CHARACTERISTICS ANALYSIS OF AC-WC MIXTURE WITH POLYVINYL CHLORIDE (PVC) ADDITIONAL INGREDIENTS ON MARSHALL PARAMETERS

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Abstract: PVC waste management is often a problem, and this happens because PVC is a material that cannot be decomposed naturally. Therefore, innovation is needed to dispose of large amounts of PVC waste. One way is to turn the waste into an additive to the asphalt mixture. Adding PVC into asphalt can improve its performance, namely by increasing its softening point value so that asphalt can resist weather changes. This study aims to: (1) Describe the characteristics of the AC-WC mixture without adding PVC in terms of Marshall parameters. (2) describe the characteristics of the AC-WC mixture with the addition of PVC in terms of Marshall parameters. (3) Determine the optimum level of PVC added to the AC-WC pavement mixture. (4) Determine the value of residual strength index (IKS) in the AC-WC mixture with the addition of PVC. PVC material is mixed into the asphalt with variations in the addition of PVC of 0%, 2%, 4%, 6%, 8%, and 10% by weight of the asphalt, and then the Marshall test is carried out. Next, the IKS test specimens were made with optimum bitumen and PVC content, and the Marshall test was carried out. The results of this study showed: (1) The characteristics of the AC-WC mixture without the addition of PVC were that the stability value increased up to 6% and decreased at 6.5% and 7% asphalt content. Meanwhile, the value of flow and VFA has increased. The VIM value decreased, as did the VMA value, which decreased at 5.5% and increased at the next level. (2) The characteristic of the AC-WC mixture with the addition of PVC is that the stability value increases by adding up to 4% PVC content but decreases at 6% to 10%. Flow, VIM, and VMA values increase as the PVC content increases, but VFA values tend to decrease. (3) The optimum level of PVC addition is found at 4.2% by weight of asphalt. (4) The mixture with the addition of 4.2% PVC has a higher IKS value than the mixture without the addition of PVC. This indicates that the AC-WC mixture with the addition of PVC can have better temperature and water resistance compared to the AC-WC mixture without adding additives.
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Keywords : *polyvinyl chloride*, *asphalt concrete-wearing course*, Marshall parameters

1. INTRODUCTION

It is common to find road pavement layers damaged before reaching the service life limit according to the plan (Ing&Riana, 2019). One reason is the volume of traffic which increases yearly in terms of the number of vehicles and the load of the cars themselves. Other causes are climatic conditions and drainage system dysfunction (Pandey, 2013). Indonesia has a tropical climate which has high air temperatures and high rainfall. High rainfall and poor drainage system resulted in puddles on the road lining. This can cause the pavement to be exposed to water frequently and affect its durability (Attamimi, dkk., 2021). This is indicated by a decrease in the residual strength index (IKS) value. To prevent this problem, innovation is needed in road planning to improve the quality of the resulting roads (Handayasari, dkk., 2020). One of the pavement modifications is adding additional materials in the form of polymers or plastics (Hadid, dkk., 2020). Adding polymeric materials with high adhesiveness can also produce asphalt mixtures with high adhesiveness (Linggo & Kurniawan, 2015).

Plastic materials are grouped into several types based on constituent materials. These types are polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), poly methyl methyl acrylate (PMMA), acrylonitrile butadiene styrene (ABS), polyamide (PA), as well as polyester (Ermawati, 2011). The continuous use of plastic results in an increase in the amount of plastic waste. The Director General of PSLB3 of the Ministry of Environment and Forestry said that the amount of plastic waste in 2021 nationally will reach 11.6 million tons or around 17% of the total waste in Indonesia. This number has increased, where in 2010, the amount of plastic waste was 11%. (CNN Indonesia, 26 Februari 2022). Based on data from Jambeck, dkk. (2015), Indonesia is the world's second-largest producer of plastic waste, reaching 187.2 million tonnes.

PVC waste management is often a problem, and this happens because PVC is a material that cannot be decomposed naturally. Burning activities will harm the environment, such as air pollution, especially carcinogenic dioxin emissions (Rachmat, dkk., 2013). The most appropriate way to overcome this problem is to do recycling, but this process will only change the waste into a new form, not overwhelm the volume. If a recycled product experiences a loss of function, the product will regenerate back into the trash (Wahyudi, dkk., 2018). Therefore, innovation is needed to dispose of large amounts of PVC waste. One way is to turn the waste into an additive to the asphalt mixture (Hasyim, 2020).

The addition of PVC waste is considered to be able to overcome waste problems and improve asphalt quality. PVC is a type of plastomer polymer, which when added to asphalt, will increase the softening point value of asphalt to produce asphalt that has resistance to weather changes. (Sistra, dkk., 2016; Suparma, dkk., 2015). Mashuri (2009), in his research, revealed that the addition of PVC powder to the asphalt mixture could increase the softening point of the modification. This causes asphalt to have better temperature resistance. Rahman, dkk., (2013) revealed that a pavement mixture added with 10% Polyethylene waste and 7.5% PVC could be used for flexible pavement construction from the standpoint of stability, stiffness, and voids. Whereas in the study, the addition of PVC waste to the asphalt-treated base (ATB) mixture resulted in an increase in the stability value of the mix with a stability value of 1004.83 Kg at 4.98% PVC content so that it was feasible to be used as ATB mixture (Rizky, dkk., 2017).

2. METHOD

This research was conducted at the Road Pavement Laboratory, State University of Malang. The materials used in this study are aggregates obtained from PT. Welang Ampuh Kali Batu, 60/70 penetration asphalt, Portland Cement (PC) filler with Tiga Roda brand, and PVC waste from PVC pipe waste with type D and 1 ½" diameter with Rucika brand.

This research was divided into three stages: the material testing stage, the preparation stage of the test object and the Marshall test, and the analysis stage. Material testing includes aggregate testing, filler testing, and asphalt testing. Aggregate testing includes testing coarse and fine aggregates' specific gravity and absorption. Filler testing comprises testing the specific gravity of the filler. Asphalt testing includes testing for specific gravity, penetration, softening, flash and burn points, ductility, and weight loss.

The stage of making the test object consists of three parts. The first part is making a test object to determine the KAO value with asphalt content of 5%, 5.5%, 6%, 6.5%, and 7%. After obtaining the KAO value, proceed with manufacturing test objects with the addition of PVC, with variations in PVC content of 0%, 2%, 4%, 6%, 8%, and 10%.

The preparation of the test object was carried out using the wet mixing method. Then proceed with making IKS test objects using KAO and KPO values.

The analysis is carried out at this stage to determine the Marshall parameter values. This stage includes stability, flow, marshall quotient, VIM, VMA, and VFA. The stability and flow values were obtained from the Marshall test results, while the VIM, VMA, and VFA values were obtained based on calculations.

3. RESULT

Aggregate and filler test results data are presented in Table 1.

Table 1. Aggregate and Filler Test Results

No	Test	Unit	Method	Result	Specification Min	Specification Max
1	Bulk Coarse Aggregate Specific Gravity	gr/cm³	SNI 03-1969-2008	2,71	2,5	-
2	SSD Coarse Aggregate Specific Gravity	gr/cm³	SNI 03-1969-2008	2,81	2,5	-
3	Specific Gravity of Pseudo Coarse Aggregate	gr/cm³	SNI 03-1969-2008	2,89	2,5	-
4	Coarse Aggregate Absorption	%	SNI 03-1969-2008	2,21	-	3
5	Specific Gravity of Bulk Fine Aggregate	gr/cm³	SNI 03-1970-2008	2,58	2,5	-
6	SSD Fine Aggregate Specific Gravity	gr/cm³	SNI 03-1970-2008	2,5	2,5	-
7	Specific Gravity of Pseudo Fine Aggregate	gr/cm³	SNI 03-1970-2008	2,58	2,5	-
8	Fine Aggregate Absorption	%	SNI 03-1970-2008	2,80	-	3
9	Aggregate Wear	%	SNI 03-2417-2008	12,47	-	40
10	Filler Specific Gravity	gr/cm³	SNI 03-2351-1991	3,11	-	-

The results of the 60/70 penetration asphalt test are presented in Table 2, while the data on the modified asphalt testing results with the addition of PVC are shown in Table 3.

Table 2. Asphalt Pen 60/70 Test Results

No	Test	Unit	Method	Result	Specification Min	Specification Max
1	Specific gravity	gr/cm³	SNI 2441-2011	1,035	1,0	-
2	Penetration	0,1 mm	SNI 2456-2011	64,4	60	70
3	Soft point	°C	SNI 2434-2011	48,05	48	-
4	Ductility	cm	SNI 2432-2011	146,33	100	
5	Flash and Burn Point	°C	SNI 2433-2011	Flash Point = 330 Burn Point = 338	232	-
6	Weight Loss	%	SNI 09-2441-1991	0,0035	-	0,8

Table 3. Asphalt Testing Results with the Addition of PVC

Pengujian	Satuan	PVC Waste Content (%)						Spesifikasi	
		0	2	4	6	8	10	Min	Max
Specific gravity	gr/cm³	1,035	1,051	1,052	1,055	1,065	1,066	1,0	-
Penetration	0,1 mm	65,3	61,4	50,4	46,9	38,8	37	60	70
Soft point	°C	48,05	48,1	48,6	49,5	51,6	52,2	48	-
Ductility	cm	146,33	140,9	136,6	84	56,3	18	100	-
Flash and Burn Point Flash Point = Burn Point =	°C	 330 338	 297 307	 288 302	 282 298	 278 296	 274 288	232	-
Weight Loss	%	0,00350	0,00532	0,01081	0,04058	0,09520	0,20728	-	0,8

Marshall parameter data consists of stability and flow derived from Marshall testing and VIM, VMA, and VFA data derived from calculations. Marshall Parameter Data is presented in Table 4.

Table 4. Marshall Parameters for Determining KAO

Marshall Parameters	Unit	Asphalt Content (%)					Specification	
		5	5,5	6	6,5	7	Min	Max
Stability	kg	858	974	1012	1001	994	800	-
Flow	mm	3,01	3,47	3,71	3,76	4,49	2	4
VIM	%	6,74	4,69	3,93	3,45	3,05	3	5
VMA	%	16,99	16,23	16,62	17,25	17,95	15	-
VFA	%	60,56	71,58	76,62	80,05	83,09	65	-

Based on Table 4, the AC-WC mixture has an optimum asphalt content (KAO) of 6% of the total aggregate weight. This KAO value is then used as asphalt content in the manufacture of mixtures with the addition of PVC. Parameter data for the Marshall mixture of AC-WC with the addition of PVC is presented in Table 5.

Table 5. Marshall AC-WC Parameter Data with the Addition of PVC

Marshall Parameters	Unit	PVC Waste Content (%)						Specification	
		0	2	4	6	8	10	Min	Max
Stability	kg	1012	1106	1284	1203	1135	1110	1000	-
Flow	mm	3,71	3,72	3,74	3,77	3,80	4,24	2	4
VIM	%	3,32	3,66	3,79	4,84	4,86	5,29	3	5
VMA	%	16,09	16,21	16,31	17,19	17,10	17,46	15	-
VFA	%	79,75	77,47	76,89	71,88	71,72	69,74	65	-

Preparation of test specimens to determine the IKS value using the optimum asphalt (KAO) and optimum PVC content (KPO) values. The test results data are presented in Table 6.

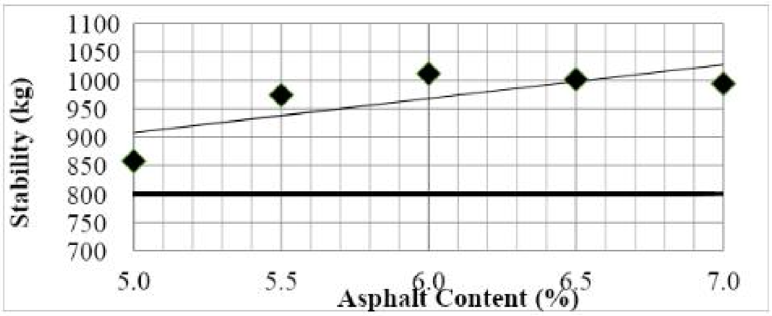
Table 3. IKS Test Result Data

	Asphalt Content (%)	PVC Waste Content (%)	Immersion Time	Stability (kg)	IKS (%)
KAO	6	-	30 minutes	1012	92,49
KAO	6	-	24 hours	936	
KPO	6	4,2	30 minutes	1284	93,07
KPO	6	4,2	24 hours	1195	

4. DISCUSSION

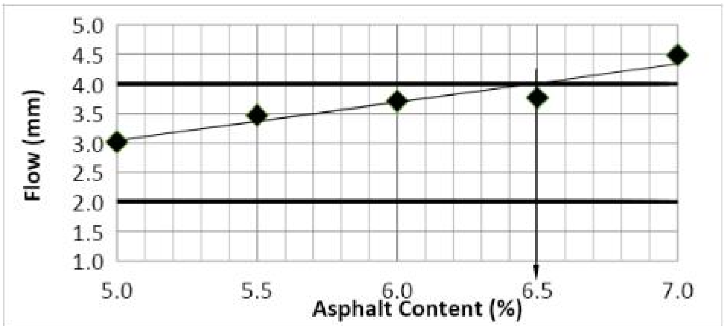
The AC-WC marshall parameters without the addition of PVC are shown in Table 4. These Marshall parameters include stability, flow, VIM, VMA, and VFA. The Marshall parameter values must meet the 2018 Bina Marga specifications. Based on the data in

Table 4, the parameter values are poured into a graph of the relationship between bitumen content and Marshall parameters.



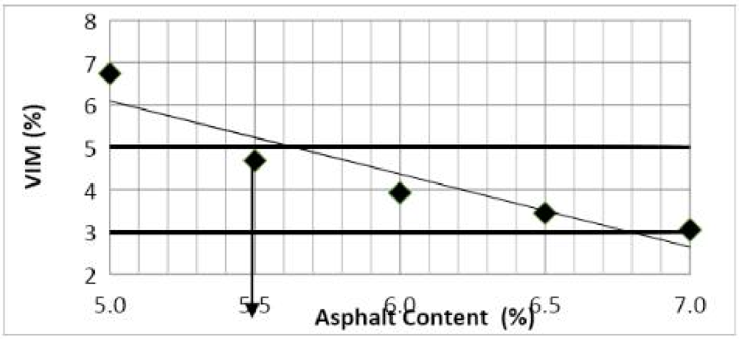
Picture 1. Relationship between Asphalt Content and Stability

Picture 1 shows the relationship between bitumen content and the stability value of the AC-WC mixture with the addition of PVC. Based on the Picture, the stability value increases from 5% to 6%, and the stability value decreases at 6.5% and 7% asphalt content. The stability values above align with the statement (Sukirman, 2016), that the stability value will increase in line with the increase in the asphalt content value. This is because asphalt functions as a lubricant when compaction is carried out, so the bonds between aggregates become good. However, the stability value will decrease when the asphalt content increases, and the stability has reached its maximum value. This is because the asphalt that fills the voids becomes more, and the bond between the aggregates becomes weaker.



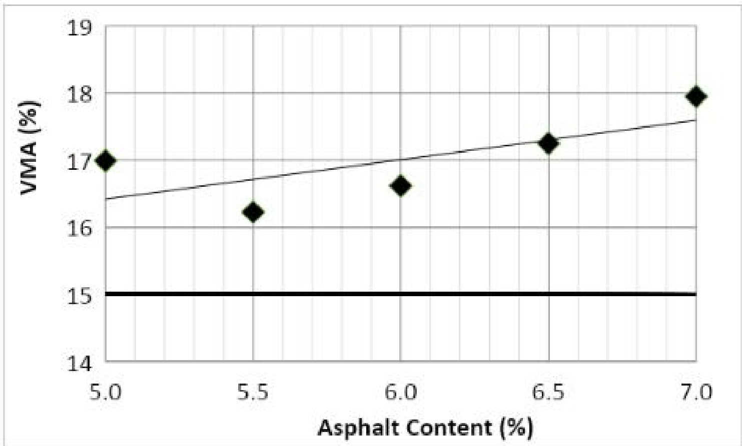
Picture 2. Relationship between Asphalt Content and Flow

Picture 2 shows the relationship between asphalt content and flow values. Based on the Picture, the flow value increases with increasing asphalt content. Increasing the asphalt content will result in more asphalt covering the aggregate, resulting in a longer fatigue life so that the mixture will follow the shape change better when loading occurs (Iskandar, dkk., 2016). At an asphalt content of 5% - 6.5%, the flow value meets the 2018 Bina Marga specifications, which is 2 - 4 mm.



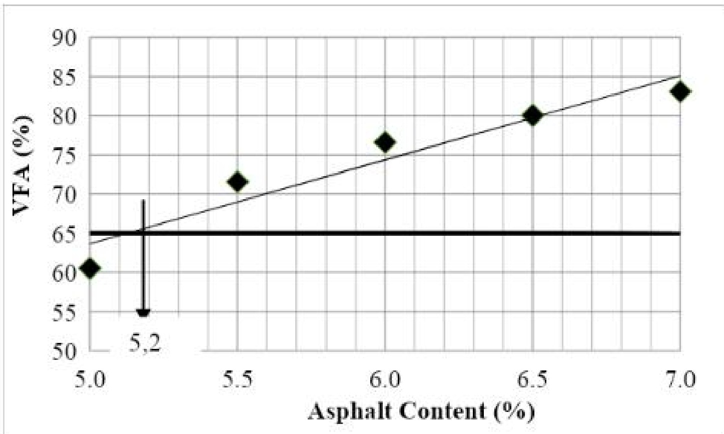
Picture 3. Relationship between asphalt content and VIM

Picture 3 shows the relationship between bitumen content and VIM values. Based on the Picture, the VIM value decreases as the asphalt content increases. This is caused by the higher the asphalt content, and the more asphalt will fill the voids in the mixture so that the voids become smaller (Wardana, dkk., 2020).



Picture 4. Relationship between asphalt content and VMA

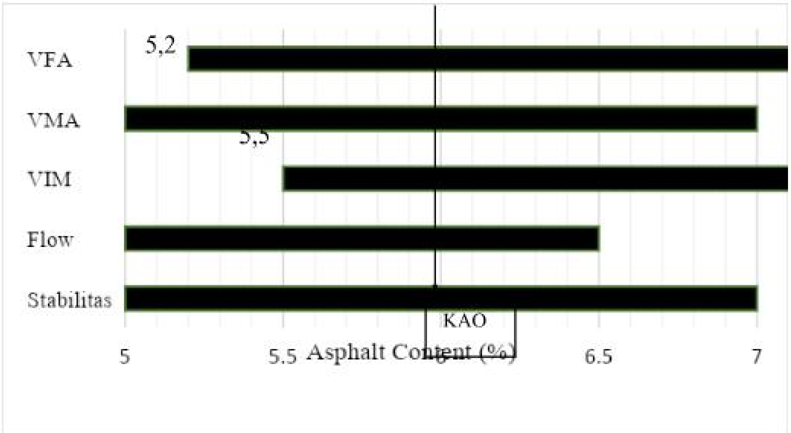
Picture 4 shows the relationship between PVC levels and VMA values. Based on the Picture, the VMA value decreased at 5.5% and increased later, in line with the increase in asphalt content. This is due to the increasing asphalt content, the thicker the asphalt blanket the VMA value becomes higher (Sukirman, 2016).



Picture 5. Relationship between Asphalt Content and VFA

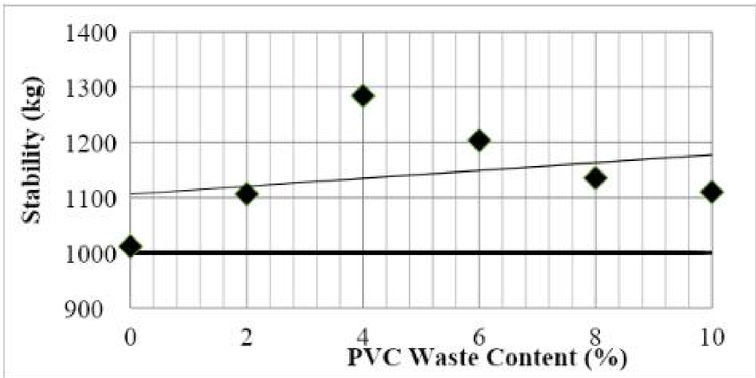
Picture 5 shows a graph of the relationship between PVC levels and VFA values. Based on the Picture, the VFA value tends to increase as the asphalt content increases. The more bitumen content added to the mixture, the more cavities filled with asphalt (Wardana, dkk., 2020).

Based on data analysis on each Marshall parameter, it was determined that the optimum asphalt content value obtained was 6%. This value is obtained based on Marshall parameter values that meet specifications, including stability, flow, VIM, VMA, and VFA. These values are then poured into interaction diagrams. The interaction diagram is shown in Picture 6.



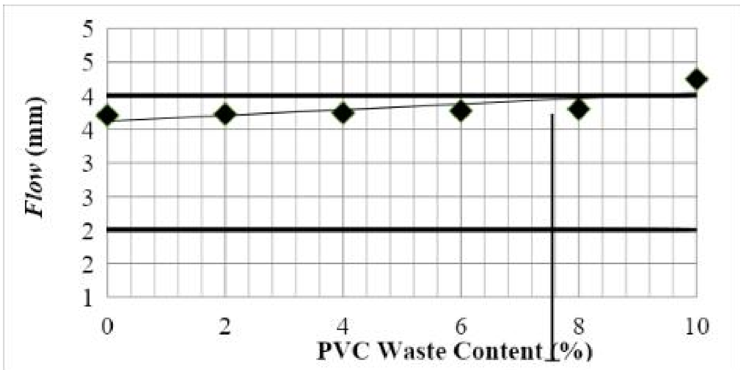
Picture 6. AC-WC Mixed Interaction Diagram

The KAO value of 6% is then used as asphalt content in the manufacture of mixtures with the addition of PVC. The results of testing the AC-WC mix with the addition of PCV are presented in Table 5. Based on these data, the parameter values are poured into a graph of the relationship between PVC content and Marshall parameters.



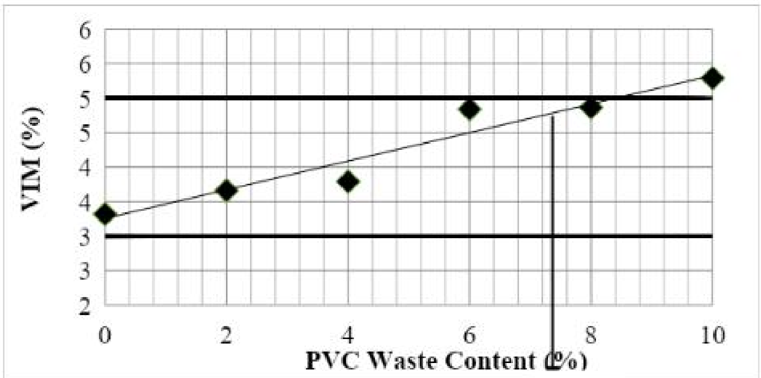
Picture 7. Relationship between PVC Content and Stability

Picture 7 shows the relationship between PVC content and the stability value of the AC-WC mixture with the addition of PVC. Based on the Picture, the stability value increases as the PVC content increases until it reaches the maximum stability value and decreases with subsequent additions of PVC. The increase in stability value occurs at levels of 2% and 4%. This happens because the asphalt added with PVC at this level can lubricate the aggregate properly so that the bond between the aggregates becomes good. If the mixture is loaded, the aggregate position will not shift quickly and increase the stability value. However, the stability value decreased at 6%, 8%, and 10% when the mixture experienced the highest stability. This happens because when the PVC content increases, the asphalt becomes more viscous and causes the asphalt-covered aggregate to become very thick so that the mixture becomes soft and the bond between the aggregates weakens. If the mixture is loaded, the aggregate will quickly shift, and deformation occurs, resulting in decreased stability value. The stability value increases by around 9% – 27%. The highest stability occurred in the addition of PVC with a content of 4% of 1284 kg. On the other hand, the lowest stability occurred when 1012 kg of PVC was added with 0% content.



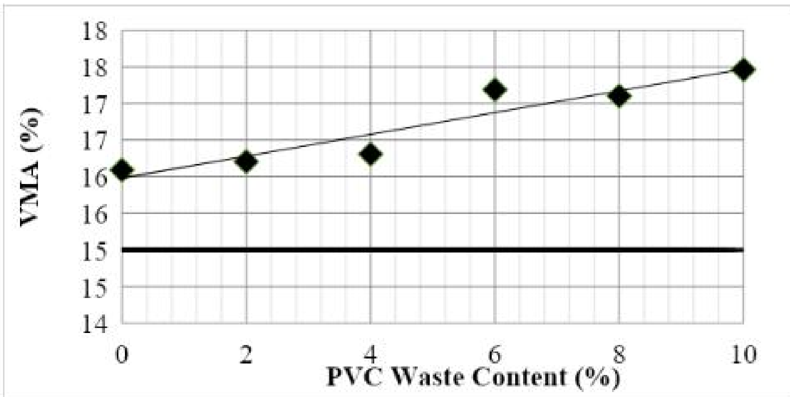
Picture 8. Relationship between PVC content and flow

Picture 8 shows the relationship between PVC content and flow value. Based on the Picture, the flow value increases as the PVC content increases. The plastic nature of PVC causes the mixture to easily change shape so that the deformation due to load will increase (Pratama, dkk., 2018). At a PVC content of 0% - 8%, the flow value meets the 2018 Bina Marga specifications, which is 2 - 4 mm.



Picture 9. Relationship between PVC content and VIM

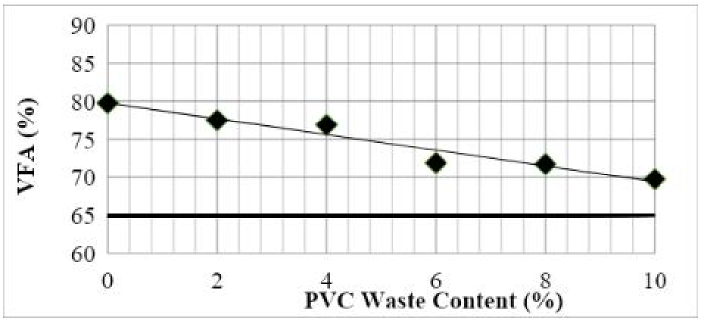
Picture 9 displays the relationship between PVC content and VIM value. Based on the Picture, the VIM value increases as the PVC content increases. This is caused by the higher the PVC content added to the asphalt, the thicker the asphalt produced, so a lot of asphalt cannot fill the voids in the mixture, so the voids in the mix become bigger (Rahmawati, 2015). The highest VIM value was found at 10% PVC content, which was 5.29%. A high VIM value will cause a decrease in the impermeability of asphalt concrete resulting in increased oxidation, accelerating asphalt aging, and reducing the durability of asphalt concrete (Sukirman, 2016). Based on the research results, the VIM value that meets the 2018 Bina Marga specifications lies in the PVC content of 0% - 8%, with a value between 3 - 5%.



Picture 10. The relationship between PVC content and VMA

Picture 10 shows the relationship between PVC levels and VMA values. Based on the Picture, the VMA value increases as the PVC content increases to 6% and decreases at 8%, then increases again at 10%. The VMA value can be affected by the asphalt ductility value. In Table 3, the data shows that the value of ductility decreases with increasing PVC content. The lower the ductility value, the higher the VMA value. This is caused by the more down the ductility value, the stiffer the asphalt will be so that the bonding capacity of the asphalt with the mineral aggregate will weaken. This resulted in the value of the VMA getting bigger (Hasyim, 2020).

Based on these data, it can be concluded that all asphalt content has a VMA value that meets the 2018 Bina Marga specifications, with a minimum VMA value of 15%.

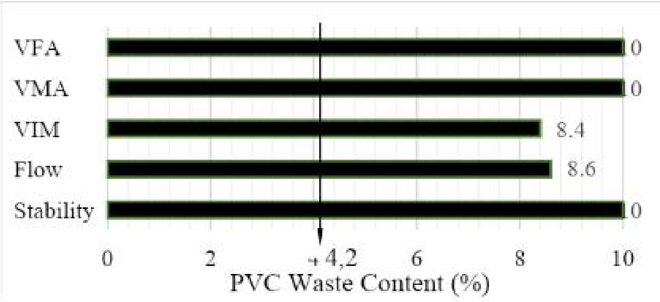


Picture 11. Relationship between PVC and VFA levels

Picture 11 shows a graph of the relationship between PVC levels and VFA values. Based on the Picture, the VFA value tends to decrease as the PVC content increases. Based on these values, it can be seen that the VFA value tends to decrease as the PVC content increases. This is due to the decrease in penetration value and ductility in line with the increase in PVC content, thus making asphalt more rigid or brittle. Rigid asphalt causes asphalt not to flow freely, so the cavities cannot be filled properly (Linggo and

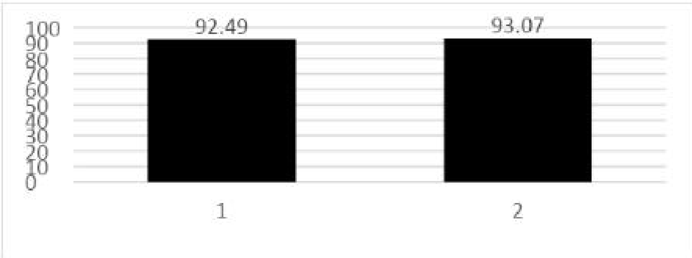
Kurniawan, 2015). All VFA values meet the 2018 Bina Marga specifications, with a VFA value of ≥65%.

Based on data analysis on each Marshall parameter, it was determined that the optimum PVC content obtained was 4.2%. This value is obtained based on Marshall parameter values that meet specifications, including stability, flow, VIM, VMA, and VFA. These values are then poured into the interaction diagram. The interaction diagram is presented in Picture 12.



Picture 12. Marshall AC-WC Parameter Interaction Diagram with the Addition of PVC

Furthermore, the manufacture of test specimens to determine the IKS value is carried out using the optimum asphalt (KAO) and PVC content (KPO). The test results data are presented in Table 6, as outlined in the comparison chart in Picture 13.



Gambar 1. Grafik Perbandingan IKS

The IKS value in the AC-WC mixture without adding PVC was 92.49%, while the IKS value in the AC-WC mix with the addition of 4.2% PVC was 93.06%. The two IKS values meet the 2018 Bina Marga specifications, namely the minimum IKS value is 90%. Based on the above research results, the mixture with the addition of PVC has a higher IKS value than the mixture without the addition of PVC. This shows that the AC-WC mix with the addition of PVC can have better temperature and water resistance compared to the AC-WC mix without the addition of additives. This indicates that adding PVC to the AC-WC mixture can increase the mixture's durability (Fatmawati, dkk., 2022).

5. CONCLUSION

Characteristics of the AC-WC mixture without the addition of PVC to the Marshall parameter are the stability value of the AC-WC mixture increased to 6% and decreased to 6.5% and 7% asphalt content. Meanwhile, the value of flow and VFA has increased. The VIM value decreased, as did the VMA value, which decreased at 5.5% and increased at the next level. Based on these characteristics, the optimum bitumen content obtained is 6%.

The characteristic of the AC-WC mixture with the addition of PVC to the Marshall parameter is that the stability value increases by adding up to 4% PVC content but decreases at 6% to 10%. Flow, VIM, and VMA values increase as the PVC content increases, but VFA values tend to decrease. The optimum level of PVC addition is found at 4.2% by weight of asphalt.

The mixture with the addition of 4.2% PVC had a higher IKS value than the mixture without the addition of PVC. This indicates that the AC-WC mix with the addition of PVC can have better temperature and water resistance compared to the AC-WC mix without the addition of additives.

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