Marshall Characteristics Of Asphalt Concrete – Wearing Course (AC-WC) With Substitution Of Silica Sand As Fine Aggregate

Mukhlis[1*], Lusyana[2], Enita Suardi[3],Denisa Rahma Sukri[4], Alyza Sazama[5]
[1,2,3,4,5]Department of Civil Engineering, Padang State Polytechnic, Indonesia

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ABSTRACT

The growth of traffic loads in Indonesia has increased significantly, but road infrastructure has developed disproportionately. Excessive loads can damage roads because they exceed the planned capacity. Aggregates, especially fine aggregates, play an important role in inclined flexible pavement layers, namely in AC-WC layers. AC-WC aims to provide smoothness, safety and comfort for road users, as well as protect the underlying layers from damage due to traffic loads such as collapse, grooves and bleeding. The use of silica sand is an alternative used to improve the quality of AC-WC layers. This research aims to obtain the Optimum Asphalt Content (KAO) value. The KAO value using the Marshall method on the AC-WC mixture was 5.99% for 0% silica sand, 5.88% for 25% silica sand, 5.845% for 50% silica sand, 5.835% for 75% silica sand, 5.810% in the 100% silica sand variation. Thus the more percentage of silica sand added as a fine aggregate substitution in the AC-WC mixture, the lower the KAO value obtained.

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Corresponding Author:

Mukhlis,
Department of Civil Engineering,
Padang State Polytechnic,
Jl. Kampus, Limau Manis, Kec. Pauh, Kota Padang, Sumatera Barat 25164, Indonesia.
Email: *palito_alam@yahoo.com

1. INTRODUCTION

Indonesia is experiencing significant traffic load growth, but this is often not matched by adequate development of road infrastructure. This phenomenon occurs because the growth of traffic load is faster than the development of road infrastructure. Excessive traffic loads can cause road damage. When a road has to bear a traffic load that exceeds the planned capacity, the damage will occur gradually and have an impact on the quality of the road infrastructure. Flexible pavement is an important component in road infrastructure designed to withstand traffic loads and provide a safe and comfortable surface for road users. Aggregate is one of the main components in flexible road pavement, and fine aggregate has an important role in flexible road pavements that are often damaged, namely the wear layer (AC-WC). The AC-WC coating aims to provide smoothness, safety, comfort for road users and protect the underlying layer from damage due to repeated traffic loads including the formation of deformations in the form of subsidence, grooves, and release of granules.

One of the provinces in Indonesia that has abundant natural resources, both organic and inorganic, is West Sumatra. One of the abundant natural resources in this province is silica sand. Silica sand in West Sumatra is a reserve of 82.5% of Indonesian silica sand but has not been used optimally [1]. Besides that, especially PT Semen Padang, there is a lot of silica sand left over from its industry, therefore the author is interested in using the remaining silica sand from the processing of PT Semen Padang in order to reduce environmental pollution. because if the remaining silica sand waste is not managed and directly disposed of into the environment it is very dangerous for the surrounding environment.

Generally, physically the surface of silica sand has a rough texture with uneven grain shape, equipped with many protrusions and depressions that are capable of interlocking between grains. This results in a stronger bond between the silica sand and asphalt, and forms a more stable AC-WC layer that is resistant to ravelling [4].

The formulation of the problem in this study is how many Marshall Optimum Asphalt Content (KAO) obtained in each mixture variation. The purpose of this research is to utilize silica sand to be a solution in reducing the remaining amount of silica sand from the processing of PT Semen Padang and also to increase marshall characteristics in asphalt mixtures.

Figure 1. Silica Sand
Source: PT Semen Padang

2. METHODS

This study uses a comparative method, namely a method that compares the results of the Marshall test on the percentage of asphalt mixture with silica sand. This research was conducted in the Padang State Polytechnic laboratory. This study tested the properties of coarse aggregate, fine aggregate, filler, silica sand and asphalt. Then the marshall test was carried out to obtain the optimum bitumen content. All tests are based on Indonesian National Standards [3]. To obtain the optimum asphalt content, the test specimens were prepared with five variations of asphalt content (3 specimens for each variation), namely -1.0%, -0.5%, Pb% (estimation of optimum asphalt), +0.5%, + 1.0% of the total mix [2].
The number of specimens used in this study can be seen in Table 1. The materials used in this study included: (i) aggregate passed 19 mm sieve retained 12.5 mm, (ii) aggregate passed 12.5 mm sieve retained 9, 5 mm, (iii) aggregate passed through sieve 4.75 mm retained 2.36 mm, (iv) silica sand passed sieve 2.36 mm retained 1.18 mm, (v) aggregate passed sieve 1.18 retained 0.6 mm , (vi) aggregate passing through a 0.15 mm sieve retained 0.075 mm, (vii) filler, (viii) asphalt PEN 60/70.

Table 1. Number of test items

Asphalt Content	AC-WC + Silica sand (%)				
	0	25	50	75	100
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
Total KAO Samples	75				

Source: Experiment result, 2023

3. RESULTS AND DISCUSSION

3.1 Property Testing

The following properties tests were carried out which can be seen in the table below.

Table 2. Coarse aggregate test results

No	Testing	Method	Terms	Results
	Specific gravity:			
	a. Bj Bulk	SNI 03-1970-1990	2,5-2,7	2,52
1	b. Bj SSD	SNI 03-1970-1990	2,5-2,7	2,605
	c. Bj Semu	SNI 03-1970-1990	2,5-2,7	2,753
	d. Water Absorption (%)	SNI 03-1970-1990	≤ 3%	3,361
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%	11,94
6	Oval Index (%)	SNI 03-4137-1996	Maks 10%	5,91
7	Aggregate Weathering (%)	SNI 3407-2008	Maks 10%	4,15

Source: Experiment result, 2023

Table 3. Filler test results

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

Source: Experiment result, 2023

Table 4. 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

Source: Experiment result, 2023

Table 5. 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

Source: Experiment result, 2023

Table 6. 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

Source: Experiment result, 2023

3.2 Marshall Test

3.2.1 Density

Density refers to the level of compactness of a mixture after it has been compacted. The density of asphalt mixtures increases as the asphalt content increases until it reaches a maximum value, after which it starts to decrease.

Based on Figure 2, it can be observed that each variation of silica sand shows different density values. With the same asphalt content, the density increases as the substitution of silica sand increases. This occurs because the inter-aggregate voids are filled with silica sand as the silica sand substitution increases, resulting in an increased mixture density after compaction. Based on Figure 2, it is evident that the asphalt mixture's density with 100% silica sand substitution has the highest value compared to other silica sand substitution variations.

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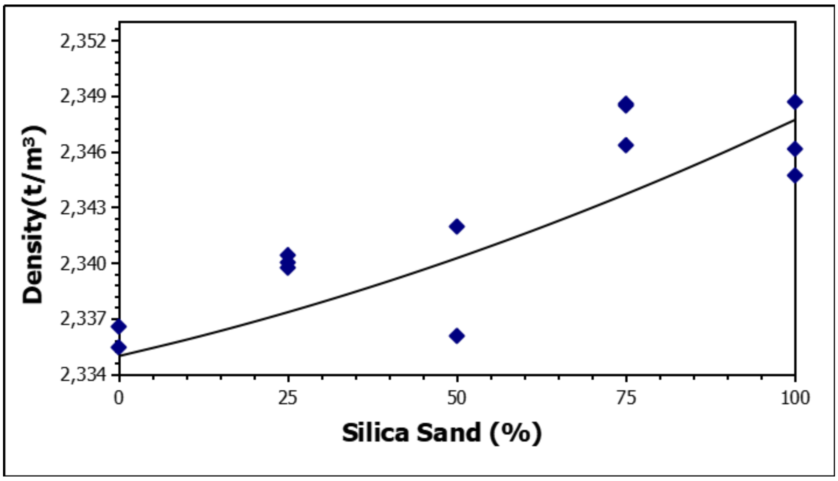

Figure 2. Comparison of density to silica sand

3.2.2 Void In Mix (VIM)

Voids In the Mixture (VIM), refers to the spaces in an asphalt mixture that are not filled with asphalt after compaction using a Marshall compactor. The VIM value significantly affects asphalt mixtures. A higher VIM value allows water and air to easily enter the voids within the mixture, leading to easy oxidation of the asphalt. This, in turn, reduces the adhesion between asphalt and aggregates. However, if the VIM value is too small, it can result in instability in the mixture and the potential for significant bleeding and plastic deformation. According to the General Specifications for Road Construction 2018 Revision 2, Division 6, the acceptable range for VIM in asphalt mixtures is between 3% and 5%.

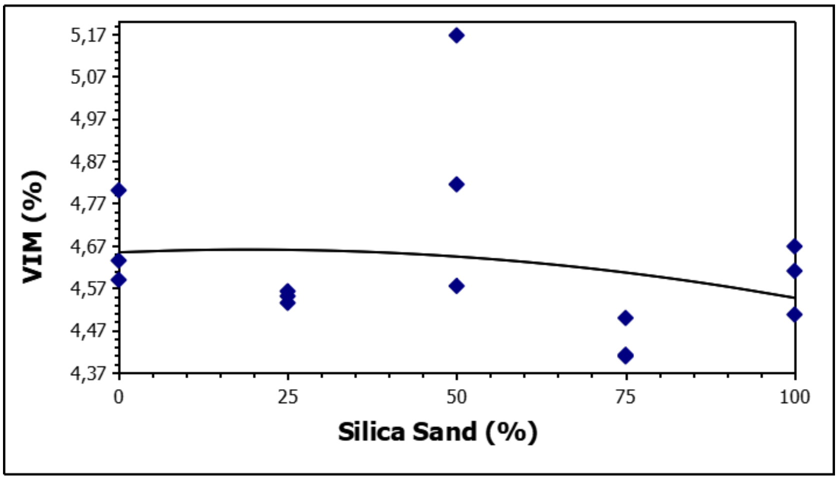

Figure 3. Comparison of VIM to silica sand

Based on Figure 2, the examination of the VIM values reveals that as the addition of silica sand increases, the VIM value decreases. This is because when silica sand is added, it can fill the voids between aggregate particles, making the mixture denser and reducing the remaining void space. Smaller voids within the mixture result in a denser asphalt mixture. Therefore, the VIM value can be influenced by density, where the density increases with the reduction in air voids in the asphalt mixture. Figure 2 also shows that the asphalt mixture without silica sand substitution has a higher VIM value compared to the other silica sand substitution variations.

3.2.3 Void In Mineral Aggregate (VMA)

Voids in Mineral Aggregate (VMA), is the percentage of void spaces between aggregate particles in an asphalt concrete mixture, expressed as a percentage of the total volume of the asphalt concrete mixture, with a minimum value of 15%. VMA value determines the potential space that will be occupied by asphalt, and as such, it significantly affects the mixture. VMA value is related to VIM (Void in Mix) and both are influenced by density. If the density of the mixture decreases, both VMA and VIM values increase. According to the General Specifications for Road Construction 2018 Revision 2, Division 6, the VMA (Voids in Mineral Aggregate) value for asphalt mixtures is specified to be ≥ 15%.

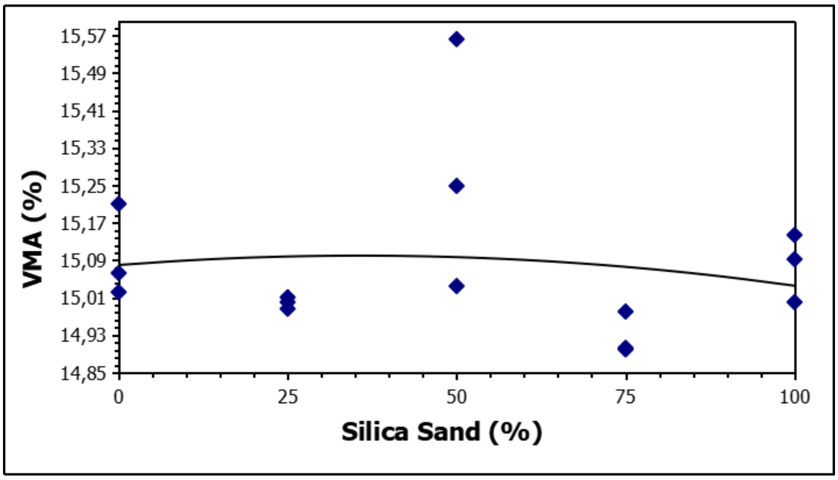

Figure 4. Comparison of VMA to silica sand

Based on Figure 4, the examination of VMA values reveals that VMA decreases with the addition of silica sand substitution. This is because when silica sand is substituted, it can fill the voids between aggregate particles, making the mixture denser and reducing the remaining void space. Smaller voids within the mixture result in a denser asphalt mixture. Therefore, the VMA value can also be influenced by density, as density increases with the reduction in air voids in the asphalt mixture. The figure also shows that the VMA value without silica sand substitution is higher than the other variations.

3.2.4 Void Filled With Asphalt (VFA)

Void Filled With Asphalt (VFA) represents the volume of voids in a compacted asphalt mixture that is filled with asphalt. The asphalt filling the VFA serves the purpose of coating the aggregate particles within the compacted asphalt mixture. In other words, VFA is the percentage of the volume of the compacted asphalt mixture that is covered by asphalt. According to the General Specifications for Road Construction 2018, Division 6, the VFA value is required to be a minimum of 65%

As shown in Figure 5, it can be observed that increasing the substitution of silica sand results in a higher VFA value. This is because silica sand has a high specific gravity, leading to low porosity in the sand. This low porosity means that the asphalt is absorbed less by the silica sand, allowing the asphalt to fill the voids in the mixture more effectively. Substituting silica sand in the asphalt mixture increases the percentage of voids covered by asphalt, and this is also influenced by the VIM value. If the VIM value of the mixture is lower, it will result in a higher percentage of voids filled with asphalt (VFA).

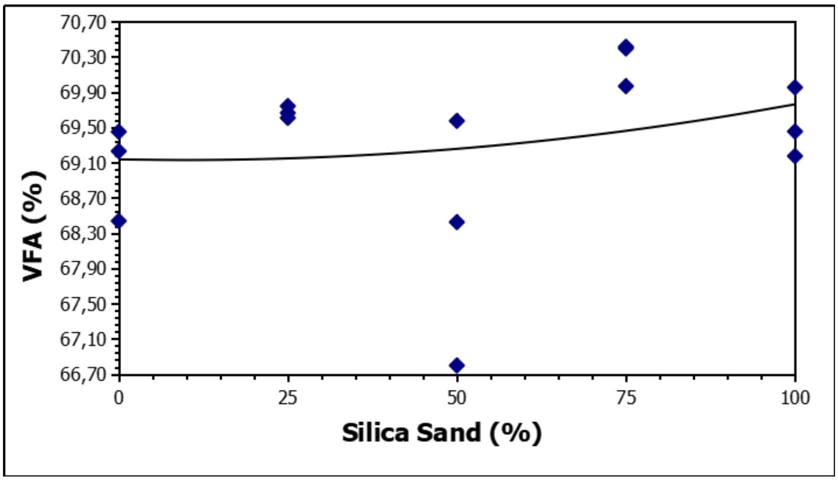

Figure 5. Comparison of VFA to silica sand

From Figure 5, it can also be observed that the VFA value of the asphalt mixture with 0% silica sand substitution is the lowest among the various silica sand substitution variations. A higher VFA value in a mixture contributes to its longevity and makes it less prone to oxidation, which can lead to brittleness in the mixture.

3.2.5 Stability

The stability of pavement must be sufficient to withstand traffic loads. The stability value of a road pavement is influenced by asphalt content, interlocking properties, surface texture, and aggregate gradation. According to the General Specifications for Road Construction 2018, Division 6, the minimum stability value for AC-WC (Asphalt Concrete - Wearing Course) mixtures is 800 kg.

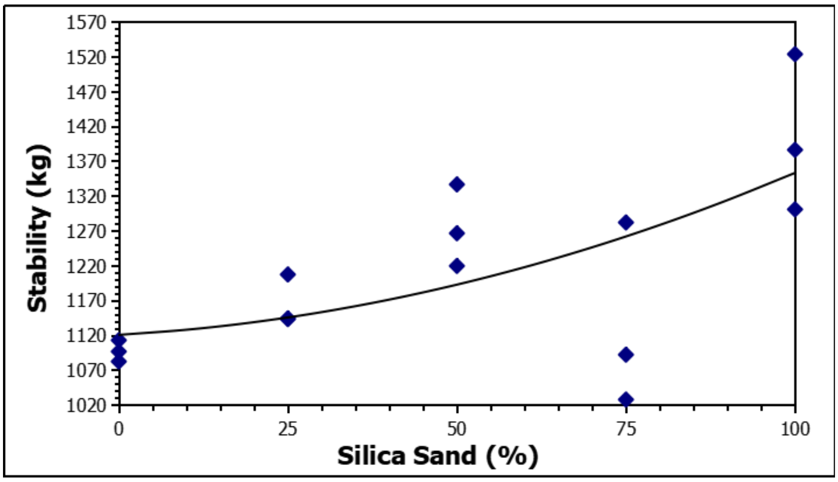

Figure 6. Comparison of stability to silica sand

Based on Figure 6 it can be seen that the greater the percentage of silica sand added as fine aggregate, the higher the resulting stability value. This is because the addition of silica sand to the AC-WC mixture increases the interlocking of the mixture and closes the gaps between existing aggregates, thus strengthening the interlocking properties of the mixture. The stability value is also affected by the penetration value obtained. The greater the percentage of silica sand used, the lower the resulting penetration. The low penetration value results in a high stability value. However, high stability can make the pavement stiff and prone to cracking due to traffic loads.

3.2.6 Flow

Flow, or deformability, represents the amount of vertical deformation that occurs from the initial loading to a decrease in stability. The flow rate of a mixture is influenced by the asphalt content in the mixture, temperature, asphalt viscosity, and the shape of aggregate particles. According to the General Specifications for Road Construction 2018 Revision 2, the flow or deformability is limited to 2-4%.

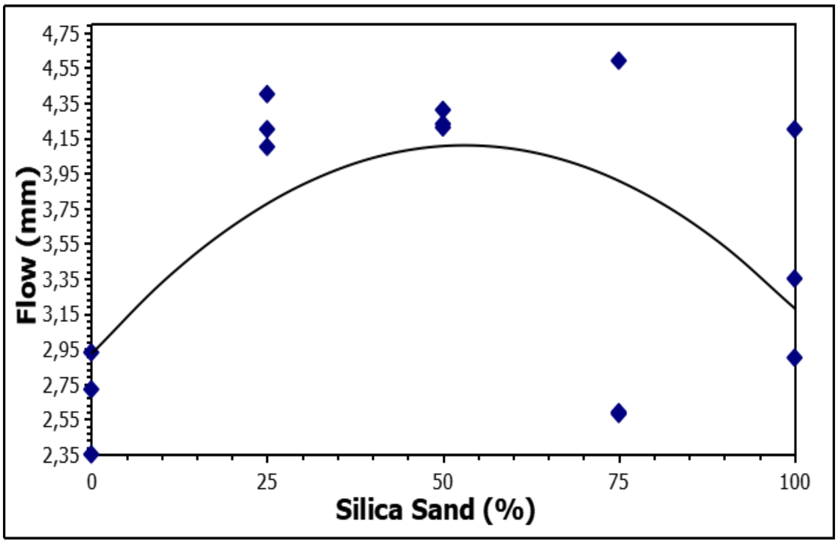

Figure 7. Comparison of melting to silica sand

Based on Figure 7 it can be seen that the higher the percentage of silica sand added as fine aggregate, the higher the melting value produced and will decrease after reaching the maximum value along with the addition of the percentage of silica sand in the AC-WC mixture. This is because the AC-WC mixture with the addition of silica sand makes the asphalt mixture thicken, making the AC-WC mixture plastic and easily changes shape. The greater the deformation due to traffic loads, the higher the flow value in the asphalt mixture with the addition of silica sand.

3.2.7 *Marshall Quotient* (MQ)

Marshall Quotient (MQ) is a measure that indicates the stiffness of a mixture, which is a comparison between stability and susceptibility. A high MQ value indicates that the mixture has high strength but the potential for cracking. Conversely, a low MQ value indicates that the mixture is susceptible to shape changes or permanent deformation.

Based on Figure 8 it can be seen that the higher the addition of the percentage of silica sand as fine aggregate, the lower the MQ value and will increase after reaching the minimum value produced along with the addition of the percentage of silica sand in the AC-WC mixture. This is caused by the high stability value and accompanied by a high flow value so that the mixture tends to be less stable and flexible. So that the mixture becomes more plastic, if it receives a load it will experience a greater deformation, and the provision of sufficient bitumen content will increase the bond between the aggregates so that the mixture becomes more rigid.

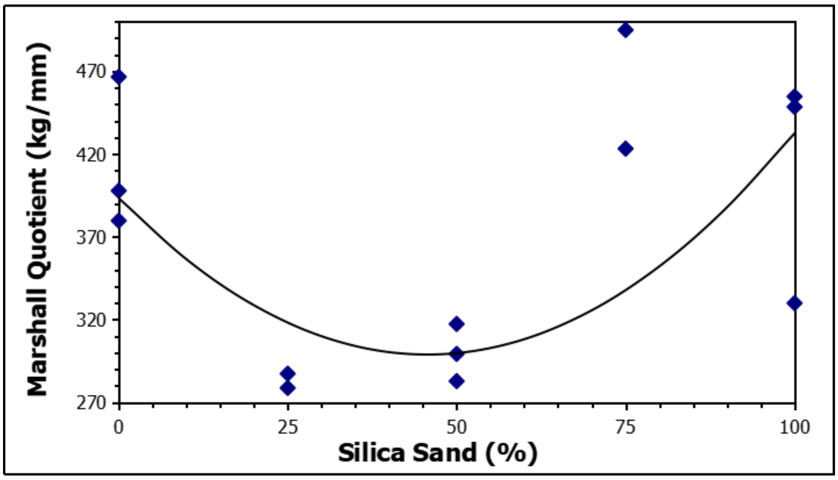

Figure 8. Comparison of the Marshall quotient against silica sand

3.3 Optimum Asphalt Content (KAO)

Based on laboratory test results of substitution of silica sand as fine aggregate in the AC-WC mixture, KAO at a percentage of 0% silica sand is 5.99%, KAO at a percentage of 25% silica sand is 5.88%, KAO at a percentage of 50% silica sand is 5.845%, KAO at a percentage of 75% silica sand is 5.835%, and KAO at a percentage of 100% silica sand is 5.810%. Comparison of Marshall KAO values from five variations of adding silica sand to the AC-WC mixture can be seen in Figure 9.

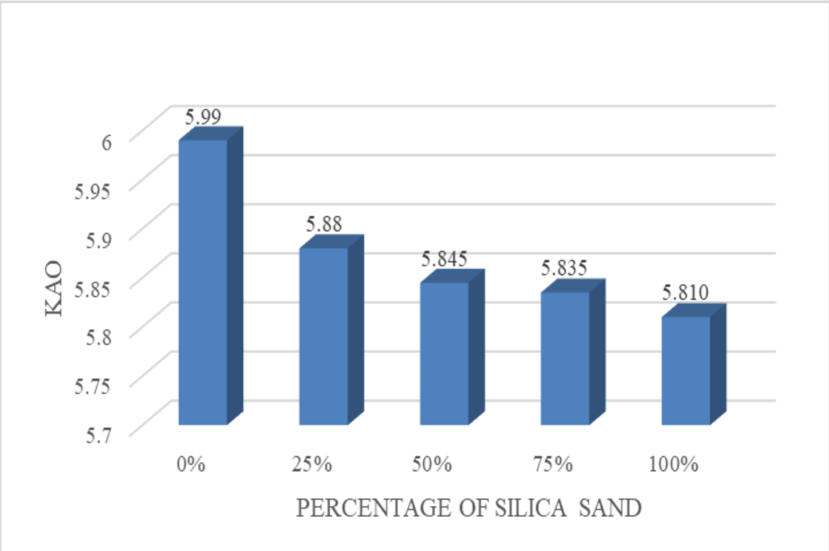

Figure 9. Comparison of Marshall KAO values to silica sand

4. CONCLUSION

Based on research on the AC-WC mixture using silica sand as a fine aggregate substitution that has been carried out, it can be concluded that the KAO value was obtained using the Marshall method for the AC-WC mixture of 5.99% at 0% variation of silica sand, 5.88% at variation 25 % silica sand, 5.845% for 50% silica sand variation, 5.835% for 75% silica sand variation, 5.810% for 100% silica sand variation.

Thus the increasing percentage of silica sand as a fine aggregate substitution in the AC-WC mixture, the lower the KAO value obtained.

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