, VIM, VMA, and VFA values. The use of One Way Anova in this study is to test research hypotheses to assess differences in the mean of two or more groups. In this study, the conclusion with the One Way Anova statistical test was carried out using a significant value (Sig) where if the Sig value > 0.05 then Ho failed to be rejected (there was no difference in average) while if Sig < 0.05 then Ho was rejected (there is an average difference). Furthermore, decision making, if the test results show that Ho failed to be rejected, it is necessary to carry out a further test (post hoc test). However, if the test results are the other way around, namely Ho is rejected, there is no need for further testing. The function of the post-Anova follow-up test is to find out which groups are different. The hypothesis in this study is Ho: $\mu_1 = \mu_2 = \mu_3$; Ha: $\mu_1 \neq \mu_2 \neq \mu_3$ (there is an average difference).

3. RESULTS

3.1 Aggregate, Filler, and Asphalt Test Results

Based on the results of tests that have been carried out at the Civil Engineering Highway Laboratory, State University of Malang, the data obtained from testing results on coarse aggregate, fine aggregate, filler, and asphalt are as follows.

Table 1. Aggregate Test Results

Jenis Pengujian	Metode Pengujian	Spesifikasi		Hasil Pengujian
		Min	Maks	
Agregat Kasar				
Berat Jenis Bulk (gr/cm^3)	SNI 1969:2016	2,5	-	2,56
Berat Jenis SSD (gr/cm^3)		-	-	2,63
Berat Jenis Semu (gr/cm^3)		-	-	2,76
Penyerapan Air (%)		-	3	2,73
Keausan (%)	SNI 2417:2008	-	40	34,42
Agregat Halus				
Berat Jenis Bulk (gr/cm^3)	SNI 1970:2016	2,5	-	2,50
Berat Jenis SSD (gr/cm^3)		-	-	2,56
Berat Jenis Semu (gr/cm^3)		-	-	2,67
Penyerapan Air (%)		-	3	2,63

Table 1 shows that the results of testing for specific gravity, water absorption, and wear of coarse and fine aggregates that have been tested have all met the requirements for use as an AC-WC mixture.

Table 2. Filler Test Results

Jenis *Filler*	Jenis Pengujian	Hasil Pengujian
PC	Berat Jenis	3,08 (gr/cm^3)
Fly Ash	Berat Jenis	2,51 (gr/cm^3)
Zeolit	Berat Jenis	2,35 (gr/cm^3)

Table 2 shows that PC filler, fly ash, and zeolite can be used in the AC-WC mixture.

Table 3. Asphalt Test Results

Jenis Pengujian	Metode Pengujian	Spesifikasi		Hasil Pengujian
		Min	Maks	
Penetrasi (mm)	SNI 2456:2011	60	70	69,50
Titik Lembek (°C)	SNI 2434:2011	48	-	50,00
Titik Nyala (°C)	SNI 2433:2011	232	-	320,00
Titik Bakar (°C)		-	-	330,00
Daktilitas (cm)	SNI 2432:2011	100	-	133,67
Berat Jenis (gr/cm^3)	SNI 2411:2011	1	-	1,08
Kehilangan Berat (%)	SNI 2440:1991	-	0,8	0,2

The asphalt used in this AC-WC mixture is asphalt produced by Pertamina with a penetration of 60/70 from PT Sriwijaya 87 (Asphalt Mixing Plant). Table 3 shows that the asphalt has met the requirements required by SNI.

3.2 Marshall Parameter Analysis Results

In this research, five levels of asphalt were used, namely 5%, 5.5%, 6%, 6.5%, 7% with each asphalt content amounting to three test objects so that the total number of test objects amounted to 45 pieces. Compaction of the test object as much as 2 x 75 times the collision. The results of the Marshall parameter analysis of each filler include the values of stability, flow, VIM, VMA, and VFA.

Table 4. Marshall Parameter Analysis Results with PC

Parameter *Marshall*	Kadar Aspal					Spesifikasi	
	5%	5,5%	6%	6,5%	7%	Min	Maks
Stabilitas (kg)	1226,36	1339,71	1479,07	1236,84	1216,48	800	-
Flow (mm)	3,21	2,88	2,63	3,18	3,38	2	4
VIM (%)	10,92	7,63	4,98	4,93	2,61	3	5
VMA (%)	17,91	15,80	15,39	15,37	14,00	15	-
VFA (%)	39,51	52,00	67,81	67,92	81,61	65	-

Table 4 shows that the stability value and flow value meet the specifications at 5%-7% asphalt content. VIM values at 5%, 5.5% and 7% asphalt content did not meet the specifications. The VMA value at 7% asphalt content does not meet the specifications. VFA values at 5% and 5.5% asphalt content did not meet the specifications.

Table 5. Marshall Parameter Analysis Results with Fly Ash

Parameter *Marshall*	Kadar Aspal					Spesifikasi	
	5%	5,5%	6%	6,5%	7%	Min	Maks
Stabilitas (kg)	910,45	1089,08	1104,88	993,85	930,12	800	-
Flow (mm)	3,52	3,75	3,90	4,00	4,29	2	4
VIM (%)	6,73	4,86	4,73	1,88	1,67	3	5
VMA (%)	14,05	15,11	15,36	12,99	12,68	15	-
VFA (%)	52,21	67,49	69,25	85,64	86,92	65	-

Table 5 shows that the stability values meet the specifications at 5%-7% asphalt content. The flow value at 7% asphalt content does not meet the specifications. VIM values at 5%, 6.5% and 7% asphalt content did not meet the specifications. VMA values at 5%, 6.5% and 7% asphalt content did not meet the specifications. The VFA value at 5% asphalt content does not meet the specifications.

Table 6. Marshall Parameter Analysis Results with Zeolite

Parameter *Marshall*	Kadar Aspal					Spesifikasi	
	5%	5,5%	6%	6,5%	7%	Min	Maks
Stabilitas (kg)	1193,71	1224,89	1430,74	1222,25	1191,07	800	-
Flow (mm)	3,68	3,52	3,35	3,66	3,75	2	4
VIM (%)	9,78	8,60	4,88	4,98	7,12	3	5
VMA (%)	16,86	16,69	15,08	15,29	17,98	15	-
VFA (%)	42,18	48,64	67,68	67,46	60,52	65	-

Based on Table 6 shows that the stability value and flow value meet the specifications at 5%-7% asphalt content. VIM values at 5%, 5.5% and 7% asphalt content did not meet the specifications. The VMA value meets the specifications at 5%-7% asphalt content. VFA values at 5%, 5.5% and 7% asphalt content did not meet the specifications.

3.3 Correlation of Asphalt Content and Marshall Parameters

Based on the results of data analysis in Tables 4, 5, and 6, the following is a graph of the relationship between asphalt content and marshall parameters (stability values, flow, VIM, VMA, VFA).

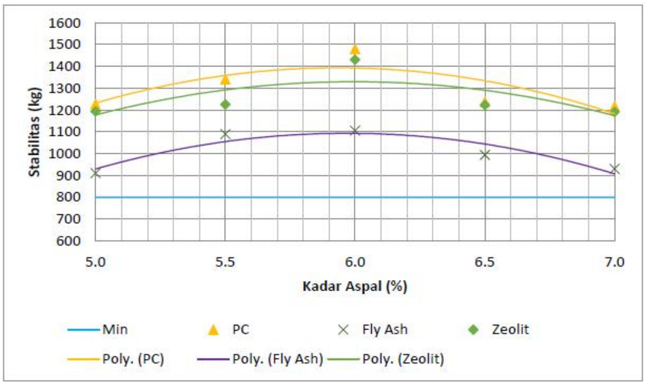

Figure 1. Correlation between Asphalt Content and Stability

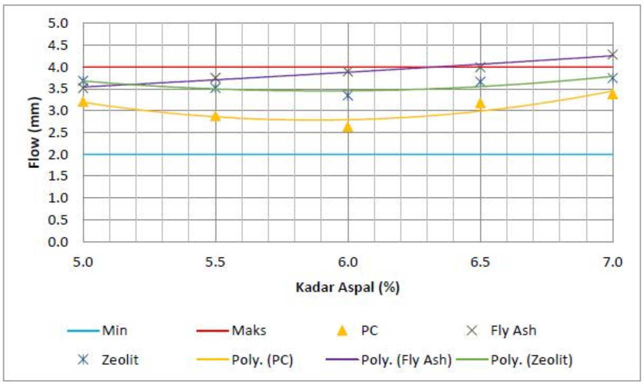

Figure 2. Correlation between Asphalt Content and Flow

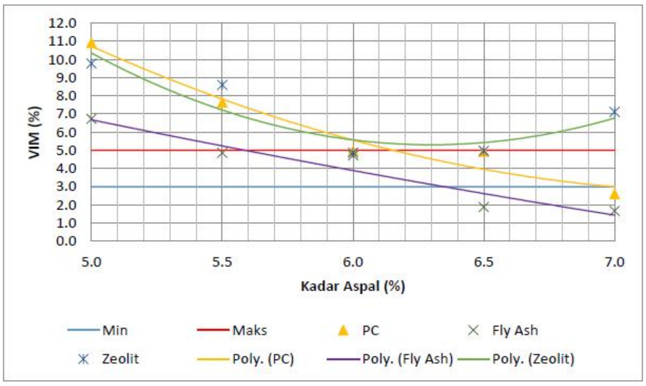

Figure 3. Correlation between Asphalt Content and VIM

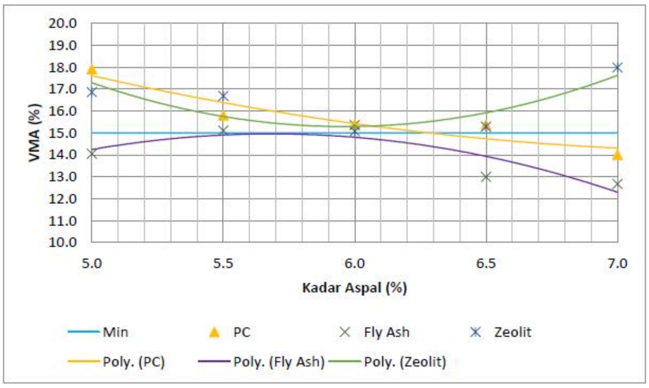

Figure 4. Correlation between Asphalt Content and VMA

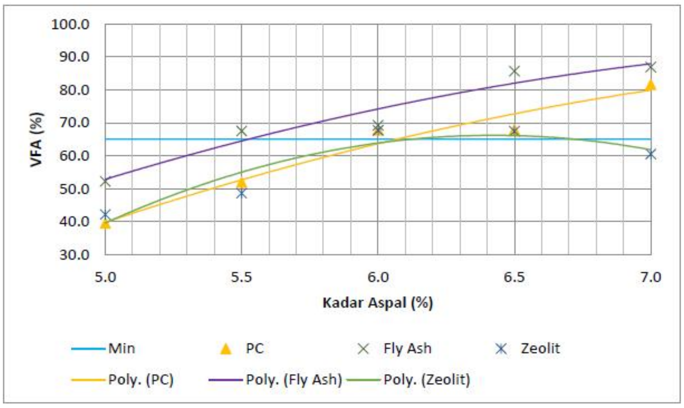

Figure 5. Correlation between Asphalt Content and VFA

3.4 The Difference Between PC Filler, Fly Ash, Zeolite to Marshall Parameter Value

Statistical analysis in this study is presented in the form of an analysis of whether there is a significant difference or not between filler PC, fly ash, zeolite on the results of Marshall parameters including stability, flow, VIM, VMA, and VFA values. Statistical tests used to determine differences between groups of variables are the One Way Anova test if the data is normally distributed and the Kruskal-Wallis test if the data is not normally distributed (an alternative to the One Way Anova test). Hypothesis testing is done between filler PC, fly ash, zeolite with stability, flow, VIM, VMA, VFA. The hypothesis in this study is Ho: $\mu_1 = \mu_2 = \mu_3$; Ha: $\mu_1 \neq \mu_2 \neq \mu_3$.

Table 7. Recapitulation of Inferential Statistical Analysis Results

Parameter *Marshall*	Sig.		α
	Uji Hipotesis	*Post Hoc Test*	
Stabilitas	0,006	0,006	0,05
Flow	0,001	0,001 0,016	
VIM	0,182	-	
VMA	0,036	0,033	
VFA	0,267	-	

Based on these results, it shows that there is a significant difference in the average value of stability, flow, and VMA between PC filler, fly ash and zeolite because Sig < 0.05, a further test (post hoc test) is needed. There is no difference in the average value of VIM and VFA between filler PC, fly ash and zeolite significantly because Sig > 0.05. **NB**: hasil harus merujuk perpoint berdasarkan rumusan masalah di dalam penelitian

4. DISCUSION

1.1 Marshall Characteristics of AC-WC Mixture with PC Filler, Fly Ash and Zeolite

Figure 1 shows a graph of the relationship between asphalt content and stability. Based on the graph, it shows that in the specimens with PC filler, fly ash and zeolite in general there is an increase in the stability value up to 6% asphalt content. The ultimate condition that occurs is reached up to 6% asphalt content but after that there is a decrease in the stability value. This indicates that the test object with the three fillers gives maximum results if given a mixture with an asphalt content of 6%. However, if the asphalt content exceeds this limit, it will not give significant results because the stability value will tend to decrease. The decrease in the stability value is because the test object contains too much asphalt which causes the mixture to become soft, flexible, easily deformed so that this will result in bleeding conditions and a decreased stability value. These results are in accordance with the theory of the relationship between asphalt content and stability value according to Sukirman (2007) stability will increase with increasing asphalt content until it reaches the maximum value, then stability will decrease.

Figure 2 shows that the flow value of the test specimens with PC filler, fly ash and zeolite in general tends to increase with increasing asphalt content. This indicates that inversely proportional to the stability graph, the lower the flow value, the higher the stability value which causes the pavement to crack easily due to vehicle loads. This result is in accordance with the theory of the relationship between asphalt content and flow value, according to Sukirman (2007), the melt or flow will continue to increase with increasing asphalt content. Asphalt mixtures that have high flow values with low stability tend to be plastic and easily change shape when subjected to loading.

Figure 3 shows that the value of air voids in the mixture (VIM) on specimens with PC filler, fly ash and zeolite in general tends to decrease in value with increasing asphalt content. This is because at each addition of asphalt content, asphalt is still easy to enter into the cavities between the aggregate grains in the mixture which makes the mixture denser and denser so that the VIM value decreases. This condition is in accordance with the research of Putrowijoyo (2006), the value of VIM decreases with increasing asphalt content. This result is also in accordance with the theory of the relationship between asphalt content and VIM value, according to Sukirman (2007), the curve of the VIM graph will continue to decrease with increasing asphalt content until it ultimately reaches the minimum value.

Figure 4 shows that the value of air voids between aggregates (VMA) on specimens with PC filler, fly ash and zeolite generally tends to decrease with increasing asphalt content. This can be influenced by the compaction factor during the process of pounding the test object and the increasing asphalt content. This condition is not in accordance with the research of Putrowijoyo (2006) where the VMA value is unstable, namely as the asphalt content increases, the VMA value decreases then rises and then decreases and rises again.

Figure 5 shows that the value of voids filled with asphalt (VFA) on specimens with PC filler, fly ash and zeolite in general tends to increase with increasing asphalt content. This is because the asphalt is increasing so that the amount of asphalt that can envelop the aggregate in the mixture is also getting bigger and the voids filled with asphalt are increasing. This result is in accordance with the VFA chart at the Directorate General of Highways (2006) that the VFA curve increases with increasing asphalt content.

1.2 Comparison of the Strength of AC-WC Mixture Judging from the Marshall Parameter Results between PC Filler, Fly Ash and Zeolite

Based on the results of statistical tests obtained the value of Sig. for stability is 0.006 smaller than = 0.05. So, it can be concluded that Ho is rejected and Ha is accepted, which means that at the asphalt content of 5%, 5.5%, 6%, 6.5%, 7% between filler PC, fly ash, zeolite there is a significant difference in the average value of stability value. The results of the post hoc test showed that there was a significant difference between fly ash and PC fillers due to differences in composition and percentage of chemical constituents which caused a significant difference in the average stability value between the two fillers.

Based on the results of statistical tests obtained the value of Sig. for flow is 0.001 smaller than = 0.05. So, it can be concluded that Ho is rejected and Ha is accepted, which means that at the asphalt content of 5%, 5.5%, 6%, 6.5%, 7% between filler PC, fly ash, zeolite there is a significant difference in the average value. to the flow value. The post hoc test results showed that there was a significant difference between PC filler with fly ash and PC with zeolite because the mixture using PC filler had stiffer properties than the mixture using fly ash or zeolite filler, causing a significant difference in the average flow value. between the PC and the two fillers.

Based on the results of statistical tests obtained the value of Sig. for VIM is 0.182 greater than = 0.05. So it can be concluded that Ho failed to be rejected, which means that at the asphalt content of 5%, 5.5%, 6%, 6.5%, 7% between filler PC, fly ash, zeolite there is no significant difference in the average value of the VIM. This is because in PC filler, fly ash, zeolite the VIM value produced is almost the same, this is due to good interlocking or bonding between aggregate grains in the mixture so that it is able to fill air cavities.

Based on the results of statistical tests obtained the value of Sig. for VMA is 0.036 less than = 0.05. So it can be concluded that Ho is rejected and Ha is accepted, which means that at the asphalt content of 5%, 5.5%, 6%, 6.5%, 7% between filler PC, fly ash, zeolite there is a significant difference in the average value of VMA value. The results of the post hoc test showed that there was a significant difference between fly ash and zeolite fillers.

Based on the results of statistical tests obtained the value of Sig. for VFA is 0.267 greater than = 0.05. So it can be concluded that Ho failed to be rejected, which means that at the asphalt content of 5%, 5.5%, 6%, 6.5%, 7% between filler PC, fly ash, zeolite there is no significant difference in the average value of the VFA. This is because the three fillers are equally able to provide greater impermeability to the mixture so that it will produce VFA values that are not much different.

5. CONCLUSION

Based on the results and discussions that have been presented, several conclusions can be drawn. The stability value of the three types of fillers increased along with the increase in asphalt content to a maximum point of 6% asphalt content and then decreased to 7% asphalt content with the highest average stability value, namely PC filler of 1299.69 kg, then zeolite filler of 1252.53 kg, followed by fly ash filler of 1005.68 kg. Flow values for all types of fillers tend to increase with increasing asphalt content with the highest average flow value, namely fly ash filler of 3.89 mm, then zeolite filler of 3.59 mm, followed by PC filler of 3.06 mm. The value of air voids in the resulting mixture (VIM) tends to decrease with increasing asphalt content with the highest average VIM value being zeolite filler of 7.07%, then PC filler of 6.21%, followed by fly ash filler of 3.97 %. The value of air voids between aggregates (VMA) tends to decrease with increasing asphalt content with the highest average VMA value being zeolite filler of 16.38%, then PC filler of 15.69%, followed by fly ash filler of 14.04%. The value of the cavity filled with asphalt (VFA) tends to increase with increasing asphalt content with the highest average VFA value, namely fly ash filler of 72.30%, then PC filler of 61.77%, followed by zeolite filler of 57.30%.

There is a significant difference in the average value of stability, flow, and VMA between PC filler, fly ash and zeolite. The difference for the stability value is in the fly ash filler with PC, while for flow, namely PC with fly ash and PC with zeolite, for

VMA, namely fly ash with zeolite. There is no significant difference between the VIM and VFA values between PC filler, fly ash and zeolite.

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