

Performance analysis of a porous asphalt mixture with the use of concrete waste as a coarse aggregate and the addition of gilsonite materials

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Abstract. A Porous asphalt mixture uses an open gradation with a percentage of the coarse aggregate greater than the fine aggregate, so that it has a larger air void. This mixture has a main obstacle, i.e. the low stability value which is caused by a number of cavities in the asphalt porous mixture. So as to increase the stability value of the asphalt porous mixture, one of the methods used is by adding a substance, i.e. gilsonite which aims to improve the quality of oil asphalt and the quality of the mixture. The use of concrete waste as the coarse aggregate can also increase the mixture stability. The method used in this study is an experimental method with a laboratory scale. The aggregate used in this study is the Australian gradation. The proportion of the coarse aggregate between concrete waste and crushed stone is 0 and 100, 25 and 75, 50 and 50, 75 and 25, 100 and 0. Meanwhile, the added material used is gilsonite, with gilsonite variation of 4.5%; 5.5%; 6.5%; 7.5% and 8.5%. The use of optimum asphalt content of 5.13, the optimum waste content of 100% concrete waste and the optimum gilsonite content of 8.5% resulting in a better characteristic and performance value of the porous asphalt mixture than the normal porous asphalt mixtures by marshall test, dynamic stability, slip resistance and resilient modulus.

1. Introduction

According to Putman, B. J, and Kline, L. C, porous asphalt mixtures are designed with an open-graded aggregate to increase the number of permeable air voids, which allows water to penetrate through the voids, removing it from the surface of a roadway much faster than traditional dense-graded pavement. Porous asphalt was created to help increase safety on roadways but also provides numerous other advantages. The high air void content creates permeability that decreases the water on the roadway, thus reducing the splashing and spraying in wet weather. This decreases the potential for hydroplaning and increases visibility, both of which improve the safety of the roadway. The surface texture also help increase friction and skid resistance, as well as decrease the noise attributable to pavement-tire interaction [1].

Djakfar, L. H. Bowoputro, and Y. Zaika, conducted a study on the effect of adding additives on the performance of Marshall in porous asphalt mixture. The results of the study stated that the porous asphalt mixture with added gilsonite material was proven to increase the stability value of Marshall compared to latex added material, and could be used for roads with moderate traffic. However, this study has weaknesses. The more gilsonite contents used, the smaller the VIM (Voids in Mix) value obtained by the porous asphalt mixture. So it does not meet the existing requirements. Therefore, another solution is needed [2].



On the other hand, in the implementation of construction, there is also a lot of concrete waste as results from building debris caused by earthquakes, demolition of buildings and roads, due to fire, concrete waste originating from failures in manufacturing in precast concrete plants or concrete waste resulting from testing the compressive strength of concrete in laboratories in large quantities will cause new problems.

The contribution of concrete waste to the construction waste heap is quite large. This is in line with the increasing activity of building construction. In Indonesia, construction waste is usually not utilized properly. Most are thrown away on open land and some are used as storage materials. The availability of these materials is very large. So the potential for recycling is very possible [3].

This study will discuss about the utilization of concrete waste from the concrete compressive strength testing in the laboratories as a coarse aggregate in the mixture of porous asphalt with gilsonite added material. In this study, concrete waste used as coarse aggregate is concrete waste that results from concrete compressive strength testing in laboratories with concrete quality of K-350. The proportion of coarse aggregate between concrete waste and crushed stone is 0 and 100, 25 and 75, 50 and 50, 75 and 25, 100 and 0. It is expected that the use of concrete waste and gilsonite can find better porous asphalt mixture characteristic.

2. Method

The study design of the mixture uses an Australian open gradation. The concrete waste is used as coarse aggregate and Gilsonite added material is used on asphalt. In the first stage, a mixture of coarse aggregate of concrete waste and crushed rock is made, i.e. 0 and 100, 25 and 75, 50 and 50, 75 and 25, 100 and 0. Then, Marshall characteristics will be chosen, especially the highest stability. From the highest stability value, the optimum asphalt content and the optimum concrete waste content will be obtained.

The next step is making a second stage specimen by adding Gilsonite materials with a composition of mixture of optimum waste content and optimum asphalt content that has been obtained. After obtaining optimum waste content, optimum asphalt content, optimum gilsonite content, dynamic stability testing, skid resistance and resilient modulus are tested.

3. Results and discussion

3.1. Testing characteristics of mixture with marshall test

The following is the results of Marshall Test that has been carried out:

Table 1. Resume of characteristics of marshall testing mixture on each concrete waste contents.

	Specification[4]	Normal	25% Waste Concrete	50% Waste Concrete	75% Waste Concrete	100% Waste Concrete
Optimum Asphalt Content		5.25	5.25	5.25	4.9525	5.1265
Density		1.90	1.90	1.86	1.84	1.76
VMA	>16	28.44	28.42	30.08	26.95	30.27
VIM	18-25	23.13	21.04	20.81	22.15	23.12
VFB		20.16	25.90	30.80	17.76	23.54
Stability	Minimum 500	212.79	315.51	394.86	503.99	526.94
Flow	2 – 6	5.36	5.09	5.44	5.32	4.64
Marshall Quetiont	Maksimum 400	36.47	66	72.57	136.15	112.83

Table 1 shows the variation of the characteristics of the asphalt mixture at each level of concrete waste. The criteria needed to be used in the next step is a mixture of asphalt porous which has a high stability value. By considering these factors, the optimum asphalt porous mixture is obtained, i.e. an asphalt mixture with 100% concrete waste with Optimum Asphalt Content of 5.1265%.

3.2. Optimum gilsonite content

The next step is testing the porous asphalt mixture with the Gilsonite addition of 4.5%, 5.5%; 6.5%; 7.5%; and 8.5%. At this stage, the coarse aggregate used is 100% concrete waste. This test is used to determine the optimum level of gilsonite. Marshall Test Results can be seen in table 2.

Table 2. Resume of characteristics of porous asphalt mixture using gilsonite.

Characteristics	Optimum Asphalt Content = 5.13 %					
	Level of Gilsonite (%)					
	0	4.5	5.5	6.5	7.5	8.5
VIM (%)	23.12	21.72	21.15	21.20	19.94	21.43
Stability (Kg)	526.94	645.12	647.25	652.29	719.81	756.97
Flow (mm)	4.64	5.95	6.15	5.35	5.55	5.50

Since its practice only uses one content, it is necessary to determine the optimum gilsonite content which will produce optimum Marshall characteristics. From the table above, it can be seen that the optimum gilsonite content is 8.5%. The stability value continues to increase as the amount of gilsonite increases.

3.3. Permeability testing

The permeability testing aims to determine the ability of porous asphalt pavement to drain water. The asphalt content used in this testing is the optimum asphalt content of 5.13% with an optimum waste content of 100%.

Based on the 2004 Australian Asphalt Pavement Association requirements, the permeability coefficient value is 0.1 cm/sec to 0.5 cm/sec. Permeability Testing Results can be seen in table 3.

Table 3. Result of permeability testing.

Optimum Asphalt Content (%)	Coefficient of Permeability (cm/det)					Specification of AAPA 2004 (cm/det) [4]
	4.5%	5.5%	6.5%	7.5%	8.5%	
5.13	0.1224	0.1052	0.1034	0.0976	0.1023	0.1 – 0.5

Based on table 3, the permeability value at the addition of 4.5% -7.5% gilsonite has decreased, but it has increased again at the addition of 8.5%. The permeability values with the addition of 4.5%, 5.5%, 6.5% and 8.5% gilsonite already meet the requirements of the 2004 Australian Asphalt Pavement Association. Yet, at 7.5% gilsonite content, the permeability value does not meet the requirements.

3.4. Results of resilient modulus testing

The resilient modulus measured in the indirect tensile mode according to ASTM D 4123 reflects effectively the elastic properties of asphalt mixtures under repeated load. Since then, owing to its simplicity and applicability to test both field cores and laboratory fabricated mix specimens resilient modulus measured in the diametral test according to ASTM D 4123 has been selected by most engineers as the preferred method to measure the resilient modulus of asphalt mixed [5]. Results of Resilient Modulus Testing of the porous asphalt mixture can be seen in Figure 1.

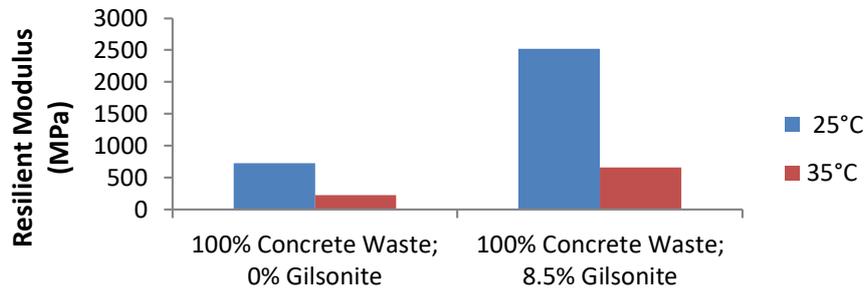
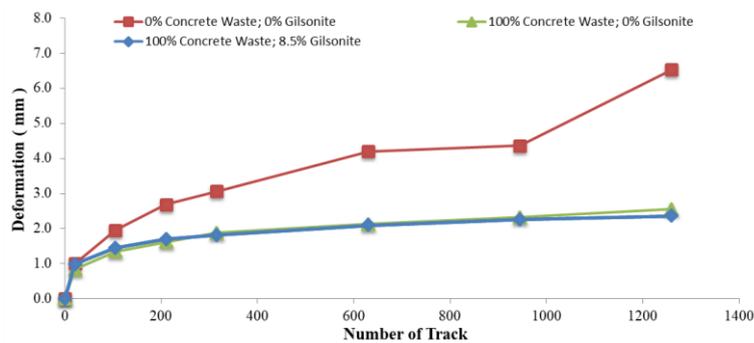


Figure 1. Result of resilient modulus testing.

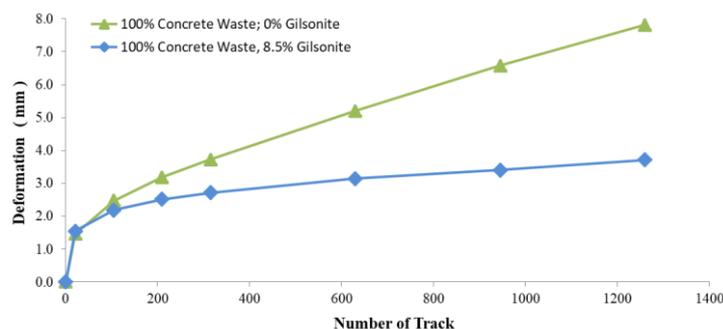
Based on Figure 1, the resilient modulus value of porous asphalt mixture using 100% concrete waste and 8.5% gilsonite produces 2524 MPa at 25°C. The resilient modulus value of this mixture is higher than the porous asphalt mixture which uses 100% concrete waste and 0% gilsonite. This shows that a mixture of porous asphalt which uses 100% concrete waste and 8.5% gilsonite is better than porous asphalt mixture which uses 100% concrete waste and 0% gilsonite at 25°C and meets the 2010 Bina Marga requirements, which is equal to 1100 Mpa [6].

3.5. Results of dynamic stability testing

The dynamic stability testing with the use of the Wheel Tracking Machine (WTM) tool is carried out to give a review of the durability of the mixture in holding the wheel tracks and changes in shape that will be received by the pavement structure. Dinamic stability with Wheel Tracking Machine (WTM) is one of the important mechanical properties used to design asphalt pavement structures [7]. Testing is carried out by using temperatures of 45°C and 60°C [6]. The results of dynamic stability testing can be seen at figure 2.



(a) Temperature of 45°C



(b) Temperature of 60°C

Figure 2. Relationship between number of tracks with deformation.

Based on **Figure 2**, the deformation velocity and dynamic stability values are obtained. The Table shows that the deformation velocity value is directly proportional to the temperature. As the temperature increases, the resulting deformation velocity value will be even greater. Meanwhile, the deformation velocity value is inversely proportional to gilsonite content. Along with the addition of gilsonite, the deformation value will decrease. The faster the deformation occurs, the deeper the path produced by the test object. With these results, it can be proved that the addition of gilsonite will reduce the deformation velocity so that the rutting value produced is relatively small.

From the testing results, the dynamic stability value is also obtained. The mixture of the test object with content of 8.5% gilsonite has a dynamic stability value of 5727.3 trajectories/mm at a temperature of 45°C and 2032.3 trajectories/mm at a temperature of 60°C. This dynamic stability value is higher than other porous asphalt mixtures. With the addition of gilsonite, it affects the resulting dynamic stability value. This shows that the mixture of test object with content of 8.5% gilsonite has a better performance than a mixture of normal porous asphalt (0% concrete waste, 0% gilsonite) and porous asphalt which uses 100% concrete waste, 0% gilsonite.

3.6. Results of skid resistance testing

Table 4. Results of skid resistance testing.

No.	Type of Mixture	Temperature (°C)	Average	Correction	Value of BPN
1	0% waste concrete, 0% gilsonite	30	70.2	+ 1	71.2
2	100% waste concrete, 0% gilsonite	30	80	+ 1	81
3	100% waste concrete, 8.5% gilsonite	30	88.6	+ 1	89.6

Based on table 4, the value of BPM obtained from porous asphalt mixture that uses 100% concrete waste and 8.5% gilsonite has the largest skid resistance value of 89.6. This value when compared with the Road Research Laboratory (1996) standard, the value of the skid resistance produced still meets the standard and falls into the C category.

4. Conclusion and suggestion

4.1. Conclusion

Based on the results of the research on the characteristics of porous asphalt that has been carried out, the following conclusions can be drawn:

- The Asphalt Optimum Content value is 5.13% with optimum concrete waste content of 100%. Meanwhile, the Optimum gilsonite content value is 8.5%.
- The use of concrete waste as the coarse aggregate can improve the characteristics of porous asphalt mixtures, namely stability. The stability value continues to increase along with the increasing number of replacing concrete waste as coarse aggregate. The highest stability is 100% concrete waste with a stability value of 526.94 kg.
- The stability value also continues to increase along with the number of the addition of gilsonite. The stability value using 8.5% gilsonite has a higher stability than the others. Meanwhile, the VIM (Void in Mix) value with the use of gilsonite has decreased. On the other hand, the flow (melt) value with the use of gilsonite tends to increase. The flow (melt) value without the use of gilsonite is 4.64 mm while the use of 8.5% gilsonite is 5.5 mm. This shows that porous asphalt mixture without the addition of gilsonite is more rigid and prone to cracking than the use of 8.5%. The nature of gilsonite which increases the flow value can improve the nature of porous asphalt mixture by using 100% concrete waste that is rigid and prone to cracking. Meanwhile,

the stability value of the remaining porous asphalt mixture with the addition of gilsonite is not stable. However, the lowest residual stability value is by using 8.5% gilsonite, i.e. 73.84%.

- The permeability value at the addition of 4.5% -7.5% gilsonite has decreased, but increased again at the addition of 8.5%. Permeability value with the addition of 4.5%, 5.5%, 6.5% and 8.5% gilsonite has already met the requirements of the 2004 Australian Asphalt Pavement Association. Yet, at the content of 7.5% gilsonite, the permeability value does not meet the requirements.
- The porous asphalt mixture performance using 100% concrete waste and 8.5% gilsonite based on permanent deformation value of 2.37 mm, dynamic stability value of 5727.3 trajectories/mm, skid resistance value of 89.6 BPN, resilient modulus value of 2524 MPa. Thus the performance of porous asphalt mixture by using 100% concrete waste and 8.5% gilsonite has experienced an increase by reducing the depth of the track of the vehicle wheels by 175.53%, increasing the friction force between the road surface and vehicle wheels by 25.84%, and increasing the resilient modulus by 129.45%.

4.2. Suggestion

Some suggestions that can be submitted to further refine this study include:

- It is expected that further studies will use varying quality of concrete waste.
- Further studies should be carried out using other gradations, such as the gradation of Philippines which tends to have a climate similar to Indonesia.

References

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