Jurnal Teknik Sipil & Perencanaan 24 (1) (2022) p 42 - 51

UNNES JOURNALS

JURNAL TEKNIK SIPIL & PERENCANAAN

10.15294/jtsp.v24i1.31913

Durability of Residual Strength on Ac-Wc Mixture Using Bottom Ash as Fine Aggregate Substitution

Irianto[1, a)], Didik S.S.Mabui[1, b)], Ardi Azis Sila[1, c)],

[1]*Civil Engineering Study Program, Faculty of Engineering and Information Systems, Yapis University Papua*

[a)] Corresponding author: irian.anto@gmail.com
[b)] didiksurya.m@gmail.com
[c)] ardi.azis.sila@gmail.com

Abstract. This study aims to determine the durability of the residual strength in the Asphalt Concrete – Wearing Course (AC-WC) mixture that uses bottom ash waste as a substitute for fine aggregate. The Marshall Test revealed that the stability value of all variations of the tested immersion met the minimum standard, which was greater than 800 kg, namely for the 0 hour immersion variation of 2170.75 kg, the 24-hour immersion variation of 2014, 62 kg, the immersion variation 48 hours of 1938.07 kg, variation of immersion 96 hours of 1853.45 kg, and the variation of immersion 168 hours of stability value obtained is 1747.68 kg. And for the residual strength index in the 24-hour immersion variation the residual stability index was obtained at 92.81%, for the 48-hour immersion variation the residual stability index was obtained at 89.33%, while for the 96-hour immersion variation the residual stability index was obtained at 85.38%. and for the variation of immersion 168 hours residual stability index was obtained at 80.51%, so that which meets the standard of at least 90% is the 24-hour variation.

Keywords: Patterns of settlement distribution, disaster-prone areas, Geographic Information System (GIS)

INTRODUCTION

Coal is an energy source for power generation or industrial fuel. Fly ash and bottom ash are produced when coal is burned [1]. Waste that is not managed properly will cause environmental damage. For this reason, it is necessary to process waste into usable materials. The use of bottom ash as a building material is one of them. The use of bottom ash to replace fine aggregate in road pavement is an innovation.

Water is one of the most common causes of road construction damage. Asphalt Concrete-Wearing Course (AC-WC) as a wear-resistant layer. AC-WC is a layer that is in direct contact with the load and the surrounding environment. It is designed according to specifications to make this coating waterproof, weatherproof and stable.

The study entitled "The Effect of Using Bottom Ash as Substitution of Fine Aggregate and Addition of Sika Fume as a Filler in Laston Ac-Wc" used bottom ash as fine aggregate as much as less than 10%, therefore in this study In this study, the researchers tried to replace the fine aggregate by using bottom ash as a whole to see the difference and the Marshall value obtained[2].

The use of asphalt retona blend 55 is still very rarely used in the construction of road infrastructure in Indonesia based on research by DS Mabui and irianto (2019) "Experimental Study of Marshall Characteristics of Ac-Bc Mix Using Asbuton Modified Type Retona Blend 55 as a Binding Material". The asphalt retona blend 55 as a binder in the AC-BC layer produces a fairly high Marshall value, therefore the researchers used asphalt retona blend 55 as a binder in the AC-WC layer[3].

LITERATURE REVIEW

Asphalt Concrete Wearing Course (AC-WC) Layers

Laston Asphalt concrete wearing course (AC-WC) is a pavement layer that comes into direct contact with vehicle tires and is waterproof, weather-resistant, and rough with a minimum thickness of 4 cm. The surface layer (Wearing Course) has the following functions [4].

Road Pavement Composition Material

Aggregates are grains of crushed stone, gravel, sand or other minerals both natural and artificial in the form of solid minerals in the form of large or small sizes or fragments.[5]

- Modified Buton Asphalt

Refinery Buton Asphalt (Retona) is Kabungka or Lawele asbuton which reduces the minerals in it (half-extracted using chemicals) and mixes them with bitumen. In addition, it can be liquefied in the AMP asphalt tank, and can be pumped into a mixer containing aggregate regardless of whether there is additional oil asphalt. [6]

- Bottom Ash

Bottom ash is a waste material generated during coal combustion in power plants. The particle size is larger and heavier than fly ash. Bottom ash falls to the bottom of the furnace (boiler) and is collected in the ash hopper (ash hopper) The water is taken from the stove and then disposed of or used as additives on the road surface. [7]

Marshall Test

Marshall test is a test method for measuring stability and flow, as well as density and porosity analysis, using a solid mixture formed by the Marshall instrument.[8]

- Stability

Stability is the ability of an asphalt mixture to accept a load until the occurrence of plastic melting which is expressed in kilograms. For stability values, the values shown on the watch need to be converted to Marshall instruments. The reading on the stability watch must be multiplied by the calibration value of the proving ring used on the Marshall instrument.[9]

- Flow

The flow value indicated by the watch hand on the Marshall tool. For the flow watch, the value obtained is already in mm, so there is no need to carry out further conversions

- Density

Volume weight or density is the ratio between the dry weight of the test object and its volume. To get the density value

- Marshall Quotient (MQ)

Marshall quotient is a comparison of stability value and flow value of marshall quotient

- Residual Strength Index

The Equation of Residual Strength Index on the Marshall Test can be seen in equation 1 below: [10]

$$IKS = \frac{s2}{s1} x100\% \quad (1)$$

with:

IKS = Residual Strength Index (%)
S_1 = The average value of Marshall stability without immersion T1 (Kg)
S_2 = The average value of Marshall stability after immersion T2 (Kg)

METHODOLOGY

This research was conducted at the Civil Engineering Laboratory, Faculty of Engineering and information systems, Yapis University, Papua, on the basis of using a hot asphalt mixing system Asphalt Concrete - Wearing Course (AC-WC). The Bina Marga Public Works Standards (2nd revision) from 2010 were used as the testing criteria. The steps to be taken in carrying out this research are the first stage, based on the estimated optimum asphalt content of 6.25% obtained from secondary data. irianto's research (2019) "Experimental Study of Marshall Ac-Bc Characteristics Using Modified Asbuton" [3] made specimens with the type of asphalt retona blend 55 with three samples of specimens for each variation of asphalt content with immersion 0 hours, 24 hours, 48 hours, 96 hours and 168 hours using bottom ash as fine aggregate. Then the standard Marshall test with 2x75 collisions and durability tests were carried out to determine VIM, VMA, VFA, density, stability, melting, Marshall quotient and residual stability index. From the relationship between asphalt content and Marshall parameters, it can be determined how much the durability index value is to be analyzed.

RESULT AND DISCUSSION

Results of Examination of Aggregate Characteristics

The aggregates plays a significant role in determining the strength of road pavements, aggregates that do not meet the specified specifications are not recommended to be used as materials on road pavements.

TABLE 4. Aggregate characteristic inspection results

No	Aggregate	Test Type	Test Type		Result
			Min	Max	
1	Coarse Aggregate	Bulk Density	2.5	-	2,705
		SSD Density	2.5	-	2,759
		Apparent Density	2.5	-	2,859
		Absorption	-	3	1,989
2	Fine Aggregate	Bulk Density	2.5	-	2,691
		SSD Density	2.5	-	2,74
		Apparent Density	2.5	-	2,830
		Absorption	-	3	1,833

Source: Laboratory test results 2021

Based on the results of testing the characteristics of the aggregate in the table 4, the aggregate material used in this study was visible crushed stone. The water absorption in the coarse aggregate is 1,989 and the fine aggregate is 1,833. This value still meets the specification limits for 2010 revision 3 of the bina marga with a maximum value of 3%, while the results of the filler test are as follows:

TABLE 5. Filler characteristic inspection results

No.	Inspection	Result Test	Spesification	
			Min	Max
1	Water Absorbtion	2.28	-	3.0
2	Bulk Density	2.59	2.5	-
	SSD Density	2.65	2.5	-
	Apparent Density	2.76	2.5	-

Source: Laboratory test results 2021

Based on the results of testing the characteristics of the filler in the table 5, in this case the filler material used is cement of 2.28, this value still meets the specification limits of Bina Marga 2010 revision 3 with a maximum value of 3%

Bottom Ash Characteristic Examination Results

Buttom ash is a waste material from the coal combustion process in a Steam Power Plant (PLTU) which has a heavier and larger particle size, while the characteristics of Buttom Ash are as follows:

TABLE 6. Bottom Ash Characteristic Examination Results

No.	Inspection	Result Test	Spesification	
			Min	Max
1	Water Absorbtion	0,594	-	3.0
2	Bulk Density	2,068	2.5	-

SSD Density	2,08	2.5	-
Apparent Density	2.093	2.5	-

Source: (Secondary Data) ITS Laboratory Test Results Report 2018

TABLE 7. Result of Chemical Composition of Bottom Ash

Chemical Composition	
Chemical elements	Test result (%)
CaO	0,43
SiO_2	0,24
Al_2O_3	4,35
Fe_2O_3	4,45
MgO	0,86
K_2O	0,25
Na_2O	0,21

Source: ITS Laboratory Test Results Report 2018

Table 7 shows that content contained in Buttom Ash contains the chemical element silica (SiO2) of 0.24%, alumina (Al2O3) of 4.35%, calcium oxide (CaO) of 0.43%, Iron (Fe2O3) of 4.45%, Magnesia (MgO) of 0.85%, Potash (K2O) of 0.25% and Soda (Na2O) of 0.21%.

Characteristics of Modified Buton Asphalt Blend 55

In flexible pavement, the binder material is asphalt. Buton asphalt modified by Retona Blend 55 was used in this study. The examination of asphalt characteristics aims to determine the physical properties of asphalt related to the performance of the asphalt itself. Table 8 shows the results of the examination of the characteristics of the modified Buton asphalt with Retona Blend 55:

TABLE 8. The results of the examination of the characteristics of the Retona Blend 55 modified Buton asphalt.

No	**Test**	**Results**	**Spesification**	
			Min	Max
1	Penetration before losing weight (mm)	78,6	60	79
2	Softening Point (°C)	52	48	58
3	Ductility at 25°C, 5cm/min (cm)	114	100	-
4	Flash point (°C)	280	200	-
5	Density	1,12	1	-
6	Weight loss (%)	0,3	-	0,8
7	Penetration After Losing Weight (mm)	86	54	-

Source: (Secondary Data) Irianto's Dissertation 2020

From the secondary data used, the results of the examination of the characteristics of the modified Buton asphalt Retona Blend 55 are shown in Table 8. It shows that the asphalt used in this study has met the specifications required by the Bina Marga for mixtures on road pavements. [3]

Mix Gradation Determination

Based on the aggregate composition obtained, the combined aggregate proportion WAS obtained from the comparison value of the planned aggregate composition multiplied by the percent pass value in the sieve analysis. Furthermore, the proportion of combined aggregate was adjusted to the value of the specification interval, as shown in Figure 1.

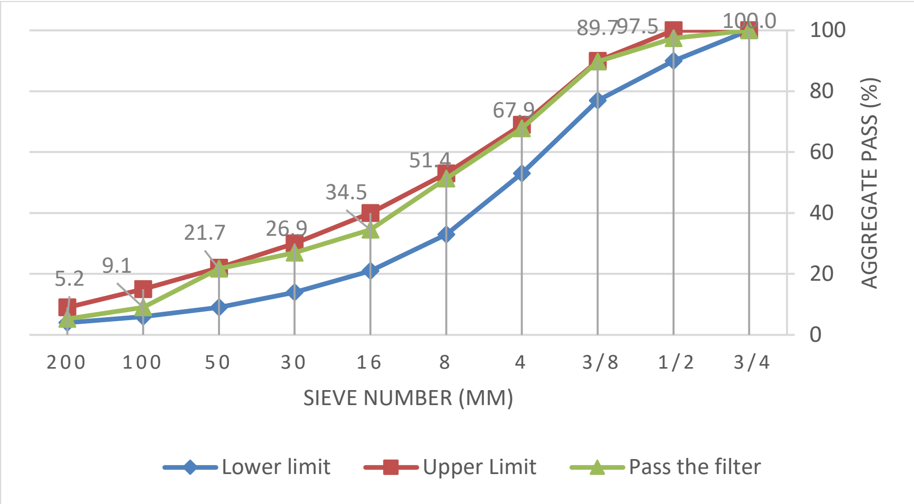

FIGURE 1. Asphalt Concrete Wearing Course (AC-WC) Combined Aggregate Mix Gradation

Mix Design

Based on the aggregate composition obtained, test specimens were made with variations in the content of asphalt content of Buton retona blend 55 of 6.25% of the total weight of the mixture. The following table shows the composition of each weight in the sieve:

TABLE 9. Material composition in weight for 1200gr test object

Description					
Optimum Asphalt Level				**Unit**	**6.25%**
Buton Asphalt Weight				**gr**	**75**
Sieve Size		**Combined Gradation**			**Aggregate Weight**
BS	**(mm)**	**% Get away**	**% stuck**		
37.5	1.1/2			gr	
25	1			gr	
19	3/4	100		gr	
12.5	1/2	97.47	2.53	gr	28.46
9.5	3/8	89.75	7.73	gr	86.85
4.75	4	67.86	21.89	gr	246.26
2.36	8	51.36	16.5	gr	185.63
1.18	16	34.53	16.83	gr	189.34
0.6	30	26.94	7.58	gr	64.04
0.3	50	21.75	5.2	gr	43.79
0.15	100	9.06	12.68	gr	107.07
0.75	200	5.25	3.81	gr	32.15
Filler			5.2	gr	59.06
Amount				gr	1125
Test Object Weight				gr	1200

Source: Calculation Results 2021

According to the weight calculated in the design mix above, the total asphalt content used was 6.25 percent of the total weight, the asphalt content weight is 75 grams of asphalt, and for fine aggregate on sieve no. 16 to no. 200, sand material was used with a Bottom Ash substitution of 25% of the weight of each sieve in the fine aggregate. Furthermore, 5 immersion variations were created, namely 30 minutes, 24 hours, 48 hours, 96 hours, and 168 hours. For each variation of immersion, 3 specimens were created, which were then immersed according to the specified variation, after which the Marshall test was performed to obtain stability and flow values.

Marshall Test Results

- The relationship of immersion variation with Stability

To get the average stability value for each immersion variation, it is known that the calibration of the proving ring or the calibration of the Marshall tool is 13.86204 kg. For the reading number on the Marshall tool at 0 hours of immersion in sample 1 is 146 and for the correlation table it is in table 2.6 which is 1.09. The following is a calculation to get the stability value at 0 hours variation for sample 1:

$$stability = 146x13,86204x1,09 = 2206,01kg \quad (2)$$

From the above formula, the stability value for the duration of immersion 0 hours in sample 1 is 2206.01 Kg. After calculating the stability on sample 1, then perform calculations to average samples 1, 2, and 3 on the 0 hour immersion variation in the following way:

$$average = \frac{2206,01+2175,79+2130,46}{3} = 2170,75kg \quad (3)$$

For stability in each immersion variation can be seen in the following table:

TABLE 10 Stability Calculation Results

Immersion Duration	Sample	Stability (Kg)
0	1	2206.01
	2	2175.79
	3	2130.46
Average		2170.75
24	1	1979.36
	2	2054.91
	3	2009.58
Average		2014.62
48	1	1918.92
	2	1964.25
	3	1934.03
Average		1939.07
96	1	1903.81
	2	1813.16
	3	1843.37
Average		1853.45
196	1	1707.39
	2	1752.72
	3	1782.94
Average		1747.68

The relationship between immersion variation and stability based on Marshall test results is shown in Figure 2 below:

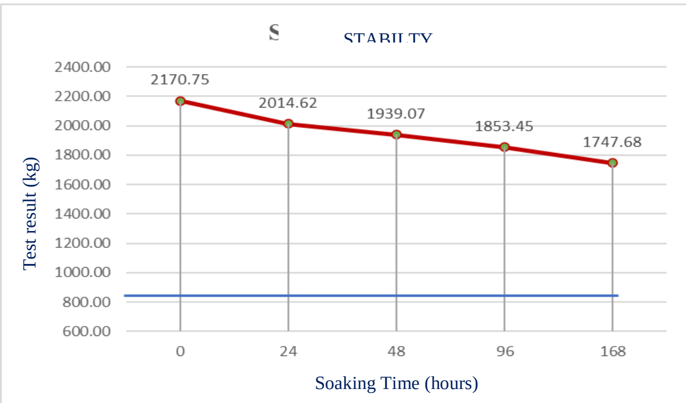

FIGURE 2. The Relationship between Immersion Variations and Stability Values

The test results show that the stability values of all tested immersion variations has met the minimum standard, which is greater than 800 kg, namely for 0 hours Immersion Variation of 2170.75 kg, 24-hour Immersion Variation of 2014, 62 kg, 48-hour Immersion Variation of 1938.07 kg, the 96 hour immersion variation was 1853.45 kg, and the stability value was 1747.68 kg for the 168 hour immersion variation.

- Immersion variation relationship with Flow

Based on the results of the Marshall test, the relationship between the variation of immersion and flow is shown in the following calculation table:

TABLE 11 Flow Calculation on Immersion Variation

Immersion Duration (hours)	Sample	Flow (mm)
0	1	2.33
	2	2.39
	3	2.41
Average		2.38
24	1	3.16
	2	3.14
	3	3.19
Average		3.16
48	1	3.4
	2	3.45
	3	3.51
Average		3.45
96	1	3.53
	2	3.64
	3	3.69
Average		3.62
168	1	3.87
	2	3.91
	3	3.92
Average		3.9

For the 0 hour immersion flow value, it is known that sample 1 has a value of 2.33mm, sample 2 has a value of 2.39mm, sample 3 has a value of 2.41mm. Therefore, to find the average value of the flow for the 0 hour immersion variation is as follows:

$$\text{Average}= \frac{2{,}33 + 2{,}39 + 2{,}41}{3} = 2{,}38mm \quad (4)$$

Based on the calculation results, the relationship between immersion variation and flow is shown in Figure 4.3

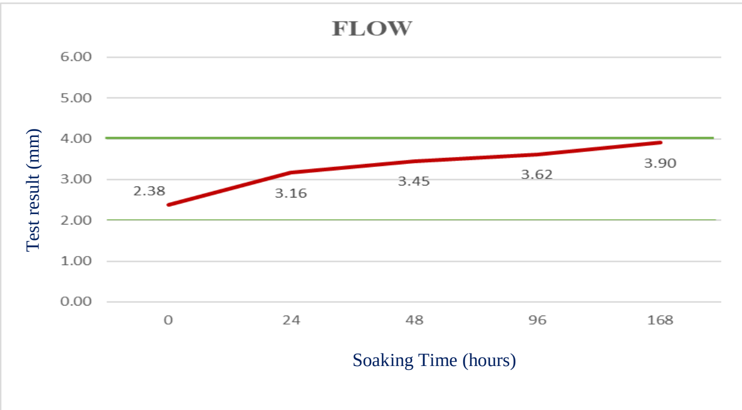

FIGURE 3. Immersion Variation Relationship with Flow Value

From the graph above, the flow value obtained from the reading of the Marshal tool with the following results, for the 0 hour Immersion Variation, the flow value is 2.38 mm, the 24-hour Immersion Variation is

3.16 mm, the 48 hour Immersion Variation is 3.45 mm , the variation of immersion 96 hours is 3.62 mm and the variation of immersion 168 hours is 3.90 mm.

From the data obtained, it shows that all variations of immersion meet the specifications for the flow value, which is between 2 to 4 mm.

- The relationship of immersion variation with Marshall Quotient

For the MQ value of 0 hours immersion duration in sample 1 has a stability value of 2206.01 kg and a flow value of 2.33 mm, to find the MQ value is:

$$MQ = \frac{\text{Stability}}{\text{flow}} = \frac{2206{,}01}{2{,}33} = 946{,}79 \qquad (5)$$

From the above formula, the MQ value for the duration of immersion 0 hours in sample 1 is 946.79 Kg/mm. From the calculation for Marshall Quotient above, the relationship between Immersion Variations and the Marshall Quotient is shown in the following graph:

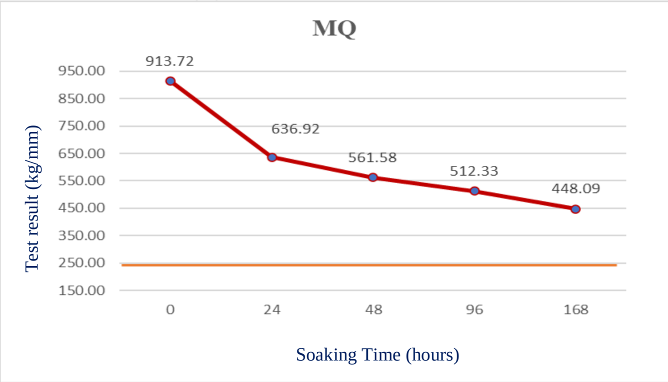

FIGURE 4. Relationship of Immersion Variation with Marshall Quotient value

The test results in the graph above show that the highest value of marshall questions is at 0 hours of immersion variation of 913.72 kg/mm. From the graph above also shows the value of marshall quetions that meet the requirements contained in the 0 hour and 24 hour immersion variation, which in the 0 hour immersion variation has a value of 913.72 kg/mm, for the 24-hour level it has a value of 636.92 kg/ mm, for the 48-hour Immersion Variation it has a value of 561.58 kg/mm while the 96-hour Immersion Variation has a value of 512.33 kg/mm and for the 168-hour Immersion Variation it has a value of 448.09 kg/mm.

Relationship of immersion variation with Residual Strength Index (IKS)

- The relationship of immersion variation with Stability

Based on the results of the Marshall test, the relationship between the Immersion Variation and the residual stability index is shown in the following calculation:

For the value of immersion 0 hours has a stability value of 2170.75 kg while for the value of immersion 24 hours has a stability value of 2014, 62 kg then to find the value of the residual stability index at the duration of immersion 24 hours is

$$MQ = \frac{\text{Stability after immersion}}{\text{stability without immersion}} X100$$

$$= \frac{2170{,}75}{2014{,}62} x100 = 92{,}81\% \qquad (6)$$

From the above formula, the IRS value for the duration of immersion for 24 hours is 92.81%, the residual strength index value for each immersion variation can be seen in the following graph:

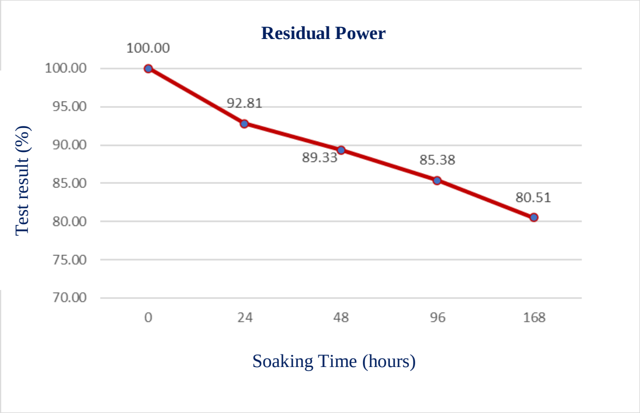

FIGURE 5. Immersion Variation Relationship

Figure 5 shows that the IRS value decreases with immersion duration. This is due to the fact that water reduces the strength of the link between the aggregate and the asphalt, lowering the stability value..

Only the 24-hour variation's IRS value met the minimal threshold of 90% till the end of the immersion variation. At a certain immersion variation, the IRS represents the percentage of remaining strength in the combination. The residual stability index for the 24-hour immersion variation was 92.81 percent, and the value still met the specified specifications; however, the IRS value for the 48-hour immersion variation was 89.33 percent, and the IRS value did not meet the specifications; and for variations of immersion 96 hours, the residual stability index was 85.38 percent, and the value did not meet the specifications; and for vars of immersion 96 hours, the value did not meet the specifications; and for vars of immersion 96 hours, and for variations of immersion 168 hours the IRS value is far from the specified requirements, the value of residual stability index is obtained at 80.51%.

CONCLUSION

- The test results from the Marshall Test show that the stability values of all tested immersion variations meet the minimum standard of 800 kg, namely for the 0 hour Immersion Variation of 2170.75 kg, 24 hours of 2014, 62 kg, 48 hours of 1938.07 kg, 96 hours of 1853.45 kg, and at 168 hours the stability value was 1747.68 kg.
- Flow value was obtained from the reading of the Marshall tool with the following results, for Variation of Immersion 0 hours obtained a flow value of 2.38 mm, 24 hours of 3.16 mm 48 hours obtained a value of 3.45 mm, 96 hours of 3.62 mm and at 168 hours by 3.90 mm. so that for flow all variations meet the requirements because for the flow itself a minimum of 2mm - 4mm.
- Marshall Quotient values that meet the requirements are found in all immersion variations where the 0 hour immersion variation has a value of 913.72 kg/mm, for 24 hours it has a value of 636.92 kg/mm, for 48 hours it has a value of 561.58 kg/mm while for 96 hours it has a value of 512.33 kg/mm and for 168 hours it has a value of 448.09 kg/mm,

  For Residual Strength Index In the 24-hour immersion variation the residual stability index was obtained at 92.81%, for the 48-hour immersion variation the residual stability index was obtained at 89.33%, while for the 96-hour immersion variation the residual stability index was obtained at 85.38% and for the variation of immersion 168 hours of residual stability index obtained by 80.51%. Therefore, the Remaining Strength Index that meets the requirements is the 24-hour variation.

REFERENCES

[1] Anggraeni, I. A., Riyanto, A., Sunarjono, S., & Harnaeni, S. R. (2019). *Nilai Durabilitas Dan Nilai Workabilitas Campuran Ac – Wc Menggunakan Bahan Tambah Genteng Polimer*. *2007*, 234–241.

[2] Haris, H. (2019). Analisis Pengujian Stabilitas dan Durabilitas campuran Aspal dengan Tes Perendaman. *Jurnal Linears*, *2*(1), 33–47.

[3] Irianto, A. R. D., Pasra, M., & Arsyad, A. (2021). Strength And Toughness Characteristics Of Ac-Wc Mixture Containing Pet And Pp Plastic Waste Under Static Compression. *International Journal*, *20*(78), 20-27.

[4] Irianto, Rachman Djamaluddin, A., Pasra, M., & Arsyad, A. (2020). Experimental study on marshall stability and flow of Asphalt Concrete Wearing Course (AC-WC) mixture using Asbuton semi extracted as binder. *IOP Conference Series: Earth and Environmental Science*, *419* (1).
[5] Kinanti, B. (2020). *Pengaruh Kadar Bottom Ash Sebagai Substitusi Agregat Halus Terhadap Karakteristik Campuran Ac-Wc* (Doctoral Dissertation, Universitas Mataram).
[6] Retona, T., Sebagai, B., Pengikat, B., & Mabui, D. S. (2019). *Studi Eksperimental Karakteristik Marshall Campuran Ac-Bc Menggunakan Asbuton Modifikasi*. *November*, 151–163.
[7] Santoso, I., Patrick, P., Andarias, A., & Roy, S. K. (2003). Pengaruh Penggunaan Bottom Ash Terhadap Karakteristik Campuran Aspal Beton. *Civil Engineering Dimension*, *5*(2), 75-81
[8] S Mashuri, M., & Rahman, R. (2020). Pengaruh Penuaan Aspal Pada Karakteristik Campuran Beton Aspal Lapis Aus Ac–Wc. *Rekonstruksi Tadulako: Civil Engineering Journal On Research And Development*, 47-56.
[9] Tajudin, A. N., & Suparma, L. B. (2017). Analisis Indeks Stabilitas Sisa Pada Campuran Asphalt Concrete Dengan Penggunaan Limbah Plastik Sebagai Agregat Pengganti. *Jurnal Muara Sains, Teknologi, Kedokteran Dan Ilmu Kesehatan*, *1*(1), 272–280.
[10] Zurni, R. (2015). *Terhadap Nilai Index Kekuatan Sisa Pada Campuran Material Perkerasan Daur*. *1*, 1–7.