Construction and Building Materials 65 (2014) 487–494

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Experimental characterization of rutting performance of Polyethylene Terephthalate modified asphalt mixtures under static and dynamic loads

Taher Baghaee Moghaddam *, Mehrtash Soltani, Mohamed Rehan Karim

Center for Transportation Research, Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

HIGHLIGHTS

- Properties of PET modified asphalt mixtures were investigated.
- Rutting behavior of asphalt mixtures was assessed.
- Static and dynamic loadings were designated.
- PET modified mixtures demonstrated different behaviors under static and dynamic loadings.

ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form 25 April 2014
Accepted 2 May 2014
Available online 2 June 2014

Keywords:
Asphalt mixture
Waste Polyethylene Terephthalate
Mixture property
Static loading
Dynamic loading

ABSTRACT

During the last decades by increasing vehicles' number and weights on roads, road pavement has been subjected to greater damages which in many cases occurred even before expected pavement service life. Hence, in order to tackle with this problem road designers and engineers are to find solutions to improve pavement characteristics. One of the most common solutions is constructing asphalt mixture with modified characteristics. This paper aims to evaluate effects of using waste Polyethylene Terephthalate (PET) as a modifier on properties of asphalt mixture in three steps. In the first step, bulk specific gravity test, Marshall test, indirect tensile stiffness modulus test and indirect tensile strength test were conducted on mixtures containing different percentages of PET. In the second step, permanent deformation of PET modified asphalt mixture were assessed under static and dynamic loads. Finally in the last step, relationships were found between the results achieved in the first and second steps. The results showed that using PET as additive can change the properties of asphalt mixture. PET modified mixtures had entirely different behaviors under static and dynamic loadings and when it could not be considered as a proper additive for pavements experiencing static loading, it was a superior additive which can considerably improve rutting properties of asphalt mixture under dynamic loading condition.

1. Introduction

In recent years, road pavement has been subjected to greater damages as result of increase in number and weight of vehicles passing on roads. One of the most common types of road damaging is rutting which has a noticeable impact on performance of road pavement during its service life. Rutting is defined as the accumulated permanent deformation of road pavement which occurs under applied loading [1–3], and in this case, asphalt layer has shown a prominent magnitude [4]. Rutting is not only reduces the service life of asphalt mixture, but also influences basic vehicle handling manoeuvres in a negative manner which can threaten passengers' lives [5].

Different factors can influence rutting properties of asphalt mixture, including: aggregate type and gradation, amount of air void in asphalt mixture, type and amount of binder content, environmental temperature as well as mode and amount of loading applied on road pavement [6–8]. It is reported that Stone Mastic Asphalt (SMA) mixture which consists of coarse aggregate skeleton and provides stone-on-stone contact between aggregates has considerably better resistance against rutting damage compared to conventional dense graded mixture [9,10]. In addition, using, large size, angular, rough texture aggregate particles as well as stiffer binders can improve rutting resistance of asphalt mixture [11]. Environmental temperature is an important factor can influence the rutting properties of asphalt mixture and this is due to the asphalt

* Corresponding author at: Center for Transportation Research, Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 108927064; fax: +60 379552182.
E-mail addresses: p.baghaee@gmail.com, payam_baghaei@siswa.um.edu.my (T. Baghaee Moghaddam).

http://dx.doi.org/10.1016/j.conbuildmat.2014.05.006
0950-0618/

properties which are highly influenced by ambient temperature [7].

In literatures, different laboratory tests have been used in order to evaluate rutting properties of asphalt mixture namely: wheel tracking test, static and dynamic creep tests [7,12], Marshall Quotient (MQ) [13,14] and indirect tensile test. Besides, it is believed that creep test has a very good correlation with actual rut depth and has a high capability to estimate rutting behavior of asphalt layer [15]. MQ which is the ratio of stability to flow (rigidity ratio), and is a well-recognized criteria to measure resistance of materials to shear stress, permanent deformation and hence rutting [12,13]. It is thought that higher value of MQ represents higher mixture stiffness which contributes to higher resistance against permanent deformation in asphalt mixture [12,14].

This study aims to evaluate permanent deformation characteristics of Polyethylene Terephthalate (PET) modified asphalt mixtures under static and dynamic loads and their relationships with other properties of mixture.

2. Literature review

2.1. Polyethylene Terephthalate (PET) modified asphalt mixture

Polyethylene Terephthalate (PET) is semi-crystalline thermoplastic polymer, and is considered as polyester material [16]. PET is one of the important technical plastic materials in the last two decades because of its superlative characteristics such as being safe, light, transparent, chemical resistance and economical [17]. Nowadays, large amount of waste PET are being produced worldwide and due to non-biodegradability of PET it causes serious environmental challenge [18].

PET can be recycled by chemical and physical procedures. Chemical recycling of PET is costly because it is performed at high pressure, temperature and in presence of chemical materials as catalysts. Further, in mechanical recycling, quality of recycled PET would be decreased due to the presence of adhesive contaminants [19]. Hence, recycling cannot be considered as only solution to overcome the crisis arises by producing large amount waste PET, thus it would be promising to find alternative solution to tackle with this problem such as using as secondary materials in asphalt mixture. Here, it is aimed to bring the history of using post-consumer PET in asphalt mixture.

Post-consumer PET was used in asphalt mixture in two different concepts. One is using PET as aggregate replacement in asphalt concrete mixture (plastiphalt), and another is modification of asphalt mixture by utilizing PET particles.

Hassani et al. have investigated the possibility of using waste PET in asphalt concrete mixture as an aggregate replacement. In this study, mineral coarse aggregates with size of 2.36–4.75 mm were replaced with PET granules with diameter of 3 mm. The mechanical properties of mixtures including Marshall stability and flow, MQ and specific gravity of compacted mixtures were evaluated. As a result it was achieved that plastiphalt with the partial aggregate replacement (20% by volume) with PET granules met most of specification requirements which made it proper for practical use [20]. In a related study, the waste PET as partial fine aggregate replacement was evaluated. The repeated load axial test and indirect tensile stiffness modulus test were performed. Results showed that though plastiphalt had less stiffness compared to the conventional mixture, it had higher resistance against permanent deformation [21].

There are two different methods for using additives in asphalt mixture namely: wet and dry methods. In the wet method procedure, the additives are added to the asphalt cement before mixing with aggregate particles. In the dry method, however, the additives are added directly to the mixture. In 2008, Casey et al, attempted to investigate suitability of different polymer materials as asphalt modifiers. In this investigation it was thought that PET cannot be considered as a suitable asphalt modifier due to its high melting point that might hinder the mixing. Hence, because PET could not be incorporated into the asphalt, it was supposed that adding PET in asphalt mixture through the wet method would not be practical [22].

Recently, PET particles have been added to asphalt mixture as an additive using dry process. In 2011, Ahmadinia et al, utilized waste PET with maximum size of 1.18 mm as additive in SMA mixtures. The Marshall and volumetric properties of mixtures were assessed and it was concluded that re-using waste PET as an additive had positive effects on properties of SMA mixture in an environmentally friendly and economically way [23]. In the next year, more investigations were performed on PET modified SMA mixtures by Ahmadinia et al. Wheel tracking, moisture susceptibility, resilient modulus and drain down tests were performed on PET modified SMA mixtures. They used the same PET particle size and percentages as they used earlier. It was found from this study that the performance of PET modified mixture has satisfied the standard requirements and that the appropriate range for the PET amount is between 4% and 6% by weight of asphalt content [24].

The fatigue properties of asphalt mixtures modified by PET particles were evaluated in another study. PET flakes with the maximum size of 2.36 mm were used and fatigue properties of PET modified asphalt mixtures were assessed. The results showed that the fatigue life increased considerably under dynamic loading and the mixtures containing higher amount of PET content showed higher resistance against fatigue cracking [25]. In other study, permanent deformation characteristics of PET modified asphalt mixture under dynamic loading was investigated at various temperatures and stresses, and it was shown that permanent strain decreased considerably by application of PET modification [7].

2.2. Static and dynamic creep tests for modified mixtures

Static and dynamic creep tests have been considered as two important test methods that can determine the rutting susceptibility of asphalt mixture. In the past literatures, more studies have assessed the permanent deformation of asphalt mixture using dynamic creep test though less studies focused on static testing. In this section, it is aimed to bring an overview on static and dynamic creep testing of modified mixtures which were conducted in the last few years.

Effect of using cellulose and mineral fibers on rutting properties of asphalt mixture was investigated by Behbahani et al. Dynamic creep test was conducted and the results suggested that rutting properties of asphalt mixture was improved by adding fibers under dynamic loads [26]. In related study, dynamic creep test was designated to evaluate the rutting performance of asphalt mixture with waste tire thread mesh reinforcement and with different percentages. It was obtained from the results that mixture containing 3% of tire thread had the lowest permanent strain and so highest rutting resistance [27].

In other investigation, effects of three elastomeric polymers have been identified on rutting properties of asphalt mixture. These elastomeric polymers were OL, EL and SB. In that study, it was concluded that using elastomeric polymers could enhance the rutting resistance of asphalt mixture; however, the results were not correlated well with each other at high and low temperatures [28].

In 2012, the effects of using mineral and cellulose fibers as well as SBS polymer were investigated on rutting properties of SMA mixture. The result of this study showed that SBS had the best effect on rutting properties of asphalt mixture [29]. Baghaee