Durability Performance of AC-WC Mixture Using Silica Sand as a Fine Aggregate Substitution

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Abstract. Damage or failure often occurs in the Asphalt Concrete – Wearing Course (AC-WC) pavement layer. This is indicated by the damage that appears in the form of grain release and surface defects in the form of holes to cracks due to fatigue. The amount of road damages indicates that silica sand needs to be used in place of fine aggregate in order to improve the quality of the road pavement. Silica sand substitution is expected to increase the durability of the road pavement. Based on the IRS, IDF, and IDS values obtained by each mixture, the substituted mixture without silica (0%) showed the smallest average loss of immersion strength compared to the other mixtures. But, even though the IRS has decreased, silica sand can still be used because the IRS value still meets the specifications, namely at least 90%.

Keywords: Damage, AC-WC, Silica Sand, Substitution, Durability.

1 Introduction

Damage or failure often occurs in AC-WC layer. One of the factors causing road damage is the traffic load that exceeds the planning capacity. In the 2016-2020 period the growth rate of vehicles in Indonesia was in the range of 4-5% annually (Statistics, 2020). 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 stand water on the road body which has an impact on the road pavement. Stagnant water occurs due to reduce catchment areas and the condition of the drainage channels that are not functioning properly so that the drainage channels are over capacity causing water to stagnate on the road body. This is indicated by the damage that appears in the form of grain release (Ravelling) and surface defects in the form of holes to cracks due to fatigue.

The amount of road damages indicates that silica sand needs to be used in place of fine aggregate in order to improve the quality of the road pavement. The replacement of silica sand is expected to improve the functionality of the pavement. One of the properties of silica sand which has a rough surface and has a good level of hardness, is expected to have better adhesion to asphalt thereby reducing ravelling on the pavement layer.

ABEC 2023, September 21, Bengkalis, Indonesia

DOI 10.4108/eai.21-9-2023.2342957

Silica sand is one of the common naturally occurring minerals found in the Earth's continental crust. Indonesia has silica sand reserves of around 4.55 billion tons with the largest locations in 11 provinces. Indonesian silica sand is found in West Sumatra Province, which is around 82.5% of all reserves in Indonesia. Next are West Kalimantan, West Java and South Sumatra.
Silica sand is widely available and considering the excellent properties of silica sand, this study uses silica sand as a substitute for fine aggregate and aims to improve the durability performance of AC-WC mixtures.

2 Research Methods

The parameter for testing durability in this research is the Residual Strength Index (IRS) which is obtained from the measurement results between the stability values of 24 hours and 48 hours of immersion with the stability standard (30 minutes of immersion) at a temperature of 60oC. If the IRS mixture is more or equal to 90% in the General Specifications provisions of the Directorate General of Highways 2018, then the mixture can be said to have fairly good resistance to damage due to the effects of air, temperature and weather.

This research first tested the properties of coarse aggregate, fine aggregate, filler, silica sand, and asphalt. The 2.36 mm sieve was used to filter the silica sand used as fine substitution aggregate, and the resulting material was collected on a 1.18 mm sieve with different percentages of substitution (0%, 25%, 50%, 75%, 100%). The property test aims to ensure that the material used to make the mixture meets the 2018 general specifications. Then testing of the asphalt mixture is carried out. There are two tests for testing asphalt mixtures: the Marshall test and the Marshall immersion test (MI). The Marshall test is used to determine the optimal asphalt content,namely the asphalt content that meets the mix design criteria required in the 2018 general specifications division 6. Test objects created using the ideal asphalt content values discovered by the Marshall technique are employed in the MI test. The Marshall test's KAO chart provides the asphalt content value that is utilized for MI. 45 (fourty five) test objects were prepared. Each variation is 3 (three) specimens for each mixture with 0%, 25%, 50%, 75% and 100% silica sand substitution and soaking for 30 minutes, 24 hours and 48 hours. A description of the test objects can be found in Table 1.

Table 1 number of test object

Mixed Type		AC-WC + Pasir Silika %				
		0	25	50	75	100
Asphalt Content	5	3	3	3	3	3
	5,5	3	3	3	3	3
	6	3	3	3	3	3
	6,5	3	3	3	3	3
	7	3	3	3	3	3
Soaking 30 minute		3	3	3	3	3
Soaking 24 hours		3	3	3	3	3
Soaking 48 hours		3	3	3	3	3
Total Sample		120				

3 Result and Discussion

3.1 Properties Testing

Coarse aggregate and fine aggregate and filler used in this reaserch came from PT. Anugrah Tripa Raya (PT. ATR) bypass Padang. For silica sand used comes from PT. Semen Padang, while asphalt comes from PT Pertamina. Test results for 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	Method	Terms	Results
1	Specific gravity:			
	a. Bj Bulk	SNI 03-1969-1990	2,5-2,7	2,52
	b. Bj SSD	SNI 03-1969-1990	2,5-2,7	2,605
	c. Bj Semu	SNI 03-1969-1990	2,5-2,7	2,753
2	AIV (%)	SNI 03-4426-1997	Maks 30%	9,202
3	ACV (%)	SNI M-20-1990-F	Maks 30%	23,209
4	Wear and tear with Los Angeles (%)	SNI 03-2417-2008	Maks 40%	16
5	Flat Index (%)	SNI 03-4137-1996	Maks 10%	8,55
6	Oval Index (%)	SNI 03-4137-1996	Maks 10%	5,91
7	Aggregate Weathering (%)	SNI 3407-2008	Maks 10%	4,15

Table 3 Fine aggregate test results

No	Testing	Method	Terms	Results
1	Specific gravity:			
	a. Bj Bulk	SNI 03-1970-1990	2,5-2,7	2,492
	b. Bj SSD	SNI 03-1970-1990	2,5-2,7	2,562
	c. Bj Semu	SNI 03-1970-1990	2,5-2,7	2,68
	d. Water Absorption (%)	SNI 03-1970-1990	≤ 3%	2,817

Table 4 Test results of silica sand

No	Testing	Method	Terms	Results
1	Specific gravity:			
	a. Bj Bulk	SNI 03-1970-1990	2,5-2,7	2,59
	b. Bj SSD	SNI 03-1970-1990	2,5-2,7	2,66
	c. Bj Semu	SNI 03-1970-1990	2,5-2,7	2,79
	d. Water Absorption (%)	SNI 03-1970-1990	≤ 3%	2,58
2	Wear and tear with Los Angeles (%)	SNI 03-2417-2008	< 40%	40,2
3	Aggregate Weathering (%)	SNI 3407-2008	< 10%	0,75

Table 5 Filler test results

No	Testing	Method	Terms	Results
1	Specific gravity	SNI 03- 4145-1996	2,5-2,7	2,551

Table 4 Asphalt test results

No	Testing	Method	Terms	Results
1	Specific gravity	SNI 2441-2011	Min. 1%	1,032
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 06-2441-1991	≤ 0,8%	0,3106
7	Viscosity (°C)	ASTM D2170-10	≤ 300	150 & 160
8	Asphalt Stickiness To Aggregate	SNI 2439-2011	Min 95%	95

3.2 Marshall Immersion test results
Residual Strength Index (IRS)

The tests carried out by Marshall Immersion were 24 hour immersion and 48 hour immersion. The results of the Marshall immersion test are shown in Table 7.

Table 5 residual strength index test results

Mixed Variations	Immersion 24 hours	Immersion 48 hours
silica sand 0%	98,34 %	97,01 %
silica sand 25%	95,79 %	94,06 %
silica sand 50%	92,08 %	91,79 %
silica sand 75%	91,87 %	90,58 %
silica sand 100%	90,65 %	90,45 %

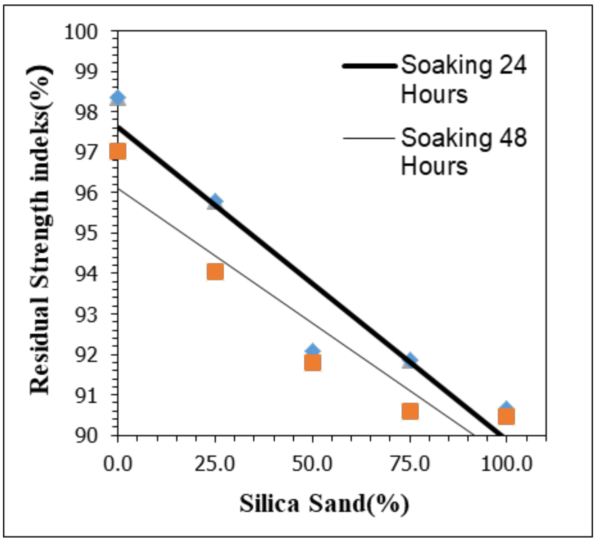

Figure 1 Comparison of the value of Residual Stability to Silica Sand Content 24 Hours Soaking and 48 Hours Soaking

From the results of testing the specimens using the Marshall Test Equipment with immersion of 24 hours and 48 hours. From Figure 1, it can be seen that the durability of the mixture tends to decrease when adding silica sand ratio and also decreases with soaking time. This happens due to the increasing number of cavities and pores in the mixture so that it will reduce the durability of the asphalt concrete mixture, because large voids in the mixture will cause the mixture to be less water and air tight, resulting in an increase in the asphalt oxidation process which accelerates the aging process in the immersion test process. . It can be seen from Figure 4.8 that the highest residual stability value is found in the variation without 0% silica sand with a value of 98.34% for 24 hour immersion and the lowest value in 100% silica sand mixture with a value of 90.66% for 24 hour immersion. While the residual stability value for 48 hours of immersion tends to decrease from 24 hours of immersion. These results as a whole indicate that by substituting silica sand it cannot increase the Residual Strength Index value of the asphalt mixture but still meets the minimum requirements of 90%.

The mixture without 0% silica sand with the highest IRS value compared to other mixtures showed the best level of resistance to the effects of water and high temperatures. The asphalt film factor which is relatively the thickest compared to other mixtures is thought to give the most dominant role in achieving the IRS. With a thick asphalt film, it will ensure that the adhesion (adhesiveness) between asphalt and aggregate particles is maintained so that it still contributes quite a lot in efforts to minimize the weakening effect caused by water infiltration and high temperatures during the 1x24 hour immersion process.

Durability Index Analysis

Along with the immersion process comes a loss in mixture stability, which is brought on by temperature and water's effects on the adhesion between asphalt and aggregate. The stability index value is affected by the decreasing durability of the mixture (r%)

Table 6 First and second durability index

Variation	Optimum Asphalt Content	Immersion Period	First durability index		Second durability index			
			r	R	a	S_a	A	S_A
(%)	(%)	(Jam)	(%/hari)	(kg/hari)	(%)	(%)	(kg)	(kg)
0	5.99	24	1.66	21.33	0.83	99.17	10.67	1276.51
		48	1.34	17.19	2.67	97.33	34.38	1252.80
	Amount		2.99	38.52	3.50	196.50	45.05	2529.31
25	5.88	24	4.20	60.95	4.20	95.80	60.95	1388.97
		48	1.74	25.17	3.47	96.53	50.34	1399.58
	Amount		5.94	86.12	7.68	192.32	111.29	2788.54
50	5.845	24	7.92	110.80	7.92	92.08	110.80	1288.59
		48	0.29	4.03	0.58	99.42	8.06	1391.34
	Amount		8.21	114.83	8.49	191.51	118.86	2679.93
75	5.835	24	8.13	112.58	8.13	91.87	112.58	1271.49
		48	1.29	17.83	2.58	97.42	35.65	1348.42
	Amount		9.42	130.41	10.71	189.29	148.24	2619.90
100	5.81	24	9.34	134.85	9.34	90.66	134.85	1308.66
		48	0.20	2.89	0.40	99.60	5.78	1437.73
	Amount		9.54	137.74	9.74	190.26	140.62	2746.40

From Table 8, the value of the first durability index (IDF) is obtained, namely (r%) which is positive (+). This positive value indicates that from several variations the mixture experiences a varied loss of strength. This indicates that at 48 hours of immersion the amount of water absorbed into the specimen may have caused the asphalt material to experience large-scale softening. The process of peeling off the asphalt film layer due to the absorption of water to the surface of the aggregate may have occurred, especially on the outside of the specimen to a certain depth. This causes a decrease in the strength of the test object.

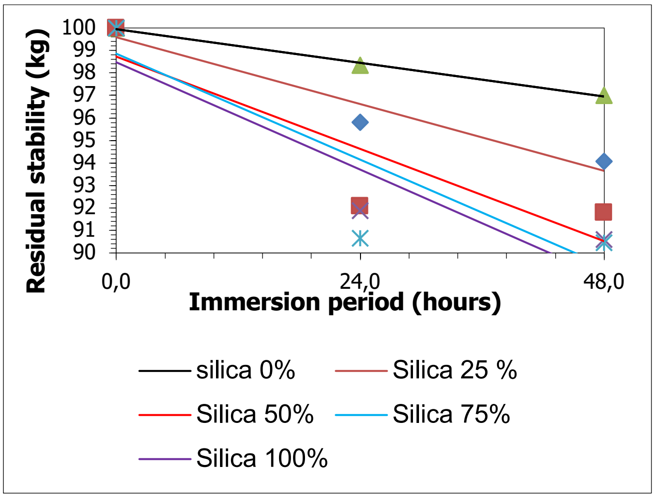

Figure 2 Durability curve

In Figure 2 it can be seen that all mixtures show the same behavior where there is a decrease in the durability curve, which means that all mixtures experience a loss of strength. This decrease is caused by the increasing amount of air absorbed into the test object and possibly has entered the surface of the asphalt-aggregate layer and the pores. This causes the stripping of asphalt from the surface of the aggregate (stripping) which has an impact on decreasing the stability of the test object. This decrease also occurs due to the reduced adhesiveness between asphalt and aggregate as a result of stripping of asphalt from the aggregate surface and softening of asphalt material. Thus, by substituting silica sand it can be concluded that it does not add strength to the asphalt mixture but still meets the existing specifications.

4 Conclusion

Based on the IRS, IDF, and IDS values obtained by each mixture, the substituted mixture without silica (0%) showed the smallest average loss of immersion strength compared to the other mixtures. therefore a mixture of substitution without silica (0%) shows that it has better durability compared to other mixtures. So, even though the IRS has decreased, silica sand can still be used because the IRS value still meets the specifications, namely at least 90%.

Acknowledgements

Acknowledgments to the Padang State Polytechnic who have helped facilitate this research and the supervisor who has guided us, as well as other parties who have assisted in this research.

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