Marshall Immersion Performance of Asphalt Concrete-Binder Course with Silica Sand as Fine Aggregate Substitute

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Abstrak. The Asphalt Concrete Binder Course (AC-BC) layer is part of the pavement structure that serves as an intermediate layer to withstand the maximum load from traffic. Damage to the pavement layer, which often occurs on the surface, can be influenced by layers with large pores and voids due to inadequate compaction during construction. In large voids, water can enter the pavement structure through cracks and gaps, forming potholes. Water trapped within the pavement structure can accelerate road deterioration, reducing the pavement layer's ability to support traffic loads. The purpose of using silica waste in this study is to assess the Marshall Immersion performance (water resistance) of the AC-BC mixture with silica sand. Variations of the AC-BC mixture using silica sands as a fine aggregate substitute include SI-0%, SI-25%, SI-50%, SI-75%, and SI-100%. The Marshall Immersion test was conducted by continuously immersing the samples in water for 0.5 hours, 24 hours, and 48 hours. To assess the Marshall Immersion performance of the AC-BC asphalt mixture, two indicators were used: the Index of Retained Stability (IRS) and the Index of First Durability (IDF). From the study, the IRS values obtained were as follows: SI-0%; 92.53%, SI-25%; 92.42%, SI-50%; 91.56%, SI-75%; 91.21%, and SI-100%; 90.78%. These results overall indicate that with silica sand substitution, the IRS values decrease but still meet the minimum requirement of 90%. The IDF values (r%) were positive (+). This positive value indicates that some mixture variations experienced different degrees of strength loss.

Keywords : AC-BC, Marshall Immersion, Silika Sand , IRS, IDF

INTRODUCTION

Damage or failure often occurs in the AC-BC layer. One of the factors causing road damage is traffic loads that exceed planning capacity. In the 2016-2020 period, the growth rate of vehicles in Indonesia was in the range of 4-5% per year [1]. The increase in the growth rate causes the traffic load to continue to increase and has direct implications for the potential for road damage. In addition, the factors that cause road damage also occur due to standing water on the road body which has an impact on the road pavement. Waterlogging occurs due to the reduction of infiltration areas and the condition of drainage channels that are not functioning properly so that drainage channels that are overcapacity cause water to stagnate on the road body. This is characterized by damage that appears in the form of grain release (Ravelling) and surface defects in the form of holes to fatigue cracks.

The large number of road defects indicates that silica sand needs to be used as a replacement for fine aggregate to improve the quality of the pavement. The replacement of silica sand is expected to improve the functionality of the pavement. One of the properties of silica sand is that it has a rough surface and has a good level of hardness, which is expected to have better adhesion to asphalt so as to reduce cracking in the pavement layer.[3]

Silica sand is one of the natural minerals commonly found in the earth's crust. Indonesia has silica sand reserves of around 4.55 billion tons with the largest locations in 11 provinces. The largest silica sand reserves in Indonesia are in West Sumatra Province, which is about 82.5% of all reserves of all reserves in Indonesia. Next are West Kalimantan, West Java and South Sumatra.[4]

Silica sand is widely available and given the excellent properties of silica sand, this study uses silica sand as a replacement for fine aggregate and aims to improve the durability performance of AC-BC mixtures.

METHODS

The parameter for marshall immersion performance in this study is the Index of Retained Stability (IRS) obtained from the measurement results between the stability values of 24 hours and 48 hours of immersion with standard stability (30 minutes immersion) at 60°C. If the IRS mixture is more or equal to 90%. [2], then the mixture can be said to have resistance to damage due to the influence of air, temperature and weather.

This study first tested the properties of coarse aggregate, fine aggregate, filler, silica sand, and asphalt. A 2.36 mm sieve was used to screen the silica sand used as fine aggregate substitution, and the resulting material was collected on a 1.18 mm sieve with different substitution percentages (SI-0%, SI-25%, SI-50%, SI-75%, SI-100%). The properties test aims to ensure that the materials used to make the mixture meet the 2018 General Specifications. Then testing of the asphalt mixture was carried out. There are two tests for testing asphalt mixtures, namely the Marshall test and the Marshall immersion (MI) test. The Marshall test is used to determine the optimum asphalt content, which is the asphalt content that meets the mix design criteria required in the General Specifications division 6. The Marshall Immersion test is used to test the adhesion resistance of asphalt and aggregate mixtures and assess the stability of the mixture after exposure to water and different temperatures as required in the General Specifications division 6. Test specimens made using the ideal asphalt content values found by the Marshall technique are used in the MI test. The Marshall test KAO chart provides the asphalt content values used for MI. A total of 45 (forty-five) test specimens were prepared. Each variation consisted of 3 (three) specimens for each mix with 0%, 25%, 50%, 75% and 100% silica sand substitution and soaking for 30 minutes, 24 hours and 48 hours. The description of the specimens can be seen in Table 1.

TABLE 1. Number of Test Objects

MIX TYPE		**AC-BC + SILICA SAND (%)**				
		0	**25**	**50**	**75**	**100**
MODIFIED BITUMEN CONTENT	5,0	3	3	3	3	3
	5,5	3	3	3	3	3
	6,0	3	3	3	3	3
	6,5	3	3	3	3	3
	7,0	3	3	3	3	3
MARSHALL	30-minute soaking	3	3	3	3	3
MARSHALL IMMERSION (MI)	24-hour soaking	3	3	3	3	3
	48-hour soaking	3	3	3	3	3
TOTAL KAO SAMPLE		120				

RESULTS AND DISCUSSION

Properties Testing

The coarse and fine aggregates and fillers used in this study came from PT Anugrah Tripa Raya (PT ATR) bypass Padang. The silica sand used came from PT Semen Padang, while the asphalt came from PT Pertamina. The test results of fine aggregate, coarse aggregate, silica sand, filler, and asphalt are shown in Tables 2, 3, 4, 5, and 6.

TABLE 2. Coarse Aggregate Test Results

No.	Testing	Reference	Specification	Results
1.	Spesific Gravity :			
	a. Bj Bulk	SNI 03-1969-1990	2,5-2,7	2,51
	b. Bj SSD	SNI 03-1969-1990	2,5-2,7	2,58
	c. Bj Semu	SNI 03-1969-1990	2,5-2,7	2,69
2.	AIV (%)	SNI 03-4426-1997	Maks. 30	9,2
3.	ACV (%)	SNI M-20-1990-F	Maks. 30	23,21
4.	Wear and tear with Los Angeles	SNI 03-2417-2008	Maks. 40	16
5.	(%)	SNI 03-4137-1996	Maks. 10	8,94
6.	Flat Index (%)	SNI 03-4137-1996	Maks. 10	5,91
7.	Oval Index (%)	SNI 3407-2008	Maks. 12	4,16
	Aggregate Weathering (%)			

TABLE 3. Fine Aggregate Test Results

No.	Testing	Reference	Specification	Results
1.	Spesific Gravity:			
	a. Bj Bulk	SNI 03-1970-1990	2,5-2,7	2,54
	b. Bj SSD	SNI 03-1970-1990	2,5-2,7	2,61
	c. Bj Semu	SNI 03-1970-1990	2,5-2,7	2,74
	d. Water Absorption (%)	SNI 03-1970-1990	≤ 3	2,79

TABLE 4. Silica Sand Test Results

No.	Testing	Reference	Specification	Results
1.	Spesific Gravity:			
	a. Bj Bulk	SNI 03-1970-1990	2,5-2,7	2,522
	b. Bj SSD	SNI 03-1970-1990	2,5-2,7	2,537
	c. Bj Semu	SNI 03-1970-1990	2,5-2,7	2,561
	d. Water Absorption (%)	SNI 03-1970-1990	≤ 3	0,607
2.	Wear and tear with Los Angeles	SNI 03-2417-2008	Maks. 40	26,8
3.	(%)	SNI 3407-2008	Maks. 12	0,747
	Aggregate Weathering (%)			

TABLE 5. Filler Test Results

No.	Testing	Reference	Specification	Results
1.	Spesific Gravity	SNI 03-1970-1990	2,5-2,7	2,551

TABLE 6. Hasil Uji Aspal

No.	Testing	Reference	Specification	Results
1.	Spesific Gravity	SNI 2441-2011	Min. 1%	1,035
2.	Penetration (mm)	SNI 2456-2011	60-70	70
3.	Ductility (cm)	SNI 2432-2011	Min 100	150
4.	Softening Point (°C)	SNI 2434-2011	Min. 48	48
5.	Flash Point and Burn Point (°C)	SNI 2433-2011	Min. 232	344 & 354
6.	TFOT Weight Loss (%)	SNI 06-2442-1991	≤ 0,8	0,02
7.	Viscosity (°C)	ASTM D2170-10	≤ 300	150 & 160
8.	Asphalt Stickiness to Aggregate (%)	SNI 2439-2011	Min. 95	96

Marshall Immersion Test Results

Index of Retained Strength (IRS)

Tests conducted with Marshall Immersion are immersion for 24 hours soaking and 48 hours soaking. Marshall Immersion test results are shown in Table 7.

TABLE 7. Residual Strength Index Test Results

Mix Variation	24-Hour Soaking	48-Hour Soaking
SI-0%	92,53	84,8
SI-25%	92,42	84,73
SI-50%	91,56	84,61
SI-75%	91,21	84,23
SI-100%	90,78	80,58

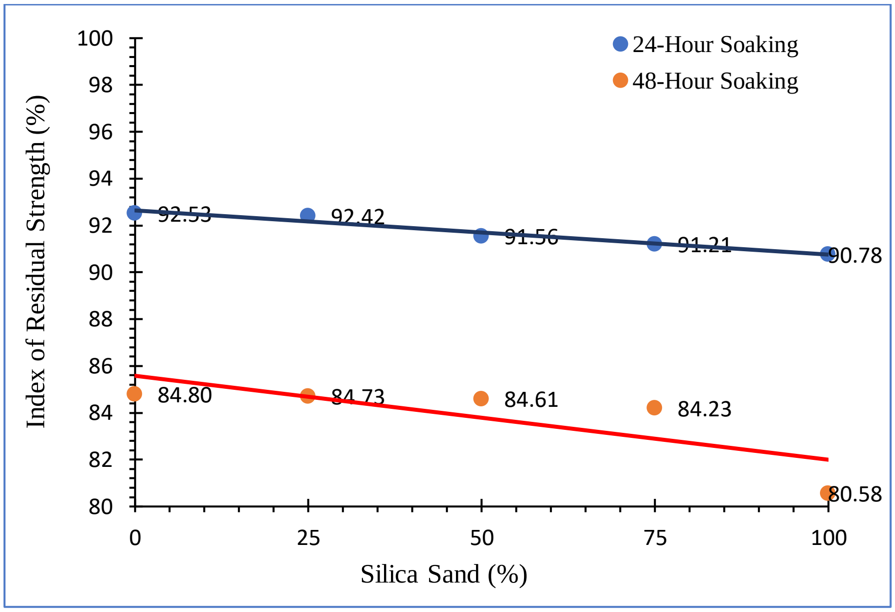

FIGURE 1. Comparison of Residual Stability Value against Silica Sand Content for 24 Hours Soaking and 48 Hours Soaking

From the results of testing test specimens with Marshall Immersion immersion for 24 hours and 48 hours. From Figure 1 it can be seen that the durability of the mixture tends to decrease with the addition of silica sand ratio and also decreases with increasing immersion time. This occurs because of the increasing number of voids and pores in the mixture so that it will reduce the durability of asphalt concrete mixtures, because large voids in the mixture will cause the mixture to be less water and air tight, resulting in an increase in the oxidation process of asphalt which accelerates the aging process during the immersion test. It can be seen from Figure 1 that the highest residual stability value is found in the variation without 0% silica sand with a value of 92.53% for 24-hour immersion and the lowest value in the 100% silica sand mixture with a value of 90.78% for 24-hour immersion. While the residual stability value for 48-hour soaking tends to decrease from 24-hour soaking. These results overall indicate that substituting silica sand cannot increase the residual strength index value of asphalt mixtures but still meets the minimum requirements of greater than 90% for 24-hour immersion. As for the 48-hour immersion, it does not meet the requirements, this is influenced by the increasing addition of silica sand causing the asphalt film thickness to get thinner and the adhesion between asphalt and aggregate to decrease due to the length of immersion, so that water easily enters and causes peeling of grains between aggregate and asphalt.[5]

The 0% silica sandless mix with the highest IRS value compared to the other mixes showed the best level of resistance to the effects of water and high temperatures. The relatively thick asphalt film factor compared to the other mixes is thought to play the most dominant role in achieving IRS. The thick asphalt film will ensure that the adhesion between the asphalt and the aggregate particles is maintained, thus contributing significantly to minimize the weakening effect caused by water infiltration and high temperature during the 1x24 hour soaking process.[8]

Durability Index Analysis

Along with the soaking process, there is a decrease in the stability of the mixture caused by the effect of temperature and water on the adhesion between asphalt and aggregate. The value of the stability index is affected by the decrease in the durability of the mixture (r%).

TABLE 8. First and Second Durability Index Test Results

Variation (%)	Optimum Asphalt Content (%)	Soaking Period (Hour)	First Durability Index r (%/day)	R (kg/day)	Second Durability Index a (%)	S_a (%)	A (kg)	S_A (kg)
0	5,94	24	7,47	93,16	3,74	96,26	46,58	1200,35
		48	7,73	96,34	15,45	84,55	192,68	1054,25
	Total		15,20	189,50	19,19	180,81	239,26	2254,60
25	5,918	24	7,58	96,92	7,58	92,42	96,92	1182,54
		48	7,69	98,45	15,39	84,61	196,89	1082,57
	Total		15,27	195,37	22,96	177,04	293,81	2265,12
50	5,9	24	8,44	115,50	8,44	91,56	115,50	1252,50
		48	6,94	95,00	13,89	86,11	190,00	1178,00
	Total		15,39	210,50	22,33	177,67	305,50	2430,50
75	5,895	24	8,79	142,15	8,79	91,21	142,15	1475,69
		48	6,99	113,05	13,98	86,02	226,11	1391,74
	Total		15,77	255,21	22,76	177,24	368,26	2867,43
100	5,865	24	9,22	100,52	9,22	90,78	100,52	989,46
		48	10,20	111,20	20,40	79,60	222,40	867,58
	Total		19,42	211,72	29,63	170,37	322,92	1857,04

From Table 8, the first Durability Index (ID) value (r%) is obtained which is positive (+). This positive value indicates that some of the mix variations experienced varying strength loss [9]. This indicates that at 48 hours immersion the amount of water absorbed into the specimen may have caused the asphalt material to soften on a large scale. The process of peeling off the asphalt film due to water absorption into the aggregate surface may have occurred, especially on the outside of the specimens to a certain depth. This leads to a decrease in the strength of the specimen.

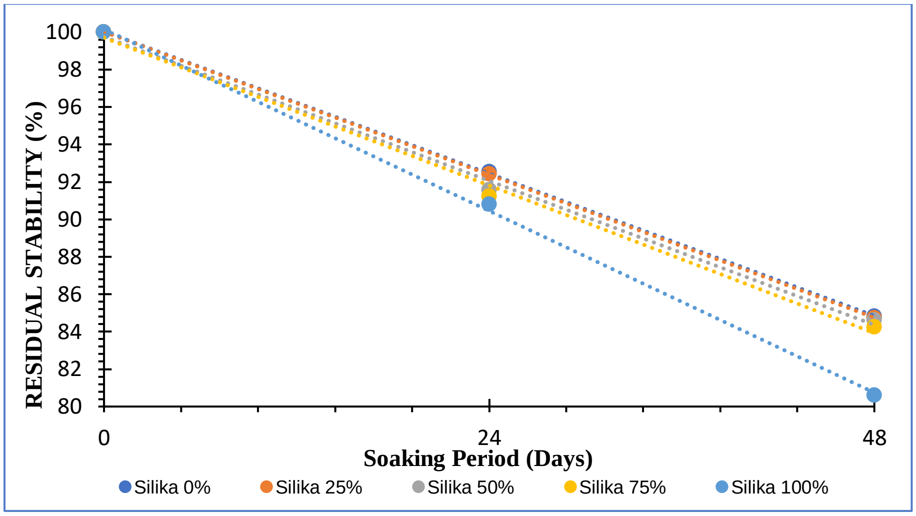

FIGURE 2. Durability Curve

In Figure 2 it can be seen that all mixes show the same behavior where there is a decrease in the durability curve, which means that all mixes experience a decrease in strength. This decrease is caused by more air being absorbed into the specimen and possibly entering the asphalt-aggregate surface layer and pores. This causes stripping of the asphalt from the aggregate surface which results in a decrease in the stability of the specimen. This decrease is also due to reduced adhesion between asphalt and aggregate as a result of stripping of asphalt from the aggregate surface and softening of asphalt material. Thus, with the substitution of silica sand, it can be concluded that it does not increase the strength of the asphalt mixture but still meets the existing specifications in the 24-hour immersion test, while in the 48-hour immersion test it does not meet the specifications because it is influenced by the increasing addition of silica sand which causes the thickness of the asphalt film to become thinner and the adhesion between asphalt and aggregate to decrease due to the length of immersion, so that water easily enters and causes peeling of the grains between the aggregate and asphalt.[10]

CONCLUSIONS

Based on the IRS and IDF, values obtained for each mixture, the mixture substituted without silica (0%) showed the smallest average loss of soaking strength compared to the other mixtures. So, although the IRS has decreased, silica sand can still be used because the IRS value of the 24-hour immersion test still meets the specification of at least 90%.

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