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Evaluation of permanent deformation performance in the mechanical properties of hot mix asphalt mixture

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ABSTRACT

The major objective of this survey was to evaluate the influence of Rynite PET particles on the mechanical properties of hot mix asphalt mixture by conducting several tests such as, indirect tensile resilient modulus, dynamic creep and wheel tracking test. As identified by the result of MR test, the stiffness of Rynite Polyethylene terephthalate mix was reasonable and guaranteed the proper permanent deformation characteristics of asphalt mixture at intensive loading situation, while result of dynamic creep has shown a better improvement to rutting, likewise wit wheel tracking test. The testing results of wheel tracking test proved that the applied of Rynite PET in the asphalt mixture improved significantly the resist to permanent deformation (rutting).

1. Introduction

Through the past decades by growing the damned of using a large amount of vehicles and weighing on roads, that led to bigger damages which in various situations happened even prior expected the service life of pavement [1]. Based on past studies, improvement of using polymer as a modified to asphalt mixture is the goal of designers and road engineers [2]. As explained by [3], the road pavement is exposed to external loads inclusive mechanical loading by heavy traffic and thermal loading induced by thermal modifications.

Recently, the demand for utilization waste plastic material has significantly increased due to the determination of the natural resources [4]. During the recent years, the benefit of using a waste plastic materials as modifier additives with asphalt blended may have multiple environmental and economic advantages [5]. Based on the idea of [6], the recycling of waste materials is an increasing technology that need to be permanently enhanced. [7], pointed out that the behavior of waste plastic is a threat and become an earnest problem globally. The utilized of waste plastic bags in bitumen mixture showed an improvement the properties of blend with addition to resolve the disposal problems [8]. The previous results showed that adding PET to asphalt mixture could raise the resist versus permanent deformation and rutting [9], as identified by [10], showed that the stiffness of bitumen mixture is a primary designing parameter of flexible pavement; also, the stiffness value is very liable to the loading and environmental situations. The quantum and sort of waste being created is increasing at massive rate [11].

2. Materials

In current study, different materials which were used to prepare the hot mix asphalt mixture including aggregate, bitumen and Rynite PET 530-NC10. The technical properties of these materials will be presented below.

For this experiment, the bitumen 80/100 PEN was used for the mix design. Based on the previous studies conducted at Highway and Transportation Laboratory in Malaysia, the specific gravity of bitumen is taken as 1.03.

2.1 Additive

Rynite® FR530 NC010 is a 30% glass reinforced, flame retardant, modified polyethylene terephthalate resin approved by UL as UL94V-0 @ 0.35mm. As proved by previous studies, outcomes were acquired by single size polyethylene terephthalate particles among the ranges of 0.425–1.18 mm [12].Therefore, PET particles were used as an additive in HMA mixture. In order to collect Rynite polyethylene terephthalate material, firstly, PET was crushed by a crushing machine, and then was sieved to obtain desirable gradation levels in 0.075µm. Tables 1 and mechanical properties of Rynite PET 530-NC10.

Table 1. Mechanical properties of Rynite® FR530 NC010 of RPET

Property	Test Method	Units	Value
Stress at Break	ISO 527	MPa (kpsi)	135 (19.6)
Tensile Strength	ASTM D 638	MPa (kpsi)	-40°C (-40°F)
Strain at Break	ISO 527	%	2
Tensile Modulus	ISO 527	MPa (kpsi)	11500 (1670)
Flexural Modulus	ASTM D 790	MPa (kpsi)	11000 (1600)

2.2 Aggregate

Aggregates used in this present research were obtained from the Batu Pahat Queerly. The gradation of mix design for aggregates is shown in Table 2. Moreover, Fig 1 shows the gradation curve of aggregate mix design.

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Table 2. The aggregate gradation used to prepare HMA mixes

Sieve Size	Percent Passing (%)			Specifications (%)
	Upper Limit	Lower Limit	Design Gradation (%)	
25mm	100	100	100	100
19 mm	85	97	90	90-100
9.5mm	62	75	68	56-80
4.75 mm	42	62	53	35-65
2.36 mm	28	45	37	23-49
0.3 mm	8	16.7	12	5-19
0.075 mm	4	7	5	2-8

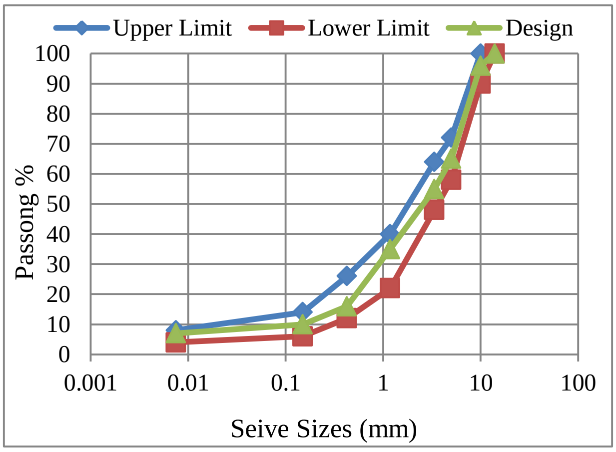

Figure 1. Gradation of Marshall Mix Design

3. Sample Preparation

According to this study, the wet method was applied as one of two process methods of asphalt mixture. In this method, the wet process was blended with the asphalt binder before adding to the mixture. Thus, bitumen was prepared using a high shear mixer, and the asphalt binder was modified with Rynite PET chips in various percentages, namely (0%, 3%, 5% and 7%) by weight of bitumen. During the process of blending, noted that the Rynite PET was sparse and homogeneous during the process of mixture design, bitumen was mixed by the shear rate 3000 rpm for an hour with desirable temperature at 150C. Before placed the accumulative weight of aggregate to the asphalt mixture, an aggregate should heated up to 165C for 2 h. The accumulative weight of aggregate for each specimen was 1200 g, after that, the sample was compacted with 50 blows from the upper and lower sides of the asphalt mixture procedure. Therefore, in order to conduct the OBC, three specimens were prepared for each bitumen contents which ranged between 5-7% by total of weight at 0.5% increase, with additive in different ratios of PET, then. After finishing the sample preparation, the volumetric properties of the samples were obtained. The value of optimum bitumen content was computed at this stage, it was calculating by volumetric properties, such as, VA, VMA and VFA.

4. Experimental Design of Asphalt Mixture

According to the tests of this research comprised of the performance mechanical tests of HMA mixture, such as, indirect tensile resilient modulus, dynamic creep and wheel tracking tests, the experiments were achieved on the OBC viable to all sorts of asphalt mixture.

4.1 Resilient tensile modulus test (MR)

MR of hot mix asphalt is considered as an important input for computation of flexible pavement responses under traffic loading [13].Moreover, the resilient modulus has not been used much to present the hot mix asphalt stiffness due to more assurance has been conducted on the dynamic modulus [14]. As explained by ASTM D 4123, the test was executed at different temperatures namely, 25°C and 40°C. This test was applied to assess the tensile characteristics of asphalt. All the specimens of the indirect tensile resilient modulus test were determined by placing the samples in a temperature at 25 °C and get them to the specified test temperatures at least 24 h before perform the test. The pulse repetitions used in this study were at 1000ms. The test was carrying out with Universal Testing Machine.

For an applied dynamic load of P in which the resulting horizontal dynamic deformations have been measured, the total Mr value is calculated from equation [15]

$$M_r = \frac{p(\mu + 0.27)}{t\pi_h}$$

Where P: maximum dynamic load, N; m: Poisson's ratio (assumed 0.35); t: sample length, mm; tH: total horizontal recoverable deformation, mm.

4.2 Dynamic creep test

The test was sophisticated to assess the permanent deformation of mixtures. The test was carried out by applying a static load to an asphalt mix sample, and the result of rutting was observed during the time [16]. In this study, the sample diameter is high at 100 mm. A loading stress of 100 kPa was applied on the specimens, and the loading cycles applied were 3600 cycles (for approximately 1 h). The test was conducted at temperature 40°C. When a load is utilized to the surface of asphalt pavement, it deforms though a plurality of recovers of deformation after the load is removed [17].

4.3 Wheel Tracking

The test is used to measure the resist of asphalt mixtures versus rutting at high temperatures and under loading. Wheel tracking could be conduct on the cylindrical kernels taken from the asphalt road and also asphalt slab which made in the lab ([18]. Moreover, rutting test with the exchanging movement of loaded wheel on asphalt samples measure the possibility of asphalt pavement rutting. This is done by conduct the rut depth formed in the specimen with the moving of device's wheel at specified time period by rut standard. Desired rut-gauges should have enough precision at least 0.1mm. The highest rut depth determines by wheel track apparatus is 20 mm and thereafter the machine turns off. Wheel tracking test was carried out accordance with the British Standard BS 598: Part 110 [19]. The test was proceeding at temperatures of 45°C.

5 Results and Discussion

5.1 Indirect Tensile Modulus Test

MR is the most general test used to measure stress–strain to assess and evaluate the elasticity properties of the bituminous mixture representing an applied stress ratio to the recoverable strain after removal of the applied stress [20]. As presented in Fig. 2, the resilient modulus value with against Rynite PET contents, the temperature of 25ºC, indicates that the MR increased slightly with an increase in the ratio of additive during asphalt mixture with 1000ms of pulse repetition. All the MR values of mixtures containing Rynite PET were generally greater than the conventional mix especially at 3%, which given less susceptibility to fatigue, with a high MR of 4429MPa. This finding led to that additional Rynite PET would enhance resist to fatigue deformation at intermediate temperatures. On the other hand, Fig 3 outlines the result for MR at temperature 40°C; therefore, it could be shown that the addition of 3% Rynite PET gave higher resilient modulus value with 1323MPa compared with the control mixture.

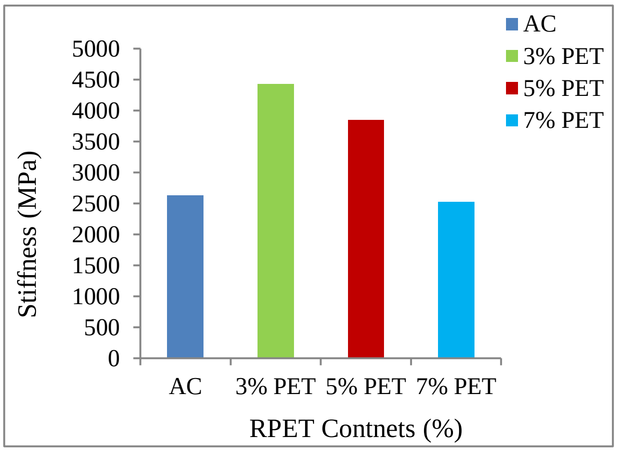

Figure 2. Resilient modulus at 25°C

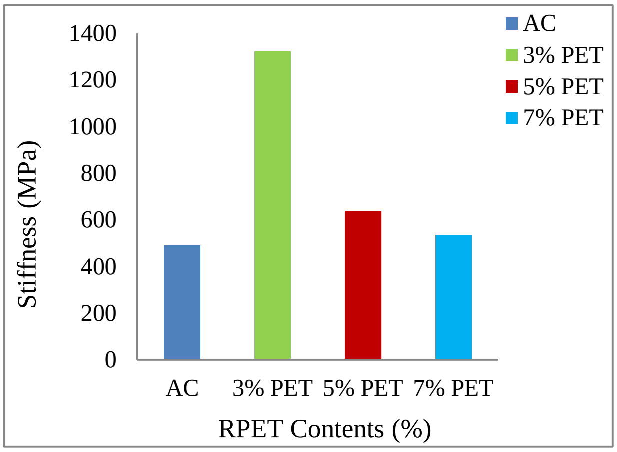

Figure 3. Resilient Modulus Test 40°C

5.2 Dynamic Creep Test

Rutting is one of the most importance distress in flexible pavements, has long been a problem in asphalt mixtures, mainly in countries with high temperatures [21]. In this test, a repeated pulsed axial stress is applied to specimen mixture while the ensuing axial deformation is recorded using Linear Variable Displacement Transducers (LVDTs). The relationship between load cycles and permanent deformation were obtained by plotting data of the dynamic creep test as displayed in figure 4. According to the results, as presented in Fig 4, the addition of 3% Rynite PET showed the lowest value compared to rest of percentages, this led to good result and improvement of permanent deformation and in terms of dynamic creep behavior.

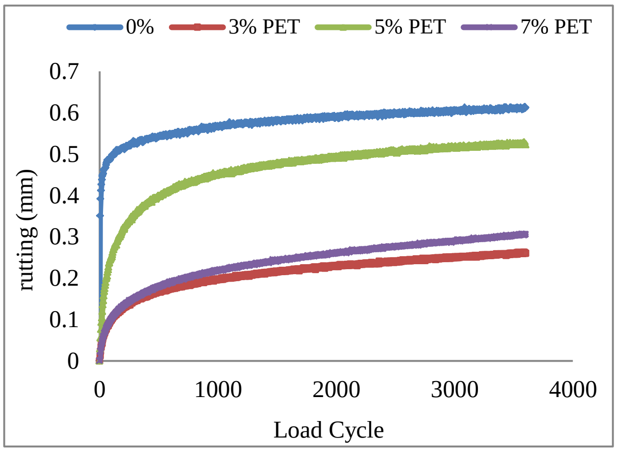

Figure 4. Relationships between dynamic creep test and load cycles

5.3 Wheel-Tracking Test

In order to check the rutting resist of the asphalt mixtures, test was conducted by wheel tracking, which is a devastating test and includes immediate connect among the loaded wheel and the rectangular test samples [22].The test was conducted at temperature of 45°C. The influence of using Rynite PET on rutting resistance for mixtures is displayed in Fig. 5. The results revealed that mixes containing Rynite PET have good permanent deformation resist compared to the conventional mixture. Moreover, the rut depth for asphalt mixtures with 0%, 3%, 5% and 7% Rynite PET contents after 45 min is 1.76 mm, 1.44 mm, 1.54 mm and 1.65mm, respectively, which indicate that the minimum rut depth obtained for the mix with 3% Rynite PET.

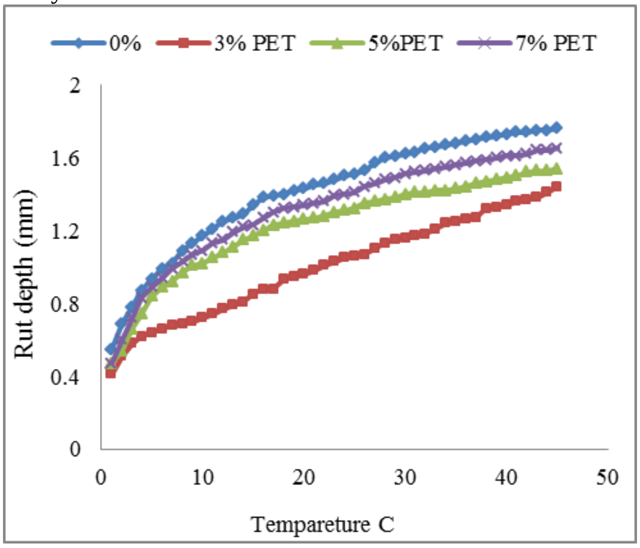

Figure 5. Wheel tracking at 45°C.

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7 Conclusions

Based on the limited laboratory work of this study, the following conclusion could be drawn below:

- The resilient modulus of the mixtures prepared using the modified Rynite PET bitumen was higher than that of the control mixture. Stiffness significantly increased at 25 °C but decreased at 40 °C. This research demonstrated that Rynite PET can decrease the susceptibility to permanent deformation (rutting) and can improve the resistance to fatigue in asphalt mixtures.
- The dynamic creep test was also performed at 40 °C and at different stress levels. The rutting properties of the Rynite PET -modified asphalt were evidently improved compared with those of the control mixture; among the mixtures, 3% Rynite PET showed the most efficient performance in terms of good resistance against permanent deformation.
- The results of wheel tracking test at temperature 45°C indicated show that 3% Rynite PET of asphalt mixture has better performance and reduce for permanent deformation compared to the control specimens.

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