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PERFORMANCE OF POROUS ASPHALT CONTAINING MODIFICATED BUTON ASPHALT AND PLASTIC WASTE

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ABSTRACT: Many areas in the Southern region in Buton Island, Indonesia possess immense sources of solid bitumen (high hydrocarbon substances). The compounds of Buton rock asphalt (BRA) are approximately 30% bitumen and 70% mineral. Although several products of BRA in granular form have been used in asphalt mixture production but due to the limited information of BRA products those have yet to be tapped for widely usage. In recent decades several BRA companies have been successfully extracted the bitumen from the rock asphalt. Bitumen of BRA has similar properties with the petroleum asphalt, therefore, it can be blended with petroleum bitumen to produce modified Buton asphalt (MBA). In this study Polyethylene Therephthalate (PET) and Buton modified asphalt (BMA) was used to produce porous asphalt mixture. The compacted porous asphalt specimens were subjected to Marshall stability-flow test, indirect tensile strength and horizontal strain in order to evaluate its performance. The experimental results indicated that the PET and BMA based porous asphalt mixture with proper binder formulation can provide desired performance.

Keywords: Porous asphalt, Modified Buton asphalt, Waste plastic, Marshall stability-flow, Indirect tensile strength, Horizontal strain

1. INTRODUCTION

In Indonesia drinking bottle is made by used extensively PET for domestic consumption. Annually, waste PET bottles with other waste plastics generated from polystyrene (PS), polypropylene (PP) and polyvinyl chloride (PVC) are disposed in a large quantity to landfills due to limited approaches for its recycling. PET bottles are not biodegradable material hence they still unchanged state in the environment. Environmental impacts can be decreased by the usage of waste plastics instead of dumping them.

Several alternatives have been proposed for reducing the waste PET bottle. One of the emerging recycling alternatives is to use waste plastic including PET bottles in the asphalt pavement construction. The natural state of PET is a semi-crystalline resin [1–3], and its glass transition temperature (Tg) is about 70°C [4,5,6]. A study conducted by Ahmadinia (2011) [7] has found that PET as a constituent in stone mastic asphalt (SMA) mixture can be successfully blended with petroleum bitumen and improves the Marshal properties of stone mastic asphalt (SMA) mixture. PET becomes a material with less or more crystal properties due to heating and the semi crystal state of PET rendered the mixture stiffer with higher stability.

In Indonesia aquaplaning and temporary flood on the surface road are always generated by the heavy precipitation of high-intensity rainfall. One of the interesting solutions to overcome the temporary flood problem is the utilization of porous asphalt mixture as a surface layer of a pavement structure. Porous asphalt consists of higher proportions of coarse aggregate and lower content of sand and filler. This composition creates interconnected voids which in rainy conditions can allow the storm water runoff to flow into the ground and prevent ponding on the road surface. Porous asphalt is used worldwide as the surface layer on motor way (e.g, J. Shih Shen, D. Hsien Shen, M. Miradi) [9, 10,11].

Many roads in worldwide have carried out road construction using PA as a surface layer. In Malaysia with behaving similar conditions to Indonesia has developed PA as surface pavement in order to decrease the impact of hydroplaning on safe driving and to avoid poor visibility generated by splash and spray during rainy conditions. In Indonesia with has frequently heavy rainfall the use of PA is becoming a viable and prevalent option is the surface layer of pavement.

Indonesia has several resources of sedimentary rock containing bitumen (high hydrocarbon substances) in large quantities. All of the natural rock asphalt resources occurs in Buton Island and named as Buton rock asphalt. Rock asphalt naturally composes of approximately 30% bitumen and 70% sediment or mineral. Over the last decades, many efforts have been conducted to boost the feasibility of Buton asphalt products as an ingredient for asphalt mixture production. Recently, extracted bitumen from rock asphalt can be blended with petroleum bitumen to produce modified Buton asphalt (MBa). In order to enhance the road infrastructure development it is important to extensively use Buton asphalt products such as MBa in the pavement construction.

This paper attempts to study the use of MBa and waste PET to fabricate porous asphalt mixture. At constant MBa content, the porosity, raveling resistance, stability-flow value, and tensile strength of fabricated specimen with various contents of PET was evaluated to ascertain the suitability of MBa and PET as constituents of porous asphalt mixture.

2. MATERIAL AND METHOD

2.1 Modified Buton Asphalt (MBA)

Table 1 shows properties the modified Buton asphalt. Commercial modified Buton asphalt was used as a prominent binder in this research.

Table 1. Properties of modified Buton asphalt

No.	Properties	Testing result
1	Penetration before weight loss (mm)	78.6
2	Softening point (°C)	52
3	Ductility in 25°C, 5cm/menit (cm)	114
4	Flashpoint (°C)	280
5	Spesific gravity	1.12
6	Weight loss	0.5
7	Penetration after weight loss (mm)	86

2.2 Properties of Coarse Aggregate and Filler

All materials used were collected from Jeneberang river in Gowa. Two fractions of coarse aggregates derived from crushed river stone were used: one with aggregate diameter 5-10 mm and the other with crushed stone diameter 10-20 mm. Stone dust collected from the same stone crushing plant was used as filler. Some properties of coarse aggregates and filler are shown in Table 2 and Table 3, respectively.

The mechanical properties of asphalt mixes that include various percentages of PET (0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5%) were calculated and assessed with laboratory tests. The two methods that are usually used to add the selected additive to the asphalt mixture are the wet and dry processes. In the wet process, prior to adding the binder to the mixture, the additive is mixed with the binder.

While in the dry process, the additive is blended with the aggregate before adding bitumen. In this research the dry process was used.

Table 2. Properties of coarse aggregate

Properties	(Crushed stone) Diameter 5 - 10 (mm)	10 - 20 (mm)
Water absorption, %	2.07	2.08
Bulk specific gravity	2.62	2.63
Saturated surface dry specific gravity	2.68	2.68
Apparent specific gravity	2.77	2.78
Flakiness index, %	20.10	9.38
Abrasion aggregate, %	25.72	24.36

Table 3. Properties of filler

Water absorption, %	2.28	
Sand equivalent, %	69.57	
Bulk specific gravity	Saturated surface dry specific gravity	Apparent specific gravity
2.59	2.65	2.76

2.3 Mixtures Design

The combined aggregate and filler gradation is shown in Fig. 1. The combined aggregate gradation was designed according to REAM-SP 5/2008 (*Road Engineering Association of* Malaysia) [8]. The mixtures were all prepared in the laboratory. The content of waste PET were 0.0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5% of the total weight of the aggregate in the mixture. The content of modified Buton asphalt content was 6.0% (optimum modified Buton asphalt content) of the total weight in the mixture. Table 4 shows the mixture by weight of porous asphalt mixture. Modified Buton asphalt, aggregates and filler were mixed and compacted into the cylindrical mold with a capacity of 1,200 gram and diameter of 101.6 mm. In the laboratory, the aggregate and binder (Modified Buton asphalt) were respectively mixed and compacted at 150 ± 0.5°C. The specimens were compacted with 50 blows each face by using Marshall compactor. After compaction, the specimens were removed from the molds and allowed to cool down. Mixing and compaction process were carried out in the laboratory at temperature room 27°C.

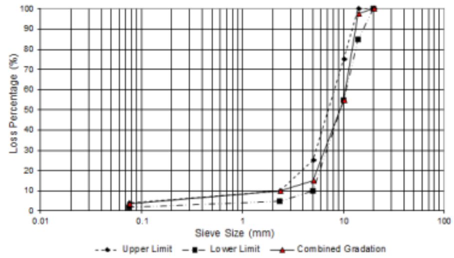

Fig. 1 Combined aggregates gradation

2.4 Ravelling Resistance Test

Raveling resistance test is commonly used to assess the binding failure between bitumen and coarse aggregate particle of fabricated PA specimen. Los Angeles machine was used to conduct raveling resistance test of fabricated PA specimen containing various contents of PET at constant BMA. Los Angeles machine without steel ball runs for 300 rounds at speeds between 30-33 rpm to investigate the raveling resistance of compacted cylindrical specimens. Specimen was weighed before and after abrasion to obtain the material loss. Three specimens collected from each PA mixture were tested and their average values reported.

2.5 Marshall Stability and Flow Test

The present study employed Marshall stability and flow test to evaluate the resistance to plastic flow of fabricated PA specimen containing constant BMA and with various contents of PET. Marshall Test was conducted with using a load-deformation recorder in conjunction with a load cell of UTM and linear variable differential transducer (LVDT). Standard loading rate of 50mm/minute was applied. Three specimens collected from each PA mixture were tested and their average reading is reported.

2.6 Indirect Tensile Strength Test

ITS test was conducting according to ASTM D6931-12. Fig 2. shows ITS test equipment. Vertical strain were derived via two linear variable differential transducers (LVDTs) measuring platen to platen displacement. The recording equipment consists of digital interface unit (data logger) connected to a computer that utilized to monitor and record data from the load actuator and LVDTs.

Fig. 2 Equipment of indirect tensile strength test

Table 4. Asphalt mixture by weight (1,200 gram)

No.	Description	Unit	Waste PET content (%)					
			0.0	0.5	1.0	1.5	2.0	72.5
A	Waste PET weight	gr	0.00	5.64	11.28	16.92	22.56	28.20
B	Combined aggregates gradation		Weight of Aggregate by Number of Sieve					
1	3/4"	gr	-	-	-	-	-	-
2	1/2"	gr	28.70	27.76	26.82	25.88	24.94	24.00
3	3/8"	gr	478.95	478.01	477.07	476.13	475.19	474.25
4	No. 4	gr	451.15	450.21	449.27	448.33	447.39	446.45
5	No. 8	gr	56.40	55.46	54.52	53.58	52.64	51.70
6	No.200	gr	73.66	72.72	71.78	70.84	69.90	68.96
7	PAN	gr	39.14	38.20	37.26	36.32	35.38	34.44
Total		gr	1128.00	1128.00	1128.00	1128.00	1128.00	1128.00
C	Total Weight of Test Piece	gr	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00

3. RESULTS AND DISCUSSION

3.1 Porosity

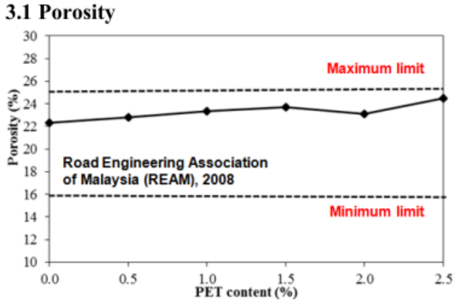

Fig. 2 Average porosity with PET contents

Porosity with PET contents curve obtained from porosity test for specimens with PET 0.5%, 1.0%, 1.5%, 2.0% and 2,5% and without PET are shown graphically in Fig. 2. The test results are presented as the average of 3 specimens. The higher and lower value of porosity corresponds does not meet specification of REAM, 2008.

Variation of PET contents in porous asphalt mixture without PET had porosity value of 23%, whereas porous asphalt with 0.5%, 1.0%, 1.5%, 2.0% and 2,5% PET had porosity value of 23.5%, 23.8%, 23.9%, 23.0% and 24.0% respectively. Although, the degradation of the porosity due to PET content can be noticed by the increment of the porosity of all mixture as compared to those without PET, whereas with PET, the porosity of mixture with 0.5%, 1.0%, 1.5%, 2.0% and 2,5% PET superpassed the mixture without PET due the presence of PET.

3.2 Ravelling Resistance

Variation of PET amount positively influenced the raveling resistance of PA made with modified asphalt Buton. Mixture without PET showed 9.82% material loss. Mixtures with PET 0.5%, 1.0%, 1.5%, 2.0% and 2.5% had 8.22%, 7.85%, 7.38%, 6.93% and 7.69% material loss, respectively, which was improved by 16.29%, 20.06%, 24.84%, 29.42% and 21.69% compared with that of PA mixture without PET.

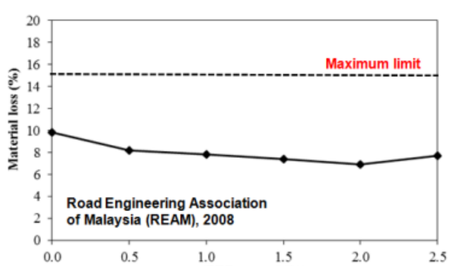

Fig. 3 Average material loss with PET contents

3.3 Stability-Flow Curves

Fig. 4 depicts the correlation between Marshall Stability value and PET content. As depicted in Fig. 4, Marshall stability value increases with addition of PET until it attained the maximum value, which was approximately 2% of the used PET and followed by a decreasing trend.

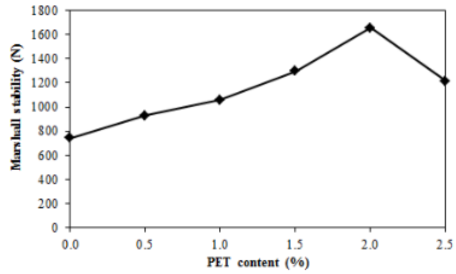

Fig. 4 Average stability with PET contents

The result demonstrated that increasing PET content could reduce the flow value until the minimum value and then it shifted to an upward movement.

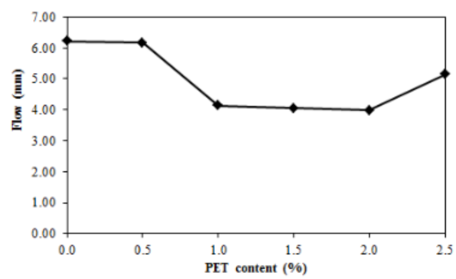

Fig. 5 Average flow with PET contents

When the increase of PET content, the MQ value first increased up to the maximum value and then decreased. It was shown that 2% is the optimum content of PET to achieve maximum MQ value.

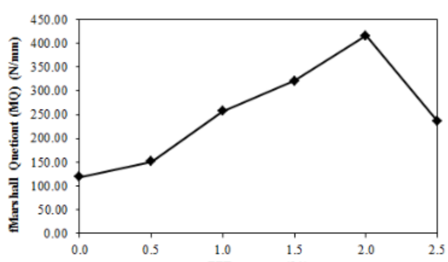

Fig.6 Average Marshall Quetiont (MQ) with PET contents

As shown in Fig 4, 5 and 6, the stability (N) without PET was 741.80 N and with PET 0.5%, 1.0%, 1.5%, 2.0% and 2.5% specimens were 931.00, 1059.90, 1297.60, 1653.20 and 1213.80, respectively, corresponding to the flow (mm) without PET was 6.21 and with PET were 6.16, 4.13, 4.05, 4.00 and 5.15, respectively with MQ (N/mm) being without PET was 6119.45 and with PET were 151.14, 256.63, 320.40, 415.38 and 235.69, respectively.

Marshall stability value of specimens with PET 0.5%, 1.0%, 1.5%, 2.0% and 2.5% were improved by 25.50, 42.88, 74.92, 122.86 and 63.62% compared without PET specimens. Flow value of specimens with and without PET can fulfill the requirement of the flexible pavement. MQ value of specimens, PET 0.5%, 1.0%, 1.5%, 2.0% and 2.5% were improved by 26.52, 114.84, 168.22, 247.74 and 97.31% compared without PET specimens.

3.4 Indirect Tensile Strength Test

Fig. 7 shows the relationship between the average of the peak indirect tensile stress and the PET content. It can be observed that the average of the peak indirect tensile stress of PA increased until it raised the maximum value, which corresponds to 2% of the PET content, and then it decreased slightly.

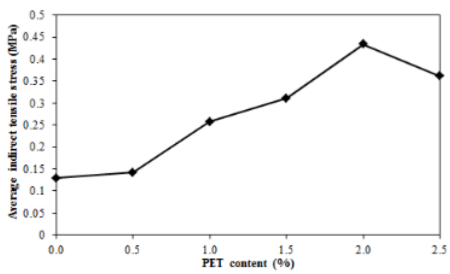

Fig. 7 Average indirect tensile stress with PET contents

It was noticed that the performance of PA mixture containing PET in terms of stability – flow relationship, indirect tensile strength was generally higher in comparison to the PA mixture without PET. The improvement of PA made with modified Buton asphalt by introducing PET due to the semicrystal state of PET can be successfully blended with modified Buton asphalt with similar to petroleum bitumen.

The average ultimate horizontal strain relates to the peak stress at which the porous asphalt specimen failure. The average strain horizontal of porous asphalt with different PET content is displayed in Fig. 8, which of the deformation average capacity.

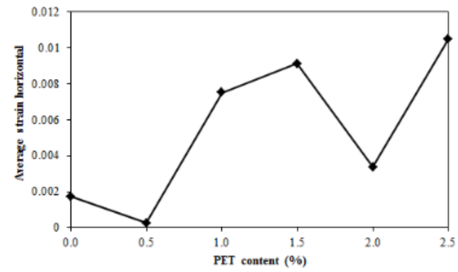

Fig. 8 Average strain horizontal curve with PET contents

In particular, average the ultimate strain of PET-1.0, PET-1.5, PET-2.0 and PET-2.5 larger than that of PA without PET, respectively. Only PET-0.5 had average horizontal strain less than the PA without PET. It can be concluded that the inclusion of PET into porous asphalt made with Buton Modified Asphalt (BMA) can improve the horizontal deformation capacity of PA. Characterizes the horizontal deformation capacity of PA made with a binder containing MBA and PET because the plastic has a good horizontal deformation capacity. Such concrete might be useful for nonstructural applications such as concrete barriers where high fracture toughness and low strength are required.

4. CONCLUSIONS

Based on the results and discussion in this study, it can be concluded that

a. Increasing the PET content has a beneficial effect on both the tensile strength, raveling resistance, Marshall stability and Marshall Quetient (MQ).
b. Porous asphalt mixture with and without PET process completion, the tensile stress obtained from ITS test showed that the porous asphalt with and without PET can retain a tensile ductility.
c. Porous asphalt mixture with and without PET, stability and MQ of porous asphalt with 0.5%, 1.0%, 1.5%, 2.0% and 2.5% PET superpassed the mixture without PET whereas raveling resistance was similar as compared to porous asphalt mixture without PET.
d. A comparison of the porous asphalt with modified Buton asphalt and without PET showed that performance of porous asphalt with 0.5%, 1.0%, 1.5% and 2.0% PET exceed the mixture without PET although 2.5% PET decreased tensile strength (16.61%), Marshall stability (26.57%) and raveling resistance (9.88%) for all mixtures.

5. ACKNOWLEDGMENTS

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