Construction and Building Materials 138 (2017) 427–433

Contents lists available at ScienceDirect

Construction and Building Materials

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

Evaluating the mechanical properties of terminal blend tire rubber mixtures incorporating RAP

Munir D. Nazzal [a,*], Md. Tanvir Iqbal [b], Sang Soo Kim [a], Ala Abbas [c], Md. Tanvir Quasema [b], Walaa Mogawer [d]

[a] Civil Engineering Department, Ohio University, Athens, OH 45701, United States
[b] Civil Engineering Department, Ohio University, Athens, OH, United States
[c] Civil Engineering Department, University of Akron, Akron, OH 45701, United States
[d] Civil Engineering Department, University of Massachusetts, Fall River, MA, United States

HIGHLIGHTS

- The GTR mixing speed is an important factors that affects the low-temperature properties of the GTR modified binder.
- GTR mixtures had similar cracking and rutting resistance to the PG 76-22 polymer modified mixes.
- There was no significant difference in the performance of the considered cryogenic and ambient GTR modified binders and mixes.

ARTICLE INFO

Article history:
Received 12 August 2016
Received in revised form 23 December 2016
Accepted 25 January 2017

Keywords:
Terminal blend GTR
RAP
Low temperature cracking

ABSTRACT

This paper documents the results of a laboratory testing program that was conducted to evaluate the mechanical properties of mixtures incorporating terminal blend ground tire rubber (GTR) modified asphalt binders and reclaimed asphalt pavement (RAP) and compare them to those produced using polymer modified binders. The laboratory testing program included ambient and cryogenic GTR modified asphalt binders as well as two polymer modified asphalt binders meeting specifications for performance grade (PG) 70-22M and PG 76-22M. The laboratory tests results indicated that the GTR mixing speed affects the low-temperature properties of the GTR modified binders. Furthermore, mixtures prepared with GTR modified binders had better tensile properties as well as resistance to low-temperature cracking and rutting than those prepared using the polymer modified PG 70-22M but similar to those with PG 76-22M polymer modified binder. In addition, the GTR modified mixes had comparable resistance to moisture-induced damage to those prepared using the considered polymer modified binders. In general, there was no significant difference in the performance of the considered cryogenic and ambient GTR modified binders and mixes.

1. Introduction

The increase in the carbon dioxide (CO_2) and other greenhouse emissions has contributed to the thinning of the ozone layer, which is thought to be responsible for the global warming and the increased occurrence of natural disasters [8]. Thus, there has been a growing interest to reduce the CO_2 emissions. One way that can be used to achieve that is to increase the use of recycled materials such as reclaimed asphalt pavement (RAP) ground tire rubber (GTR) [4]. GTR has been incorporated in asphalt binders and mixtures using two method groups, namely the dry method and the wet method [5]. In the dry method, GTR is added to the aggregates before mixing with the binder, while in the wet methods, GTR is blended with the asphalt binder before producing the mix. The latter is expected to provide better blending between the GTR particles and the asphalt binder, resulting in better GTR mixes performance [5].

GTR modified asphalt binders has been produced using the wet method by adding coarse GTR to the asphalt binder and agitating them in a special unit at high temperatures to stimulate the physical and chemical bonding between the two materials. More recently GTR modified binders were produced by adding finer GTR particles to the asphalt liquid material at the binder storage or distribution terminal before transporting it to the asphalt plant. The GTR modified binder produced using this method is commonly referred to as terminal blend GTR or pre-blended GTR. Terminal blend GTR method eliminates the need for the specialized blending

* Corresponding author.
E-mail address: nazzal@ohio.edu (M.D. Nazzal).

http://dx.doi.org/10.1016/j.conbuildmat.2017.01.102

equipment at the asphalt plant, which results in lowering the overall costs of the GTR binders.

Over the past decade studies have been performed to examine the properties of GTR terminal blend GTR binders and mixes. Abdelrahman [1] found that the performance of GTR modified asphalt binders was affected by different factors, which included: GTR particle size, surface area and production method. GTR is typically produced using ambient or cryogenic method. In cryogenic method, waste tire are frozen to a temperature ranging from −87 to −198 °C until it becomes brittle using liquid nitrogen, and a hammer mill is utilized to shatter the frozen tire rubber into smooth GTR particles. For the ambient GTR processing method, the scrap tire is processed at or above room temperature. Attia and Abdelrahman [2] indicated that the ambient GTR processing method typically provides irregularly shaped, torn particles with relatively large surface areas which helps to improve the interaction between the GTR particles with the asphalt binder.

Willis et al. [9] evaluated the effect of the GTR particle size, surface area, production method and loading rate on the properties of GTR modified asphalt binders. The test results of this study showed that the GTR particle size and loading rate had the most significant effect on the low and high-temperature performance grade of the GTR modified asphalt binders. Furthermore, the surface area had only significantly influenced the high temperature properties. However, the GTR processing method had minor effect on the GTR modified asphalt binders, which was attributed to higher surface area of the cryogenic GTR particles used in the study. Finally, this study found that the larger GTR particle results in higher rubber separation.

Shen et al. [7] examined the influence of the GTR surface area and particle size on the high temperature properties of GTR modified binders. The study included ambient and cryogenic GTR materials with three different particles sizes and two asphalt binders meeting specifications for PG 64-22 and PG 58-28. The GTR materials were blended with the two asphalt binders using a high shear mixer at 700 rpm and a mixing temperature of 176 °C for 15, 30 and 45 min. Shen et al. [7] reported that the larger the GTR particle size the higher the modulus of the GTR modified binder. Furthermore, the GTR modified asphalt binder stiffness decreased with the increase in the surface area of the GTR. However, the influence of the GTR surface area was less significant than the particle size. Finally, the ambient GTR resulted in high modulus values as compared to cryogenic GTR.

Although several research studies have been conducted to evaluate the effects of GTR properties on the high temperature properties of asphalt binders, but limited studies were conducted to examine their effects on low-temperature properties of binder and the overall mixture performance (e.g. [3]. In addition, limited research work was reported on mixtures containing GTR modified binders and RAP materials.

2. Objectives

The main objectives of this study are to evaluate the laboratory performance of mixtures incorporating RAP and GTR and examine the effect of GTR properties on the performance of GTR modified binders and mixtures.

3. Materials

3.1. GTR materials

Ambient and cryogenic GTR materials was considered in this study. While the ambient (AM) GTR was a minus mesh 30 (i.e. passing sieve No. 30), the cryogenic (CR) GTR was minus mesh 40 (i.e. passing sieve No. 40). Fig. 1 presents the gradation for the GTR types considered. The Quantachrom gas sorption surface area analyzer was used to measure the surface area of GTR materials considered in this study. The surface area was computed using the Brunauer–Emmett–Teller (BET) method. The measured surface area for ambient GTR and cryogenic GTR was 0.2893 ± 0.0597 m^2/g and 0.1645 ± 0.0274 m^2/g respectively. It is noted that the Lo Presti [5] indicated the ambient process results in irregular/jagged and bigger GTR particles while cryogenic method yields smooth shaped and smaller GTR particles, which explain the difference in the measured surface areas between the GTR materials considered in this study.

3.2. Binders

Two styrene-butadienestyrene (SBS) polymer modified binders polymer modified asphalt binders meeting specification for PG 70-22M and PG 76-22M typically used in construction of pavements in Ohio were obtained from an asphalt contractor. Samples of PG 64-22 were obtained from the asphalt contractor to be used in this study. Different types of GTR binders were prepared. The first set of GTR binders were prepared by heating the obtained PG 64-22 asphalt binder to 190 °C (375 °F) and adding 10% by weight of ambient and cryogenic GTR materials. The GTR and binder are then blended using a high shear mixer at 3600 RPM for 50 min. A heating mantle was used to ensure that the binder's temperature remained constant at 190 °C (375 °F) during mixing. To examine the effect of mixing speed on the GTR modified properties, the ambient GTR binders were also prepared using the same described procedure but with a mixing speed of 800 RPM. In addition, a suspension agent was used with the cryogenic GTR to determine the effect of suspension agents on the separation tendency and mechanical properties. All binders were placed in the oven at 177 °C (350 °F) for 24 h to allow for the interactions between the GTR and the asphalt binder and ensure the stability of the GTR modified binder.

Dynamic shear rheometer (DSR) tests were conducted on the GTR and polymer modified binders to determine their high temperature performance grade (PG) in accordance with AASHTO M320 "Standard Specification for Performance-Graded Asphalt Binder". DSR test procedure were conducted using a 2-mm gap to accommodate the presence of the GTR particles in the asphalt binder. Tests were performed on polymer and GTR modified binders. Fig. 2 presents the continuous high temperature obtained based on the DSR test results. All GTR binders had continuous high temperature greater than 76 °C. The DSR test results show that mixing speed have affected the high temperature grade; such that ambient GTR binder prepared using mixing rate of 800 rpm had lower continuous high temperature as compared to prepared with 3600 rpm mixing rate. It is clear that the binders with cryogenic

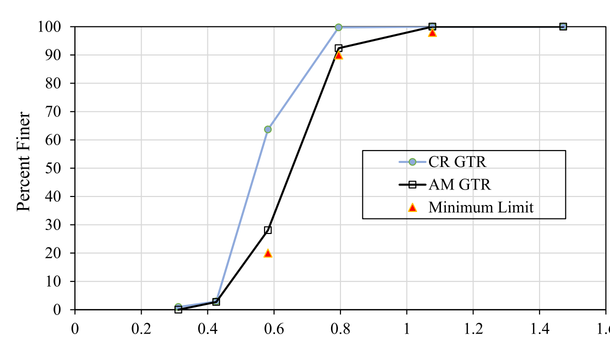

Fig. 1. Gradation of GTR material.