Utilization of Residual Sand Materials From the Mining of Kaolin and Tin in Bangka Island on Flexible Pavement Structure

Bimo Brata A[1,*] Mirka Pataras[1] Aztri Yuli K[1] Nadia Wiranda[1] Widya Wulansari[1] Bella Madu I[1]

[1] *Civil Engineering Department, University of Sriwijaya*
Jl. Raya Palembang-Prabumulih KM. 32, Inderalaya, Ogan Ilir 30662, Indonesia
**Corresponding Author. Email: bimo.adhitya@gmail.com*

ABSTRACT
Along with the times, people's needs are also increasing. No exception is the need for road infrastructure, both in urban and rural areas. The road is an important access to carry out daily activities. One of the important processes that must be carried out in the design and formation of roads is the process of road paving. Paving roads are an important point in a development, especially in terms of infrastructure for transportation. Bangka Belitung has the potential for fine aggregate material in the form of kaolin sand and tin tailing sand which are waste from mining natural resources of tin and kaolin. In order to reduce the use of river sand as standard fine agregate, kaolin sand and tin tailing sand can be used as an innovation or alternative for replacement on river sand as standard fine aggregate materials in road pavement structure. Therefore, research was carried out to find out the characteristics of kaolin sand and tin tailing sand in the AC-WC (Asphalt Concrete Wearing Course), AC-BC (Asphalt Concrete Binder Course), and Hot Rolled Sheet-Wearing Course (HRS-WC). This study uses the Marshall Tests parameter. Based on Marshall test results, the best Optimum Asphalt Content of AC-WC mixture using kaolin sand is 5.73%, AC-WC mixture using tin tailing sand is 5.45% and AC-WC mixture using river sand is 5.7%. The Optimum Asphalt Content of AC-BC mixture using kaolin sand is 5.8%, AC-BC mixture using tin tailing sand is 5.6% and AC-BC mixture using river sand is 5.55%. Optimum Asphalt Content of HRS-WC using kaolin sand is 8.045%, HRS-WC mixture using tin tailing sand of 8.18% and HRS-WC using river sand is 7.965%. It can be concluded that the Optimum Asphalt Content of AC-WC mixture with the use of kaolin sand and river sand tends to be higher than the AC-WC mixture with the use of tin tailing sand. AC-BC mixture with the use of kaolin sand and tin tailing sand, the Optimum Asphalt Content tends to be more higher than the mixture of AC-BC using river sand. HRS-WC mixture with the use of kaolin sand and tin tailing sand, the Optimum Asphalt Content tends to be more than the mixture of HRS-WC with the use of river sand.

Keywords : *Flexible Pavemen, KAO, Sand and Kaolin*

1. INTRODUCTION

Along with the times, people's needs are also increasing. No exception is the need for road infrastructure, both in urban and rural areas. The road is an important access to carry out daily activities. One of the important processes that must be carried out in the design and formation of roads is the process of road paving.

Paving roads are an important point in a development, especially in terms of infrastructure for transportation. One of the materials used as a mixture material in paving is Asphalt Concrete (AC) and Hot Rolled Sheet (HRS). This material is more commonly referred to as intermediate hot mix asphalt pavement. The characteristics of this material have a layer that is directly related to climate or weather, the thickness of layer had variation that it can withstand the maximum load of traffic passing through it.

The materials used in the Asphalt Concrete (AC) and Hot Rolled Sheet (HRS) consist of asphalt, fine aggregate, coarse aggregate, and filler. The use of coarse aggregate is used as the framework for the pavement, while the fine aggregate is used as the filling of the cavities in the coarse aggregate.

2. LITERATURE REVIEW

2.1. Asphalt Concrete Wearing Course

Asphalt Concrete-Wearing Course (AC-WC) or wear layer asphalt binder layer is a layer of pavement structure that is at the top and functions as a wear layer (Suherman Sulaiman et al., 2010) [6]. According to Cut Khairani (2018) [7] , the AC-WC layer serves as a link between the asphalt concrete layer and the Asphalt Concrete Binder Course (AC-BC) or top base layer or base layer.

2.2. Asphalt Concrete Binder Course

Asphalt Concrete Binder Course (AC-BC) or often referred to as concrete asphalt binder layer is an intermediate layer of wear layer concrete asphalt (AC-WC) with the Asphalt Base layer (AC-Base) (Cut Khairani, 2018) [7].

Based on PUSLITBANG (Research and Development Centre), AC-BC aims to reduce stress and support traffic loads, so it must have sufficient strength. This coating must also be waterproof so that it does not penetrate through surface cracks or holes.

2.3. Hot Rolled Sheet-Wearing Course

HRS or Concrete Asphalt Thin Layer (Lataston) is one type of pavement layer derived from hard asphalt, aggregate with unequal grading, and filler that is put together, stretched, and compacted at certain temperatures and conditions with a thickness of approximately 2.5 to 3 cm (Sukirman, 1999: 10) [8].

The HRS pavement construction consists of two layers that are mixed, namely HRS for wear layers (HRS-WC) and HRS for foundation layers (HR-SBC). HRS-WC is used as a wear layer for the asphalt surface. HRS-WC is waterproof, strong resistant to grooves, has a smooth surface, can distribute loads, and has slip resistance. This layer rubs directly against the wheels of the vehicle and the weather so it is easy to wear out.

2.4. Tin Tailings Sand

Tin is the main natural resource originating from the island of Bangka Belitung. The large amount of tin in Bangka Belitung produces waste due to the mining process, and this waste is called tin tailing.

Tin tailing comes from the decomposition of tin metal that has been leached during mining activities (Inonu et al. 2011) [5]. Mangara et al. (2007) states that the tailing material comes from 50% fraction of fine sand with a diameter of 0.075 - 0.4 mm, while the rest is a clay fraction with a diameter of 0.075 mm. This tin tailing sand can be used as a fine aggregate material for road trays [9].

Figure 1. Tin Tailing Sand

2.5. Kaolin Sand

Kaolin is a clay that is soft, smooth, and has a white colour. According to Utari (1994) kaolin is a type of rock that includes clay (clay) [10]. The composition of the content in kaolin is SiO_2, Al_2O_3 and H_2O. Kaolin is generally used as a manufacture of cosmetics, rubber, or paper. Kaolin comes from the mining area which forms irregular holes in the form of a lake filled with bright blue water surrounded by white sand. Kaolin mining is generally carried out by open techniques and by way of spraying (hydraulicking).

Usually kaolin processing is carried out by spraying the kaolin sediment with a monitor so that it is uncovered and forms a thick kaolin sludge which will then be filtered. This filtering process produces a new composition of kaolin, or what is called kaolin mining waste in which there is kaolin sand.

Figure 2. Kaolin Sand

2.6. River Sand (Standard Fine Agregate)

River sand is sand obtained from rivers and is a natural material as a result of erosion of strong and sharp rocks which are then carried away by the river flow and settling on the bottom. River sand is in the form of grains with a size between 0.063 mm - 5 mm, not too big and not too small. River sand is one of the building materials that is often used in construction.

Figure 3. River Sand (Standard Fine Agregate)

2.7. Marshall Test

Marshall Test is conducted to determine the stability and flow of the asphalt mixture. Marshall testing is done using a Marshall engine. Prior to the Marshall test, samples were immersed in a water bath with a temperature of 60ºC for 30 minutes. Other Marshall Parameters are VIM, VMA, VFA, and MQ. The Optimal Bitumen Content can be determined using Marshall Paramaters (Stability, Flow, MQ, VIM, VMA, and VFA).

3. RESULTS AND DISCUSSION

3.1. Sand Test Results

Fine Agregate Test on this study referring to the General Specifications of Bina Marga 2018 Division 6 Section 6.3. The result of sand tests :

Table 1. Sand Test Results

No.	Characteristics	Results			Spec.
		Kaolin Sand	Tin Tailling Sand	River Sand	
1.	Bulk Specific Gravity (g/cm^3)	2,570	2,568	2,558	Min 2,5
2.	SSD Specific Gravity(g/cm^3)	2,593	2,592	2,591	Min 2,5
3.	Apparent Specific Gravity (g/cm^3)	2,631	2,631	2,646	Min 2,5
4.	Water Absorption (%)	0,908	0,918	1,297%	Maks 2%
5.	Weight Content	1,443	1,464	1,458	-
6.	Value Equal to Sand (%)	95,45%	94,03%	86,97%	Min 50%

3.2. Marshall Test Results

The materials used consist of 1-2 crushed stones and 1-1 crushed stones, rock ash, kaolin sand, tin tailling sand, river sand (standard fine aggregate), cement as filler and asphalt 60/70 penetration. The specimens made in this study consist of 3 types of pavement, namely AC-WC, AC-BC and HRS-WC. From the Marshall test, the values of stability, flow, VMA, VFA, VIM and Marshall Quotient were obtained. Following are the Marshall test results after making the test object:

Table 2. Marshall Test Results of AC-WC Mixture Using Kaolin Sand

No.	Characteristics	Terms	Asphalt Content				
			4,5%	5%	5,5%	6%	6,5%
1	VMA	Min. 14	15,706	16,057	16,811	17,054	17,209
2			15,988	15,932	16,427	17,854	17,612
3			15,273	16,148	16,385	17,498	17,264
	Average		**15,656**	**16,046**	**16,541**	**17,469**	**17,362**
1	VFA	Min. 65	63,787	69,401	72,645	78,301	84,359
2			62,452	70,048	74,686	74,072	82,025
3			65,930	68,933	74,914	75,909	84,029
	Average		**64,056**	**69,461**	**74,082**	**76,094**	**83,471**
1	VIM	3-5	5,688	5,107	4,598	3,701	2,692
2			6,003	5,160	4,158	4,629	3,166
3			5,204	5,017	4,110	4,215	2,757
	Average		**5,632**	**5,094**	**4,289**	**4,182**	**2,872**
1	Stability	Min. 800	1018,35	1013,70	1154,2	1083,37	1029,98
2			1123,20	1039,08	1247,0	1125,68	995,10
3			1149,60	1078,77	1169,4	998,40	966,58
	Average		**1097,05**	**1043,85**	**1190,22**	**1069,1**	**997,22**
1	Flow	Min. 2	2,94	3,1	3,26	3,32	3,42
2			3,1	3,14	3,20	3,34	3,4
3		Max. 4	3,13	3,1	3,22	3,31	3,44
	Average		**3,05**	**3,11**	**3,22**	**3,32**	**3,42**
1	MQ	Min 250	346,37	327,00	354,05	326,31	301,16
2			362,32	330,92	3389,69	337,03	292,67
3			367,28	347,99	363,17	301,63	280,91
	Average		**358,66**	**355,30**	**368,97**	**321,66**	**291,60**

Table 3. Marshall Test Result of AC-WC Mixture Using Tin Tailing Sand

No.	Characteristics	Terms	Asphalt Content				
			4,5%	5%	5,5%	6%	6,5%
1	VMA	Min. 14	15,160	15,723	16,609	17,232	17,242
2			15,570	15,942	16,276	16,533	17,122
3			15,426	16,427	16,252	16,544	17,485
	Average		**15,385**	**16,031**	**16,379**	**16,770**	**17,283**
1	VFA	Min. 65	66,541	71,186	73,738	77,360	84,196
2			64,478	70,027	75,544	81,312	84,910
3			65,188	67,567	75,677	81,249	82,782
	Average		**65,402**	**69,594**	**74,986**	**79,974**	**83,963**
1	VIM	3-5	5,072	4,530	4,362	3,901	2,725
2			5,531	4,778	4,981	3,090	2,584
3			5,370	5,328	3,953	3,102	3,011
	Average		**5,324**	**4,879**	**4,098**	**3,364**	**2,773**
1	Stability	Min. 800	971,50	1053,2	1088,10	1032,85	956,930
2			957,94	1029,9	1057,23	985,660	970,190
3			973,29	1028,3	1071,82	1012,18	964,218
	Average		**967,59**	**1037,1**	**1072,38**	**1010,23**	**963,780**
1	Flow	Min. 2	3,35	3,5	3,5	3,6	3,66
2			3,4	3,48	3,47	3,55	3,68
3		Max. 4	3,35	3,4	3,54	3,63	3,6
	Average		3,35	3,5	3,5	3,6	3,66
1	MQ	Min 250	290,01	300,92	310,88	286,90	262,17
2			281,74	295,97	304,67	277,65	263,63
3			290,53	302,44	302,77	278,83	267,83
	Average		**287,43**	**299,77**	**306,11**	**281,13**	**264,55**

Table 4. Marshall Test Result of AC-WC Mixture Using River Sand (Standar Fine Agregate)

No.	Characteristics	Terms	Asphalt Content				
			4,5%	5%	5,5%	6%	6,5%
1	VMA	Min. 14	14,625	15,953	15,772	16,901	17,534
2			15,146	15,525	16,383	17,457	17,508
3			15,068	16,229	16,617	16,867	17,495
	Average		**15,424**	**15,897**	**16,258**	**16,938**	**17,213**
1	VFA	Min. 65	69,367	70,016	78,377	79,142	82,453
2			66,572	72,217	74,906	76,111	82,599
3			66,977	68,509	73,645	79,332	82,675
	Average		**65,179**	**70,247**	**75,643**	**78,979**	**84,325**
1	VIM	3-5	4,480	4,778	3,410	3,525	3,077
2			5,063	5,313	4,111	4,170	3,046
3			4,976	5,111	4,380	3,486	3,031
	Average		**5,374**	**4,734**	**3,967**	**3,570**	**2,699**
1	Stability	Min. 800	963,56	1027,6	1097,40	1036,95	1002,78
2			976,82	1016,4	1090,42	1011,37	963,560
3			974,66	1053,08	1088,10	1016,40	1025,51
	Average		**971,663**	**1032,37**	**1091,9**	**1021,57**	**997,287**
1	Flow	Min. 2	3,23	3,4	3,48	3,57	3,6
2			3,3	3,3	3,4	3,55	3,6
3		Max. 4	3,4	3,46	3,5	3,4	3,57
	Average		**3,31**	**3,38**	**3,46**	**4,50**	**3,59**
1	MQ	Min 250	298,31	302,25	315,34	290,46	278,55
2			296,00	308,00	320,71	284,89	267,65
3			286,65	304,36	310,88	298,94	287,25
	Average		**293,65**	**304,87**	**315,64**	**291,43**	**277,82**

Table 5. Marshall Test Results of AC-BC Mixture Using Kaolin Sand

No.	Characteristics	Terms	Asphalt Content				
			4,5%	5%	5,5%	6%	6,5%
1	VMA	Min. 15	15,967	16,199	16,309	16,904	17,183
2			15,942	16,564	16,617	17,022	17,202
3			15,730	16,519	16,182	16,832	17,150
	Average		**15,880**	**16,427**	**16,369**	**16,919**	**17,178**
1	VFA	Min. 65	62,551	68,675	75,328	79,144	84,513
2			62,667	66,867	73,663	78,481	84,395
3			63,670	67.088	76,038	79,546	84,705
	Average		**62,963**	**67,543**	**75,010**	**79,057**	**84,538**
1	VIM	4-6	5,979	5,074	4,024	3,525	2,661
2			5,952	5,488	4,376	3,663	2,684
3			5,715	5,437	3,877	3,443	2,623
	Average		**5,882**	**5,333**	**4.093**	**3,544**	**2,656**
1	Stability	Min. 800	1046,25	1315,95	1517,34	1579,50	1283,40
2			1022,40	1259,16	1517,45	1556,25	1302,00
3			960,0	1281,92	1442,81	1428,00	1308,41
	Average		**1009,55**	**1287,65**	**1511,87**	**1251,25**	**1297,94**
1	Flow	Min. 2	2,80	3,43	3,65	3,88	3,9
2			3,05	3,3	3,55	3,8	3.98
3		Max. 4	3,22	3,44	3.75	3.75	3.8
	Average		**3,023**	**3,390**	**3,650**	**3.81**	**3,33**
1	MQ	-	373,66	383,65	415,71	407,08	329,07
2			335,21	381,56	443,78	409,53	327,13
3			298,13	372,56	385,75	380,80	344,31
	Average		**335,670**	**379,290**	**414,750**	**399,142**	**333,511**

Table 6. Marshall Test Result of AC-BC Mixture Using Tin Tailing Sand

No.	Characteristics	Terms	Asphalt Content				
			4,5%	5%	5,5%	6%	6,5%
1	VMA	Min. 15	14,690	15,251	15,632	16,518	17,326
2			14,591	15,162	15,435	16,727	17,681
3			14,184	14,965	15,940	16,821	17,871
	Average		**14,488**	**15,126**	**15,669**	**16,689**	**17,626**
1	VFA	Min. 65	69,051	73,799	79,262	81,403	83,705
2			69,600	74,310	80,459	80,182	81,672
3			71,940	75,464	77,446	79,646	80,615
	Average		**70,197**	**74,524**	**79,056**	**80,410**	**81,998**
1	VIM	3-4	4,546	3,996	3,242	3,072	2,823
2			4,436	3,895	3,016	3,315	3,241
3			3,980	3,672	3,595	3,424	3,464
	Average		**4,321**	**3,854**	**3,284**	**3,270**	**3,176**
1	Stability	Min. 800	1136,925	1292,700	1327,219	1348,1	1234,2
2			1148,550	1270,500	1340,831	1314,9	1188,98
3			1132,106	1320,600	1352,175	1315,8	1256,55
	Average		**1139,194**	**1294,575**	**1340,07**	**1326,30**	**1226,576**
1	Flow	Min. 2	3,75	3,5	3,95	4	4,19
2			3,5	3,55	3,91	3,9	4,12
3		Max. 4	3,46	3,75	3,87	3,89	3,9
	Average		**3,570**	**3,600**	**3,910**	**3,930**	**4,070**
1	MQ	-	303,180	369,343	336,005	337,025	294,558
2			328,157	357,887	342,924	337,167	288,587
3			327,198	352,160	349,399	338,271	322,192
	Average		**319,512**	**359,797**	**342,776**	**337,488**	**301,779**

Table 7. Marshall Test Results of AC-BC Mixture Using River Sand (Standard Fine Agregate)

No.	Characteristics	Terms	Asphalt Content				
			4,5%	5%	5,5%	6%	6,5%
1	VMA	Min. 15	14,074	14,715	16,365	17,495	17,593
2			14,055	14,865	16,383	17,305	17,592
3			14,323	14,522	16,241	17,224	17,585
	Average		**14,151**	**14,701**	**16,330**	**17,342**	**17,590**
1	VFA	Min. 65	72,545	76,922	75,007	75,906	82,116
2			72,662	76,014	74,906	76,918	82,119
3			71,078	78,122	75,691	77,353	82,160
	Average		**72,095**	**77,019**	**75,201**	**76,726**	**82,132**
1	VIM	3-5	4,065	4,017	3,754	3,480	3,146
2			4,042	3,927	3,914	3,456	3,146
3			4,142	3,844	3,948	3,665	3,137
	Average		**4,083**	**3,929**	**3,872**	**3,534**	**3,143**
1	Stability	Min. 800	1045,89	1232,25	1284,113	1032,30	999,75
2			1085,77	1211,51	1339,200	1055,55	1008
3			1066,31	1253,89	1259,156	1082,19	971,29
	Average		**1065,99**	**1232,55**	**1294,15**	**1056,6**	**993,01**
1	Flow	Min. 2	2,84	3,08	3,54	3,71	3,65
2			3,71	3,3	3,67	3,6	3,78
3		Max. 4	2,87	3,34	3,58	3,7	3,7
	Average		**3,140**	**3,240**	**3,597**	**3,670**	**3,710**
1	MQ	-	368,272	400,08	362,74	278,248	273,90
2			292,662	367,12	364,90	293,208	266,66
3			371,537	375,41	351,72	292,485	262,51
	Average		**344,157**	**380,87**	**359,78**	**287,980**	**267,694**

Table 8. Marshall Test Results of HRS-WC Mixture Using Kaolin Sand

No.	Characteristics	Terms	Asphalt Content				
			7%	7.5%	8%	8.5%	9%
1	VMA	Min. 18	21,486	21,878	22,235	22,660	22,800
2			21,358	21,480	22,202	22,918	22,490
3			21,326	21,287	22,440	22,723	22,592
	Average		**21.39**	**21.55**	**22.29**	**22.77**	**22.63**
1	VFA	Min. 68	69,360	73,011	76,694	79,957	84,450
2			69,891	74,743	76,842	78,791	85,956
3			70,023	75,606	75,792	79,670	85,454
	Average		**69.76**	**74.45**	**76.44**	**79.47**	**85.29**
1	VIM	4-6	6,583	5,905	5,182	4,542	3,545
2			6,431	5,425	5,142	4,861	3,158
3			6,393	5,193	5,432	4,620	3,286
	Average		**6.47**	**5.51**	**5.25**	**4.67**	**3.33**
1	Stability	Min. 600	953.25	990.45	1167.19	1090.97	932.33
2			993.60	971.03	1214.96	1123.09	948.60
3			988.80	985.37	1159.31	1051.20	973.65
	Average		**978.55**	**982.28**	**1180.49**	**1088.42**	**951.52**
1	Flow	Min. 2	2.00	2.1	2.70	2.85	3.5
2			2.09	2.11	2.73	2.7	3.53
3		Max. 4	2.11	2.18	2.79	2.89	3.56
	Average		**2.07**	**2.13**	**2.74**	**2.81**	**3.53**
1	MQ	Min. 250	476.63	471.64	432.29	382.80	266.38
2			475.41	460.20	445.04	415.96	268.73
3			468.63	452.00	415.52	363.74	273.50
	Average		**473.55**	**461.28**	**430.95**	**387.50**	**269.53**

Table 9. Marshall Test Results of HRS-WC Mixture Using Tin Tailing Sand

No.	Characteristics	Terms	Asphalt Content				
			7%	7.5%	8%	8.5%	9%
1	VMA	Min. 18	17.76	17.90	18.34	18.68	18.75
2			18.61	18.17	18.81	18.79	18.65
3			17.74	18.17	18.49	18.87	19.11
	Average		**18.04**	**18.08**	**18.55**	**18.78**	**18.84**
1	VFA	Min. 68	87.90	93.76	97.61	101.99	108.07
2			83.01	92.11	94.62	101.22	108.78
3			88.01	92.10	96.65	100.75	105.55
	Average		**86.31**	**92.66**	**96.30**	**101.32**	**107.47**
1	VIM	4-6	6.99	5.95	5.25	4.42	3.27
2			7.96	6.25	5.79	4.55	3.15
3			6.97	6.25	5.42	4.64	3.70
	Average		**7.31**	**6.15**	**5.49**	**4.54**	**3.38**
1	Stability	Min. 600	1076.48	1127.63	1297.73	1140.36	1016.40
2			1069.50	1107.15	1322.68	1151.41	983.45
3			1039.09	1120.65	1306.80	1154.79	992.29
	Average		**1061.69**	**1118.48**	**1309.07**	**1148.85**	**997.38**
1	Flow	Min. 2	2.73	2.85	2.98	3.05	3.11
2			2.77	2.81	2.91	3.11	3.15
3		Max. 4	2.72	2.83	2.96	3.01	3.12
	Average		**2.74**	**2.83**	**2.95**	**3.06**	**3.13**
1	MQ	Min. 250	394.31	395.66	435.48	373.89	326.82
2			386.10	394.00	454.53	370.23	312.21
3			382.02	395.99	441.49	383.65	318.04
	Average		**387.48**	**395.22**	**443.83**	**375.92**	**319.02**

Table 10. Marshall Test Results of AC-BC Mixture Using River Sand (Standard Fine Agregate)

No	Characteristics	Terms	Asphalt Content				
			7%	7.5%	8%	8.5%	9%
1	VMA	Min. 18	20.464	20.119	21.042	21.505	21.922
2			20.273	20.606	21.253	21.985	21.721
3			19.979	20.831	20.380	21.888	21.768
	Average		**20.24**	**20.52**	**20.89**	**21.79**	**21.80**
1	VFA	Min. 68	73.743	81.149	82.250	85.476	88.795
2			74.616	78.751	81.218	83.098	89.846
3			75.992	77.678	85.638	83.571	89.599
	Average		**74.78**	**79.19**	**83.04**	**84.05**	**89.41**
1	VIM	4-6	6.593	5.018	4.946	4.327	3.654
2			6.369	5.596	5.199	4.912	3.406
3			6.024	5.864	4.148	4.794	3.464
	Average		**6.33**	**5.49**	**4.76**	**4.68**	**3.51**
1	Stability	Min. 600	1081.11	1118.53	1348.49	1216.47	1056.16
2			1060.88	1110.20	1344.54	1228.26	1049.09
3			1056.26	1136.32	1328.40	1173.88	1035.51
	Average		**1066.08**	**1121.68**	**1340.48**	**1206.20**	**1046.92**
1	Flow	Min. 2	2.32	2.40	3.31	3.10	3.20
2			2.34	2.45	3.00	3.41	3.34
3		Max. 4	2.35	2.38	3.70	3.24	3.45
	Average		**2.34**	**2.41**	**3.34**	**3.25**	**3.33**
1	MQ	Min. 250	465.99	466.05	407.40	392.41	330.05
2			453.37	453.14	448.18	360.19	314.10
3			449.47	477.44	359.03	362.31	300.15
	Average		**456.28**	**465.55**	**404.87**	**371.64**	**314.76**

3.3. Optimum Asphalt Content (KAO)

After obtaining Optimum Asphalt Content (KAO), then look for the Marshall Parameter value against Optimum Asphalt Content (KAO) against the three layers, namely AC-WC, AC-BC and HRS-WC. The results can be found at :

Table 11. Results of Marshall AC-WC Parameters on KAO

No.	Parameter	AC-WC mix		
		Kaolin Sand	Tin Tailing Sand	River Sand
1.	KAO (%)	5,73	5,45	5,7
2.	VMA (%)	16,662	15,690	16,563
3.	VFA (%)	76,005	78,174	76,860
4.	VIM (%)	4,002	3,604	4,464
5.	Stability (Kg)	1516,954	1344,249	1215,235
6.	*Flow* (mm)	3,719	3,813	3,588
7.	MQ (Kg / mm)	409,024	352,750	339,898

The results obtained from the Marshall parameter above have different KAO values in each mixture. The difference in value will be used as a comparison of the three mixtures.

Based on table 10, the Optimum Asphalt Content of the AC-WC mixture using kaolin sand is 5.73%, AC-WC using tin tailings sand 5.45%, and the AC-WC mixture using river sand is 5.7%, and 5.7%. The highest is the value of KAO for the utilization of kaolin sand.

The combination of AC-WC with kaolin sand produced a VMA value of 16,662, which is higher than AC-WC mix with tin tailing sand utilization 15,690 and AC-WC mixture with river sand utilization 16,563.

The high VFA value in the asphalt mixture shows that the more air voids between the aggregates and mixture are filled with asphalt. In this table, tin tailings sand has the highest value with a value of 78.174 while river sand is 76.860 and kaolin sand is 76.005.

The table shows that the AC-WC mixture using river sand is 4.115. When compared with the AC-WC mixture of kaolin sand (4.002) and tin tailing sand (3.604), river sand is the highest level.

Kaolin sand has the highest stability value at 1516,954 while tin tailing sand is 1344,249 and river sand is 1215,235. This means that the lower the stability value of a mixture, the higher the potential to experience changes in shape due to traffic loads.

The AC-WC mixture with the utilization of tin tailing sand produced the highest flow/melting value at 3,813, while kaolin sand at 3,719 and the lowest was owned by the AC-WC mixture with the utilization of river sand at 3,588. The higher the flow/melting value of an asphalt mixture, the more flaccid and pliable the mixture will be. Conversely, the lower the flow/melting value of a mixture, the stiffer the mixture will be and tends to crack easily when given a load.

From the results of the MQ value data, it can be seen that the AC-WC composite with the use of kaolin sand has the best stiffness and resistance to deformation with a height of 409.024 compared to the AC-WC mixture with the use of 352,750 tin tailings sand and 339,898 river sand. However, with the high MQ value, the AC-WC mixture with the utilization of river sand had a greater tendency to crack than the other two mixtures.

Table 12. Results of Marshall AC-BC Parameters on KAO

No.	Parameter	AC-BC mix		
		Kaolin Sand	Tin Tailing Sand	River Sand
1.	KAO (%)	5,8	5,6	5,55
2.	VMA (%)	17,014	16,460	16,410
3.	VFA (%)	75,779	76,000	75,557
4.	VIM (%)	4,126	4,464	3,954
5.	Stability (Kg)	1104,711	1055,637	1120,092
6.	*Flow* (mm)	3,277	3,533	3,460
7.	MQ (Kg/mm)	337,415	298,977	308,268

The Marshall Parameter results obtained were different for each mixture due to the different KAO values in each mixture. From these differences in values, a comparison of the values between the three mixtures can be made.

Based on table 11, the KAO value of AC-BC mixture using kaolin sand, AC-BC mixture with residual sand, and AC-BC mixture using river sand were 5.8%, 5.6% and respectively. 5.55%. Therefore, AC-BC mixture with the utilization of river sand, the use of asphalt tends to be less than the AC-BC mixture with the utilization of kaolin sand and tin tailings sand.

A mixture of AC-BC with the use tin tile sand and a mixture of AC-BC with the use of river sand. So that AC-BC mix the kaolin sand tends to have more cavities or pores among the aggregates among other AC-BC mixtures.

Based on the research results, the AC-BC mixture using tin tailings sand had a greater VFA value between the AC-BC mixture using kaolin sand and the AC-BC mixture using river sand.

The AC-BC mixture with the use of tin tailings sand showed a lower VIM value than the AC-BC mixture using kaolin sand and AC-BC mixture using the utilization of tin tailings sand. It can be concluded that AC-BC mixtures using tin tailings sand tend to have less cavities or pores in the mixture than AC-BC mixtures using kaolin sand and AC-BC mixtures using river sand

Mixture of AC-BC with utilization of river sand shows greater stability value between AC-BC admixture with the utilization of kaolin sand and tin tailings sand. So it can be concluded that the AC-BC admixture with the utilization of river sand has the ability to withstand the load without experiencing a change in shape, greater than the AC-BC mixture using kaolin sand and AC-BC mixture using residue tin sand.

Based on table 11, the AC-BC admixture with the utilization of tin tailings sand has a greater melting value (flow) among the AC-BC admixture with the utilization of kaolin sand and the AC-BC admixture with the utilization of river sand.

Based on data from the results of the MQ value, it can be seen that the HRS-WC mixture with the use of kaolin sand has the best stiffness and resistance to deformation, with a value of 337,415 compared to the HRS-WC mixture with the use of tin tailings sand 298,977 and river sand 308,268. However, with the high MQ value, the HRS-WC mixture with the utilization of tin tailings sand had a greater tendency to crack than the other two mixtures.

Table 13. Results of Marshall HRS-WC Parameters on KAO

No.	Parameter	HRS-WC mix		
		Kaolin Sand	Tin Tailings Sand	River Sand
1.	KAO (%)	8.045	8.18	7.965
2.	VMA (%)	22.284	18.578	21.047
3.	VFA (%)	76.894	98.572	81.933
4.	VIM (%)	5.184	5.106	5.037
5.	Stability (Kg)	1123.401	1227.642	1271.962
6.	*Flow* (mm)	2.579	3.563	3.097
7.	MQ (Kg/mm)	432.775	408.302	419.902

The results obtained based on the Marshall parameters above show different KAO values for each mixture. The difference in value will be used as a comparison of the three mixtures.

First is the Optimum Asphalt Contentobtained based on a mixture of HRS-WC with kaolin sand, a mixture of HRS-WC with tin tailings sand, and a mixture of HRS-WC with river sand with values of 8.045%, 8.18% and 7.965% respectively. The highest was a mixture of HRS-WC with the utilization of tin tailings sand.

The HRS-WC mixture with the use of kaolin sand showed a VMA value of 22.284%, higher than the HRS-WC mixture with the utilization of tin tailings sand 18.578% and the HRS-WC mixture using river sand 21.047%.

The high VFA value in the asphalt mixture indicates that the more air voids between the aggregates are filled with asphalt. Conversely, if the VFA value is too low, the asphalt mixture will become more hollow so that it can minimize the tightness of the asphalt mixture and can make the mixture last. The VFA value of tin tailings sand is higher with a value of 98.450% while river sand is 81.933% and kaolin sand is 76.894%.

The HRS-WC mixture using kaolin sand showed the largest percentage of VIM values, which is 5.184% when compared to other HRS-WC mixtures, such as tin tailings sand with a value of 5.106% and river sand of 5.037%. Asphalt mixtures with high VIM values will result in a mixture that is hollower and more prone to cracking.

The higher the value the stability of an asphalt mixture, the stronger the mixture while supporting more traffic. Based on the results, it shows that river sand is higher with a value of 1271.962% while tin tailings sand is 1227.642% and kaolin sand 1123.401%. Conversely, the lower the stability value of a mixture, the higher the potential to change shape due to traffic loads.

The mixture of HRS-WC with the utilization of tin tailings sand had the highest melting value, namely 3.563%, while river sand was 3.097% and the lowest was owned by the HRS-WC mixture with the use of kaolin sand of 2.579%. The higher the melting value of an asphalt mixture, the more flaccid and flexible the mixture will be. Conversely, the lower the melting value of a mixture, the stiffer the mixture will be and tends to crack easily when given a load.

Based on data from the results of the MQ value, it can be seen that the HRS-WC mixture with the use of kaolin sand has the best stiffness and resistance to deformation, with a value of 432.775% compared to the HRS-WC mixture with the use of tin tailings sand 407.302% and river sand 419.902%. However, with the high MQ value, the HRS-WC mixture with the utilization of tin tailings sand had a greater tendency to crack than the other two mixtures.

4. CONCLUSION

4.1. Based on the results obtained from the research on the performance of AC-WC flexible pavement using kaolin sand and tin tailing sand with Marshall testing, it can be concluded:

a. Tin tailings sand and kaolin sand can be used as fine aggregate material on the pavements, because the characteristics of the tin tailings sand and kaolin sand are in accordance with Bina Marga 2018 specifications.

b. Comparison of KAO values based on Marshall Parameters.

The KAO obtained based on the results of the AC-WC mixture using kaolin sand was 5.73%, the AC-WC mixture using tin tailings sand 5.45%, and the AC-WC mixture using river sand of 5.7%. Thus, the AC-WC mixture with the use of sand tends to be more efficient in the use of asphalt.

4.2. The results of research on the performance of the laston binder course flexible pavement using kaolin sand and tin tailing sand with Marshall testing, are summarized as follows:

a. Kaolin sand and tin tailings sand can be used as materials in the form of fine aggregates on road pavements, because the characteristics of kaolin sand and tin tailings meets the specifications of Bina Marga 2018.

b. Comparison of KAO values based on Marshall Parameters.

KAO obtained from the AC-BC admixture with the use of kaolin sand was 5.8%, the AC-BC admixture with the utilization of tin tailings sand was 5.6%, and the AC-BC admixture with the utilization of river sand was 5.55%. So it can be concluded that the AC-BC admixture with the use of river sand tends to be more efficient in using asphalt.

4.3. The results of research on the performance of HRS-WC flexible pavement using kaolin sand and tin tailing sand with Marshall testing can be concluded as follows:

a. Kaolin sand and tin tailings sand can be used as materials in the form of fine aggregates on road pavements, because the characteristics of kaolin sand and tin tailings meets the specifications of Bina Marga 2018.

b. Comparison of KAO values based on Marshall Parameters.

KAO obtained from the HRS-WC mixture with the use of kaolin sand was 8.045%, the HRS-WC mixture with the utilization of tin tailings sand 8.18%, and the HRS-WC mixture with the utilization of river sand by 7.965%. So it can be concluded that the HRS-WC mixture with the use of river sand tends to be more efficient in the use of asphalt.

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