Laboratory Investigation on Mixing Methods for Polymer Modified Asphalt Mixture

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Abstract. In Vietnam, better pavement materials were used in order to adapt to the high traffic volumes, the heavy truck loading, the hot temperature, and so on. One of them is the application of polymers in modified asphalt or asphalt mixture. When using polymers in asphalt concrete, there are many significant problems such as mixing procedures or mixing methods. Two main types of mixing methods which are conventional dry and wet methods are often conducted around the world. For Polyethylene Terephthalate, the dry method is usually used for its advantage. The properties of asphalt mixture using Polyethylene Terephthalate by application of traditional dry and modified dry methods are investigated through laboratory tests such as Marshall stability, indirect tensile, and static resilient modulus. On the other hand, many percent of Polyethylene terephthalate were added to the asphalt mixture for comparisons.

Keywords: Polyethylene Terephthalate · Marshall Stability · Indirect Tensile Strength · Resilient Modulus · Dry Method

1 Introduction

Nowadays, the rapid growth of the economy affects the transport infrastructure in some developed cities in Vietnam. Asphalt concrete pavement is currently widely used for roads in Vietnam, which is the first choice when designing roads or highways. However, many roads used asphalt concrete have many distresses such as rutting, cracking, and surface roughness after a short time in service life. This is the primary concern for many traffic managers and building contractors. One of the methods to limit the distresses of asphalt pavement is to improve the quality of asphalt and asphalt mixture. Adding polymer additives has been shown to be effective, but there are still many preventions, i.e. the high cost in polymer application. In Vietnam, there are many studies using waste plastic bottles in asphalt concrete to improve the properties of the concrete mixture, such as the studies of the authors Nguyen VH [1] with the goal of selecting the suitable size of Polyethylene Terephthalate (PET), and evaluate the influence of PET on the mechanical properties of asphalt concrete. Research shows that PET improves the properties of asphalt cement, such as the softening point, in comparison to conventional asphalt.

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There are two types of mixing methods: the dried process and the wet process [2]. Traditional dry mixing methods PET will be mixed with aggregates first, then mixed with asphalt. This method reduces the adhesion of the asphalt and the aggregate. In contrast, wet mixing method PET will be mixed with asphalt before mixing with the aggregate. This method has the disadvantage that it will change the properties of the asphalt cement by mixing PET and asphalt at high temperatures for a long time.

In a study about the modified dry process [3], PET is mixed after the aggregate and bitumen have been mixed together. This method is said to retain the shape and properties of PET. The author has performed experiments to evaluate air void, void in mineral aggregate, density, Marshall stability, and indirect tensile strength which have shown an improved dry mixing method and also improved the quality of asphalt concrete better than the traditional dry mixing method. Another study from Hasan et al. [4] also performed the modified dry mixing method for 5 PET contents. The study results show that the Marshall stability is greatest at 4% PET content by weight of asphalt binder, and the maximum indirect tensile strength is at 2% PET content.

The objective of this study is to study the effect of the traditional dry mixing method and the modified dry mixing method on the quality of asphalt concrete based on laboratory experiments. There are three PET contents including 0.2, 0.4, and 0.6% by weight of aggregate, modified dense-graded asphalt concrete and one control mixture is conducted for comparison. The paper also focuses on the mechanical properties of PET modified asphalt concrete, including Marshall stability, indirect tensile strength, and static resilient modulus.

2 Experimental Program

2.1 Materials

This study uses one type of asphalt cement, and the grade is the 60/70 of penetration from BachChambard joint stock company. All the properties of asphalt cement, which are 62 of penetration, 49 °C of softening point, over 348 °C of flash point, and over 110 cm of ductility, are satisfied with TCVN 7493-2005 [5], which is the specification for asphalt cement.

The aggregate used in this study is from a hot mix asphalt plant in District 9, Ho Chi Minh city. The chosen maximum aggregate size is 19mm due to its widespread application in Ho Chi Minh city. All the aggregates from the plant used in this work were sieved into the sieve size, and recombined into the chosen gradation that meets the required gradation from TCVN 8819:2011 [6] as shown in Fig. 1.

Polyethylene Terephthalate (PET) used in this paper is cut from waste mineral water bottles. The particle size of PET after cutting is about 1.5 mm × 1.5 mm, as shown in Fig. 2.

2.2 Mix Design and Mixing Procedure

The optimum asphalt content is determined based on relationships between five asphalt binder contents and Marshall stability, Marshall flow, density, void in mineral aggregate,

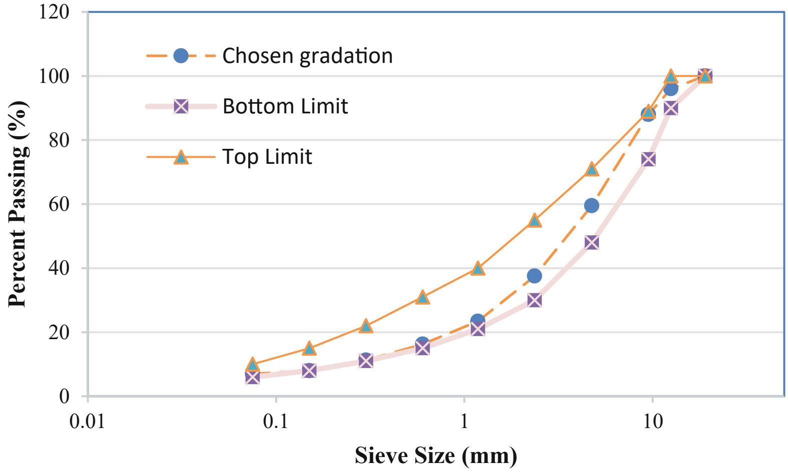

Fig. 1. Chosen aggregate gradation

and air void based on the Marshall method for asphalt concrete mix design or TCVN 8820:2011 specification [7]. The chosen optimum asphalt content is 4.97% by weight of the asphalt mixture.

After the mix design of the control mixture, the PET contents, which are 0.2, 0.4, and 0.6% by weight of total aggregate, were added to the control mixture. Two mixing methods, including the modified dry mixing method and the traditional dry method, are used. The procedure of the modified dry mixing method is as follows: Asphalt binder and aggregates were heated at temperatures of 150 °C for 2 h and 170 °C for 4 h, respectively; Asphalt binder and aggregates were mixed at 150 °C to have mixture and the PET particles were added directly to the mixture. And the procedure of the traditional dry mixing method is that aggregates and PET are mixed before adding asphalt binder into the mixture of aggregates and PET at 150 °C.

Fig. 2. Polyethylene Terephthalate particles from waste water bottle

2.3 Evaluation Properties of Asphalt Concrete

In order to evaluate the effect of PET content on asphalt concrete, the Marshall stability, indirect tensile strength, and static resilient modulus were conducted as in the set-up of Fig. 3. All samples were fabricated by using the traditional and modified dry mixing method. The samples of Marshall stability and indirect tensile strength test are made by Marshall compactor as shown in Fig. 3a. The samples of static resilient modulus are created from the hydraulic jack as shown in Fig. 3d.

Fig. 3. Set-up for all tests in this study: **a** Marshall compactor; **b** Set-up for Marshall test; **c** Step-up for indirect tensile strength test; **d** Sample preparation for static resilient modulus test; **e** Set-up for static resilient modulus test.

Marshall stability is conducted according to TCVN 8860-1:2011 specification [8]. Before the Marshall stability test, all specimens were kept in a water bath at 60 °C for 40 min and then loaded with a constant strain of 50.8mm per minute. The maximum load applied to the specimen is the Marshall stability.

The indirect tensile strength was obtained by a compressive load based on TCVN 8862-2011 [9]. The specimens were also prepared and kept in a chamber at 25 °C before testing. The compressive load increased continuously with displacement rate (50mm/min) regulations until damage. The indirect tensile strength (ITS) of the material is calculated from the load which creates the damage to the specimen (P) as follows:

$$ITS = \frac{2P}{\pi HD} \quad (1)$$

The static resilient test for all specimens were put in the chamber at 15 °C or 30 °C or 60 °C before testing after the TCCS 38:2022/TCDBVN specification [10]. The resilient modulus tests were conducted using 0.5 MPa loading pressure (p) into asphalt concrete specimens. The resilient modulus (E) of asphalt concrete is determined from the measured resilient displacement (L) and the specimen height (h) as follows:

$$E = \frac{hp}{L} \quad (2)$$

3 Result and Discussion

In this study, effect of Polyethylene Terephthalate percentages as well as two mixing methods in asphalt concrete based on Marshall stability, indirect tensile strength, and static resilient modulus are in all figures from Fig. 4, 5 and 6.

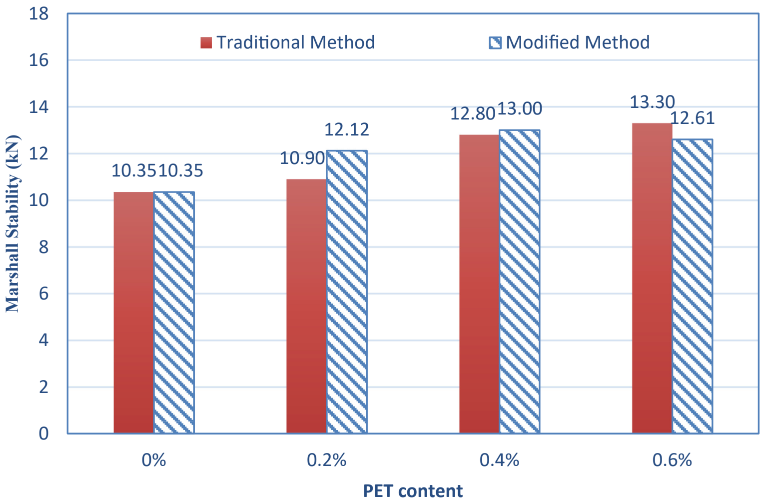

Fig. 4. Marshall stability of all mixtures from two mixing methods

In Fig. 4, the stabilities of the PET modified asphalt concretes or PET mixtures are better than conventional asphalt concrete or control mixture for the two mixing methods. For two mixing methods, the increased PET content increases the Marshall stability of that mixture except for the 0.6% PET of the modified mixing method. At 0.4% PET, the Marshall stabilities from the two methods are almost identical.

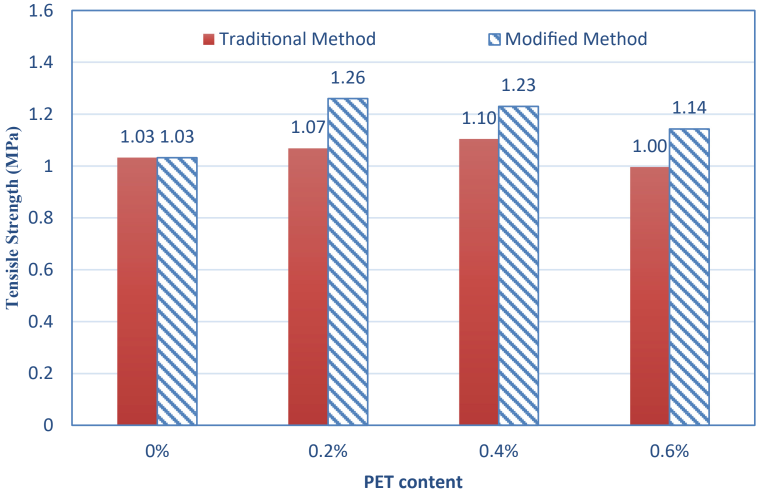

Fig. 5. Indirect tensile strength of all mixtures from two mixing methods

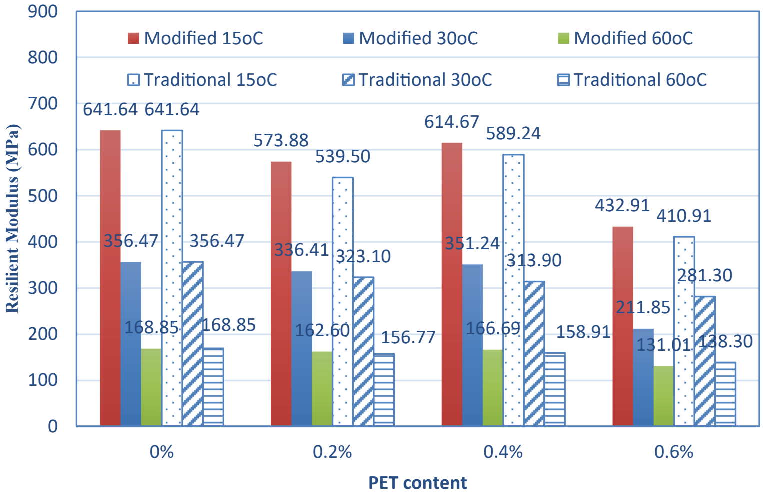

Fig. 6. Static resilient modulus results of all mixtures from two mixing methods

In Fig. 5, the indirect tensile strengths of all mixtures are shown. The PET in asphalt mixtures greatly contributes to the tensile strength, except the 0.6% PET for the traditional method. There are a few differences between the control mixture to PET mixtures used in the traditional method. The modified mixing method with 0.2% and 0.4% of PET increased about 23 to 26% compared to the control mixture.

Figure 6 shows the static resilient modulus values of all mixtures at three temperatures. The PET modified asphalt concrete is lower than the control mixture for the resilient modulus. The resilient modulus of PET mixtures using the modified mixing method are better than the conventional method. Based on the flexible pavement design based on TCCS 38:2022/TCDBVN [10], for an urban road pavement section including subgrade with $E_o = 37$ MPa, 20 cm sub-base layer with $E_1 = 150$ MPa, 15 cm base layer with $E_2 = 250$ MPa, and hot mix asphalt for the surface layer with E_3. With the control mixture, the resilient modulus **E_3 = 356.47MPa** (at 30 °C) based on test result in Fig. 6, the thickness of hot mix asphalt should be **11.1cm** for the required surface modulus on top of pavement section is 130 MPa. Similarity, when the 0.4% PET mixture based modified mixing method is used for hot mix asphalt, the resilient modulus $E_3 =$ 351.24 MPa is as in Fig. 6, and the thickness of hot mix asphalt should be **11.2cm** for the required surface modulus on top of pavement section is 130MPa. This result shows that the PET mixture needs more thickness in pavement design.

From three types of tests from Figs. 4, 5 and 6, test results from the modified dry mixing method are better than those from the traditional dry mixing method, except for Marshall stability at 0.6% PET mixture.

4 Conclusion

In this paper, two types of dry mixing methods, which are the modified mixing method and the traditional mixing method, are concerned. The asphalt content of 0% of PET or control mixture from the mix design of asphalt concrete, conducted from the Marshall method, is 4.97%. Then, the PET percentages added into asphalt concrete are 0.2, 0.4, and 0.6% by weight of aggregates. All mixtures were evaluated based on the Marshall stability, indirect tensile strength, and static resilient modulus. The following conclusions are from the obtained result:

- The asphalt concrete mixtures used in PET are worse than conventional mixtures in resilient modulus. However, PET increases the Marshall stability and indirect tensile strength of asphalt concrete;
- The pavement structure used PET modified asphalt concrete in this study could increase the thickness based on TCCS 38:2022/TCDBVN compared to control asphalt concrete because of the smaller resilient modulus. But the tensile strength of the PET mixture could increase the crack resistance of asphalt concrete based on tensile stress at the bottom of the asphalt concrete layer, and this idea would be in our further research;
- The modified dry mixing method is better than the traditional one regarding stability, indirect tensile strength, and resilient modulus, except for stability for 0.6% PET mixture.

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