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Performance of Porous Asphalt Mixtures using De-oiled Bleaching Earth (DBE) Filler with University of New Hampshire Stormwater Center (UNHSC) Gradation

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Abstract

Porous asphalt is an asphalt mixture designed with open-graded composite material and serves to drain water on the road surface into the pore of the mixture. The coarse aggregate composition that dominates the porous asphalt mixture makes it have low stability, in this research, DBE was used as a filler replacement to improve the performance of the mixture. This study aims to determine the performance of porous asphalt mixture using DBE filler with UNHSC gradation. Variations of DBE filler content used were 0%, 25%, 50%, 75%, and 100% by weight of filler. Test specimens with DBE filler were made using optimum asphalt content (KAO), with tests including Marshall test, binder drain down, permeability, and Cantabro loss. The results showed that the performance of porous asphalt mixtures with DBE fillers obtained stability and VIM values decreased and flow values increased. In the permeability test, the highest value was 0.214 cm/s at 0% DBE, the highest Cantabro loss value was 28.07% at 100% DBE, and the highest binder drain-down value was 0.24% at 0% DBE. The results of the research can conclude that the use of DBE as a filler can reduce the performance of porous asphalt mixtures.

Keywords: Asphalt mixture performance; de-oiled bleaching earth; porous asphalt mixture; UNHSC gradation

1. Introduction

Indonesia is located in a tropical region with high levels of rainfall that makes a lot of puddles on the road and can cause damage to the road such as weakening the adhesion of asphalt [1], [2]. Heavy rainfall can also affect flooding due to poor drainage, which can cause stripping, raveling, and potholes on the road [3]. One alternative that can be used to reduce the impact of puddling on the road surface is by using porous asphalt pavement [4].

Porous asphalt is an open-graded composite asphalt mix that contains less fine aggregate and more air voids than other asphalt mixtures [5]. The higher percentage of coarse aggregate gives the mix a large amount of air voids, allowing fluid to pass freely through it [6]. In this case, porous asphalt is used to drain water on the road surface into the pores of the mixture which can minimize puddles on the road surface after rain [7].

The gradation of the aggregates used has an effect on the performance of porous asphalt mixes, in addition to properties of the porous asphalt material [8], [9]. The UNHSC gradation in this research has a good mix design for porous asphalt mixtures because it has a lower percentage of fine aggregate than the coarse aggregate and fewer variations in sieve number than some other gradations such as the Australian Asphalt Pavement Association (AAPA) with ten to twelve sieve size variations [10]. The UNHSC gradation porous asphalt mixture contains a high percentage of coarse aggregate, which makes it have large air voids in the mixture and a rough surface, that can serve to reduce vehicle noise and increase skid resistance of the road [11], [12].

The many advantages of porous asphalt are not without problems, one issue with porous asphalt is its lower stability compared to other asphalt mixtures due to the composition of porous asphalt which is dominated by coarse aggregate, therefore making porous asphalt becomes stiff and brittle [13]. Porous asphalt also has the possible danger of pavement disintegration that occurs due to poor interlocking caused by using large amounts of coarse aggregate and limited fine aggregate [14]. To solve this weakness and enhance the quality of porous asphalt mixtures, modifications are needed, to affect the performance value of porous asphalt.

In this research, DBE waste is used as a replacement filler for porous asphalt mixture to overcome the weaknesses of porous asphalt, this is expected to enhance the performance of the asphalt. DBE waste is the product of SBE re-refining by reducing its oil content by 15%-20% [15]. The use of DBE as a filler is based on some of the

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elemental content of DBE which has similarities with cement which has been widely used as a filler in previous research, the highest similar elements are silica (Si), iron (Fe), calcium (Ca), and aluminum (Al) [16].

Based on the description above, the use of DBE as a replacement for filler in porous asphalt mixtures is expected to obtain good porous asphalt mixture performance and can provide a novelty, which is to reveal the performance of porous asphalt mix that uses DBE waste as a filler replacement material. Hopefully, this research can reduce the volume of waste from palm oil refining.

2. Method

2.1. Materials for mixture

The materials used in this research are aggregates, asphalt penetration 60/70, and DBE as a filler replacement. The specifications of these materials are:

2.1.1. Aggregate

Fine and coarse aggregates come from crushed stone that is clean, dry, and free from chemicals that can affect the physical properties of the aggregate. The aggregate in this research comes from PT Batu Kali Welang Ampuh, Pasuruan. The material must meet the required specification standards. The standards for coarse aggregate and fine aggregate in this research refer to RSNI 2 Design and Implementation of Porous Asphalt Mixtures.

2.1.2. Asphalt

The asphalt used in this research is pen 60/70 asphalt from PT Pertamina. The asphalt must meet the required standard specifications. The standard for pen 60/70 asphalt in this research refers to RSNI 2 Design and Implementation of Porous Asphalt Mixtures.

2.1.3. Filler

The fillers used in this research are DBE and Portland cement. The DBE used comes from PT Wilmar Nabati Indonesia, Gresik. At the same time, the cement used is the Portland cement brand, Tiga Roda. DBE and Portland cement as filler in the mixture of test specimens must pass the No. 200 (0.075 mm) sieve.

2.2. Specimen test planning

The planning stages for the test objects in this research are as follows:

2.2.1. Calculation of material requirements test objects

The calculation of material requirements at this step is carried out to determine the aggregate requirements for one research specimen. The calculation of aggregate requirements is based on the UNHSC gradation for porous asphalt mixtures [17].

The aggregate requirement for one specimen can be seen in Table 1.

Table 1. The aggregate requirements for one test specimen

Sieve Size (inch/mm)	Porous Asphalt			
	% Gradation Range	% Passing Used	% Retained	Weight (gram)
0.75/19	100	100	-	-
0.50/12.5	85-100	92.5	7.5	82.5
0.375/9.5	55-75	65	27.5	302.5
No.4/4.75	10-25	17.5	47.5	522.5
No.8/2.36	5-12	8.5	9	99
No.200/0.075	2-4	3	5.5	60.5
Pan (filler)			3	33
Total Weight			100	1100

2.2.2. Specimen test for KAO

The purpose of creating this specimen is to determine the KAO value according to the calculation of the variation of the planned asphalt content value which is 4%, 4.5%, 5%, 5.5%, and 6%. The number of test specimens can be seen in Table 2 below.

Table 2. Planning test specimens for KAO

No.	Specimen Code	Asphalt Content (%)	Asphalt Weight (gr)	Quantity (pieces)	Description
1	K.4	4	44	3	The aggregate weight for 1 test piece is 1100 grams
2	K.4.5	4.5	49.5	3	
3	K.5	5	55	3	
4	K.5.5	5.5	60.5	3	
5	K.6	6	66	3	
Total Specimen				15	

2.2.3. Specimen with DBE as a filler replacement

The DBE content as cement replacement filler in the porous asphalt mixture was carried out at 0%, 25%, 50%, 75%, and 100%. The dry method was used to mix DBE into the asphalt mixture. A total of 60 test specimens with DBE were made, with 3 specimens made for each test. Table 3 shows the number of test specimens with DBE as a filler replacement.

Table 3. Planning of porous asphalt specimen with DBE as a filler

Specimen Code	Asphalt Content	DBE Content (%)	Cement Content (%)	DBE Weight (gr)	Quantity (pieces)
D.0	KAO	0	100	0	3
D.25	KAO	25	75	8.25	3
D.50	KAO	50	50	16.5	3
D.75	KAO	75	25	24.75	3
D.100	KAO	100	0	33	3
Total Number of Marshall Test Objects					15
Total Number of Permeability Test Objects					15
Total Number of Cantabro Loss Test Objects					15
Total Number of Binder Drain Down Test Objects					15
Total Specimen					60

2.3. Testing specimen

2.3.1. Marshall test

Marshall testing has the purpose of knowing the value of stability, flow, and VIM of porous asphalt mixture. This test used the RSNI M-01-2003 standard [18].

2.3.2. Permeability test

The standard permeability test is carried out by the falling head permeability (FHP) method. This test aims to determine the ability of porous asphalt mixtures to drain water so that it can be known the water debit that can be flowed by a porous asphalt mixture pavement [19].

2.3.3. Cantabro loss test

The Cantabro loss test aims to determine the resistance or weight loss of the test specimen to grain release after an abrasion test with a los angeles machine [20]. This test used ASTM D7064/D7064M-08 standards [21].

2.3.4. Binder drain down test

The objective of the binder drain-down test is to determine the quantity of drain-down in the uncompacted paved mixture [22]. This test is based on the AASHTO T 305 standard [23].

3. Results and Discussion

3.1. Characteristics of porous asphalt mixture materials

Material testing includes testing fine aggregate, coarse aggregate, asphalt, and filler, aiming to determine the feasibility of materials to be used in porous asphalt mixtures. The results of the research were obtained through testing conducted at the Pavement Laboratory, Department of Civil Engineering, State University of Malang.

3.1.1. Coarse aggregate test

The properties of coarse aggregates were tested according to the RSNI 2 Design and Implementation of Porous Asphalt Mixtures standard. Table 4 shows the results of the coarse aggregate test.

Table 4. Coarse aggregate testing result

Properties	Normative	Specified Ranges		Results
		Min.	Max.	
Specific gravity	SNI 1969:2016			
Bulk specific gravity		2.5	-	2.56 gr/cm³
SSD specific gravity		-	-	2.63 gr/cm³
Apparent specific gravity		-	-	2.77 gr/cm³
Water absorption	SNI 1969:2016	-	3	2.96 %
Abrasion loss	SNI 2417:2008	-	30	14.6 %

3.1.2. Fine aggregat test

The properties of fine aggregates were tested according to the RSNI 2 Design and Implementation of Porous Asphalt Mixtures. Table 5 shows the results of the fine aggregate test.

Table 5. Fine aggregate testing result

Properties	Normative	Specified Ranges		Results
		Min.	Max.	
Specific gravity	SNI 1970:2016			
Bulk specific gravity		2.5	-	2.57 gr/cm³
SSD specific gravity		-	-	2.63 gr/cm³
Apparent specific gravity		-	-	2.72 gr/cm³
Water absorption	SNI 1970:2016	-	3	2.14 %

3.1.3. Asphalt test

The physical properties of asphalt were tested according to the standard RSNI 2 Design and Implementation of Porous Asphalt Mixtures. Table 6 shows the results of the asphalt test.

Table 6. Asphalt testing result

Properties	Normative	Specified Ranges		Results
		Min.	Max.	
Penetration	SNI 2456:2011	60 dmm	70 dmm	66.7 dmm
Softening point	SNI 2434:2011	48°C	58°C	49.75°C
Flash point	SNI 2433:2011	232°C	-	262°C
Fire point	SNI 2433:2011	232°C	-	278°C
Mass loss	SNI 2440:1991	-	0.8%	0.013%
Ductility	SNI 2432:2011	100 cm	-	150 cm
Specific gravity	SNI 2441:2011	1 gr/cm³	-	1.125 gr/cm³

3.1.4. Filler test

3.1.4.1. Filler element content

Table 7 is a comparison of the elemental content of Tiga Roda brand Portland cement filler and DBE filler.

Table 7. Comparison of similar element content from the filler

No.	Elements	Tiga Roda Cement	DBE
1	Al	3.26%	4.6%
2	Si	7.48%	28.6%
3	Ca	40.28%	14.9%
4	Fe	6.7%	37.1%

Table 8. Filler testing result

Properties	Normative	Specified Ranges		Results
		Min.	Max.	
Cement Tiga Roda specific gravity	SNI 15-2531-1991	3.00	3.20	3.13 gr/cm³
DBE specific gravity	ASTM D854-2006	-	-	1.996 gr/cm³

3.1.4.2. Filler specific gravity

Specific gravity testing of cement filler was carried out using SNI 15-2531-1991 standard and DBE filler using ASTM D854-2006 standard [24], [25]. The results of the test can be seen in Table 8.

3.1.5. Porous asphalt mixture test to obtain KAO

KAO is the best percentage of asphalt content for use and meets the specifications of the overall characteristic values [26]. KAO can be obtained from the middle asphalt content value of the upper and lower limit values of the qualified asphalt content from the Marshall parameters [27]. It can be seen in Table 9, that the asphalt content that matches all the specifications of the Marshall parameters is 5% asphalt content. Therefore, the KAO value used in this research is 5%. The KAO was used to make porous asphalt mixture test specimens using DBE as a filler replacement with UNHSC gradation.

Table 9. KAO value search result

KAO Test Specimen with Number of Impacts 2x50							
Marshall Properties	% Asphalt Content to Weight of Mixture					UNHSC Spec.	
	4	4.5	5	5.5	6	Min	Max
Stability (kg)	257.68	308.51	511.86	401.28	234.12	500	-
Flow (mm)	2.53	2.95	3.88	4.23	4.34	2.0	6.0
VIM (%)	17.43	16.85	16.55	14.67	13.09	16.00	22.0

3.2. Performance of porous asphalt mixture using DBE filler with UNHSC gradation

After obtaining the KAO value, research was conducted on the performance of using DBE as a filler replacement in porous asphalt mixtures with UNHSC gradation. The performance of the mixture was evaluated from 4 tests, including Marshall parameters, permeability, Cantabro loss, and binder drain down. This test uses DBE as a filler replacement with variations of 0%, 25%, 50%, 75%, and 100% by weight of filler. Table 10 is a recapitulation of the test results from porous asphalt mixtures using DBE as a filler replacement with UNHSC gradation.

Table 10. Porous asphalt mixture test result using DBE filler

Marshall Properties	% DBE Filler Content					UNHSC Spec.	
	0	25	50	75	100	Min	Max
Stability (kg)	511.86	354.21	356.53	314.51	265.64	500	-
Flow (mm)	3.88	4.20	4.29	4.64	4.71	2.0	6.0
VIM (%)	16.55	14.09	13.75	12.93	12.66	16.0	22.0
Cantabro Loss (%)	19.91	20.20	21.00	23.36	28.07	-	20.0
Permeability (cm/s)	0.241	0.188	0.166	0.153	0.131	0.1	-
Binder Drain Down (%)	0.24	0.23	0.12	0.09	0.07	-	0.3

3.2.1. Marshall test

3.2.1.1. Stability

The stability values of porous asphalt mixtures using DBE filler replacement with UNHSC gradation are listed in Table 10. Based on the data obtained, a graph of the relation between DBE content and stability is shown in Fig. 1.

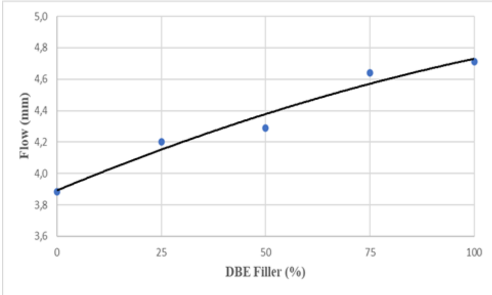

Figure 1. Marshall stability versus %DBE

The stability value of the mixture tends to decrease as the level of DBE used increases, the decrease in stability value occurs because DBE has a high Si substance, and the high Si substance in the filler can decrease the binding power of the asphalt mixture thus reducing the interlocking ability of the aggregate and asphalt in the mixture. In one of the previous studies, it was mentioned that the use of silica-based fillers in asphalt mixtures resulted a poor adhesion [28]. Other studies, state that the use of waste oil in asphalt mixtures has a softening effect on asphalt and can reduce cohesion in the mixture [29]. In this case, DBE has oil content in it, so it can affect the decrease of stability value caused by the softening of asphalt and decrease of cohesion in the mixture.

3.2.1.2. Flow

Flow values of porous asphalt mixtures using DBE filler replacement with UNHSC gradation are listed in Table 10. Fig. 2 shows the graph of the relation between DBE content and flow.

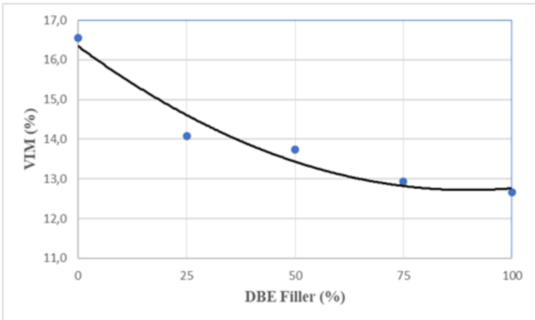

Figure 2. Marshall flow versus %DBE

The flow value of the mixture tends to increase as the level of DBE used increases, the increase in flow value occurs because the function of asphalt which was originally a binder changes to a lubricant. In one of the previous studies, it was explained that the increase in flow value in asphalt mixture is due to the function of asphalt which turns into a lubricant causing the voids in the mixture to become slippery [30]. As in similar studies, it is said that the function of asphalt, which was originally a binder for aggregates, can change to a lubricant after exceeding the required optimum value, this can lead to reduction of adhesion and friction between aggregates [31].

3.2.1.3. Void in mixture (VIM)

VIM values of porous asphalt mixtures using DBE filler replacement with UNHSC gradation are listed in Table 10. Fig. 3 shows the graph of the relation between DBE content and VIM.

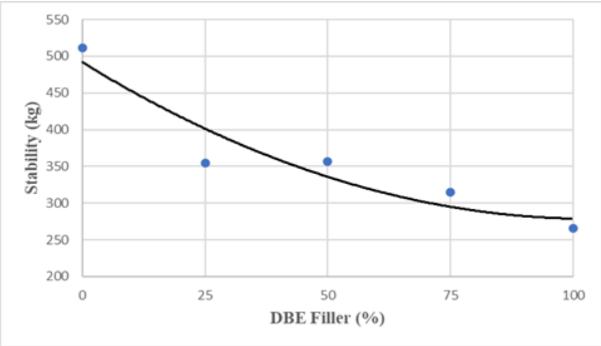

Figure 3. Marshall VIM versus %DBE

The VIM value in the mixture tends to decrease as the level of DBE used increases, the decrease in VIM value occurs because DBE has a lower specific gravity value than the specific gravity of cement used in this study. In addition, another factor for the decrease in VIM value can be seen by observing the DBE filler, after sieving the DBE, it was observed that DBE passed the sieve number 200 more easily than cement, indicating that DBE has finer particles. Finer particles make DBE fill more voids in the mixture, resulting in denser voids. In one of the previous studies, it was explained that fillers in asphalt mixtures with finer particles can fill more voids in the mixture and cause a decrease in the air voids content [32].

3.2.2. Permeability test

The value of permeability test results with DBE as a replacement for filler can be seen in Table 10. Fig. 4 is a graph of the relation between DBE and permeability.

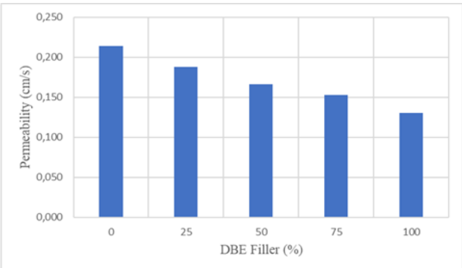

Figure 4. Permeability versus %DBE

The permeability value that decreases with each increase in DBE filler content indicates that the more DBE used in the mixture, the lower the ability of the mixture to pass water. The permeability value of the mixture that decreases as the level of DBE filler used increases is by the VIM value which also decreases the higher level of DBE filler. The fewer voids in the mixture make the ability of the porous asphalt mixture to drain water in the mixture lower. The permeability of the mixture is determined by the amount of VIM so that if the VIM value decreases, the permeability value will also be smaller [33]. In a similar study, it was mentioned that increasing the air voids content in porous asphalt mixtures causes an increase in the permeability value of the mixture [34].

3.2.3. Cantabro loss test

The results of the Cantabro loss test with DBE as a filler replacement can be seen in Table 10. Fig. 5 shows the graph of the relation between DBE and Cantabro loss.

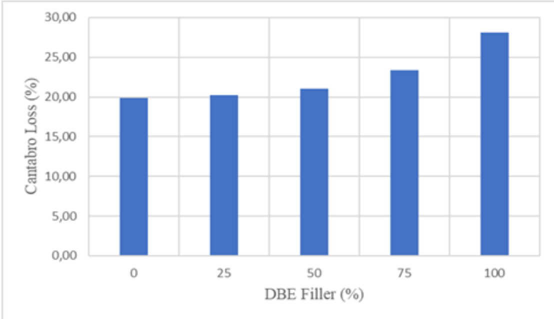

Figure 5. Cantabro loss versus %DBE

The Cantabro loss value that increases with each increase in DBE filler content indicates that the more DBE used in the mixture, the higher level of grain release in the mixture due to collisions in the Los Angeles machine. The higher Cantabro loss value is because DBE has a high Si substance, a high Si substance in the filler can reduce the adhesion of the asphalt mixture. The use of silica-based fillers in asphalt mixtures produces poor adhesion results [28]. There are other studies that state, that using waste oil in asphalt mixtures can reduce the cohesion of the mixture [29]. In this case, DBE has oil content in it, so it can affect the increase of Cantabro loss value caused by the decrease of cohesion in the mixture.

3.2.4. Binder drain down test

The recapitulated results of binder drain-down testing with DBE as a filler replacement can be seen in Table 10. From the test results, a graph of the relation between asphalt content and binder drain down is shown in Fig. 6.

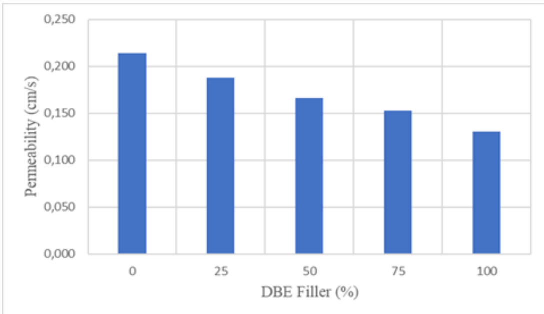

Figure 6. Binder drain down versus %DBE

The binder drain-down value of the mix decreases as the level of DBE used increases, the decrease is caused by the adsorbent properties of DBE. Fe-based fillers can improve asphalt absorption by helping to absorb excess oil from the asphalt mixture [35]. In this case, DBE has a high Fe content of 37.1%. As in other studies, SBE is a porous material in the bentonite clay category that is useful for adsorption [36]. DBE is the product of re-refining SBE, DBE is also a type of material categorized as clay bentonite [37]. The adsorption ability of DBE contributes to the decrease in binder drain down value, this is due to the ability of DBE filler to absorb asphalt so the more DBE content used in the mixture will make the possibility of asphalt falling off decrease.

4. Conclusion

Based on the results of the research, it is concluded that the use of DBE filler in porous asphalt mixtures results in a decrease in mixture performance. The decrease is shown by the stability and VIM values decrease with the higher DBE filler content, while the flow value increases. In addition, in other tests, the use of DBE fillers makes the permeability and binder drain-down values decrease, while the Cantabro loss value tends to increase as the DBE content increases. It can be concluded that using DBE as a filler in porous asphalt mixtures can have an unfavorable effect on the performance of porous asphalt mixtures.

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