Construction and Building Materials 149 (2017) 350–358

Contents lists available at ScienceDirect

Construction and Building Materials

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

Assessment of mechanical properties of rice husk ash modified asphalt mixture

Mahyar Arabani *, Seyed Amid Tahami

Department of Civil Engineering, University of Guilan, Rasht, Iran

HIGHLIGHTS

- The feasibility of using rice husk ash as an asphalt modifier in hot mix asphalt was investigated.
- The addition of RHA to asphalt binder improved the rheological and physical properties of asphalt binder.
- The use of RHA enhanced the Marshall stability and stiffness modulus of asphalt mixtures.
- Asphalt mixtures with RHA showed better rutting resistance and fatigue performance than control mixtures.

ARTICLE INFO

Article history:
Received 17 May 2016
Received in revised form 1 May 2017
Accepted 12 May 2017
Available online 24 May 2017

Keywords:
Rice husk ash
Hot mix asphalt
Conventional binder tests
Dynamic shear rheometer
Stiffness modulus
Marshall stability
Rutting resistance
Fatigue behavior

ABSTRACT

Using rice husk ash (RHA), as a waste byproduct of rice milling, in bituminous roadways provides valuable advantages such as reduction of environmental degradation, lowering construction costs and saving natural resources. However, there are limited numbers of studies on application of this material in asphalt mixture. The objective of this study was to investigate the effects of RHA as an asphalt modifier on hot mix asphalt. Bitumen blends with 5%, 10%, 15% and 20% RHA modifier. For evaluation of the rheological properties of asphalt binders, various tests including penetration grade, ductility, softening point, rotational viscosity and dynamic shear rheometer were conducted. Also, the mechanical properties of asphalt mixtures including Marshall stability, stiffness modulus, rutting resistance and fatigue behavior were assessed. The results showed that the rheological properties of bitumen were enhanced by adding RHA. Furthermore, RHA modification had positive impacts on the Marshall stability, stiffness modulus, rutting strength and fatigue performance of asphalt mixtures.

1. Introduction

Due to high road construction costs, researchers should find correct mix design and proper materials to enhance the efficiency of road construction and increase the pavement service life [1]. Increasing axle loads, traffic volume, construction and design errors cause major damages in asphalt pavement including rutting, fatigue and low temperature cracking that reduce the performance of road pavement [2]. These damages lead to an increment of maintenance cost and decrease in the service life of road. In addition, the properties of asphalt binder like viscoelastic behavior, strength, and rate of plastic deformation are closely related to these damages [3]. Asphalt binder due to its viscoelastic characteristics, cohesiveness, and strength plays a critical role in the performance of asphalt mixtures [4]. Since asphalt binder is one of the main components of hot mix asphalt (HMA) used in highway and airport pavements, modification of asphalt binder is the effective method for enhancement of the mechanical properties of asphalt mixtures [5]. In recent years, asphalt modifiers from different categories including reclaimed rubber products, fillers, fibers, catalysts, polymers (natural and synthetic) and extenders have been applied as an asphalt modifier to enhance the properties of asphalt binder [6]. Selecting an appropriate modifier is related to different factors such as geographical conditions, existing facilities in various countries, economic issues, production of modifier and environmental compatibility [7].

Many investigations should be performed on reusing waste materials in asphalt concrete mixtures, and the impact of using waste materials on performance of asphalt concrete mixtures should be evaluated [8]. Raising concerns about environmental protection, energy preservation and economic issues have been motivating researchers to find other alternative raw materials in

* Corresponding author.
E-mail addresses: arabani@guilan.ac.ir (M. Arabani), amidtahami378@yahoo.com (S.A. Tahami).

http://dx.doi.org/10.1016/j.conbuildmat.2017.05.127
0950-0618/

the asphalt pavement industry. Investigations have indicated that waste materials can be successfully used as filler, aggregate and asphalt modifier in asphalt mixtures (e.g., seashells, recycled aggregates, glass, waste brick, waste tire and reclaimed asphalt pavement [9–13]).

The burning of solid biomass can mainly produce two by-products which are fly and bottom ashes. Due to increasing the production of energy by this source, the disposal of produced ashes has caused environmental and economic problems. Also, different types of ashes are considerably considered to use in bituminous and cementitious mixtures [14]. Sharma et al. [15] studied the effects of four types of fly ashes on asphalt mastic and HMA. In this study, the rheological properties of asphalt mastic were evaluated from softening point test, viscosity test, and dynamic shear rheometer test. Also, Marshall stability, retained stability, tensile strength ratio, and static creep tests were performed to assess the properties of different asphalt mixtures. It was concluded that four groups of fly ashes could be used in asphalt mixtures and asphalt mixtures containing fly ash had better properties compared to the control mixture. In 2016, researchers investigated the effects of date seed ash on moisture sensitivity of asphalt mixtures using surface free energy method. They found that date seed ash could improve the adhesion between aggregate materials and asphalt binder that led to an increase in moisture resistance of modified asphalt mixtures [16].

Rice husk is obtained as a waste material from agricultural and industrial processes. RHA is the by-product produced during the combustion of rice husk waste in combustor facilities. RHA can be considered as agro-industry waste [17]. The annual worldwide paddy rice production is about 678 million tons which leads to production of 149.16 million tons of rice husks, and by burning this volume of rice husks; 37 million tons of RHA are produced [18]. Many rice milling plants have been supplying their fuel by burning rice husk. This huge amount of produced rice husk ash is useless and leads to economic and environmental concerns. In order to overcome these issues, many researchers have investigated the characteristics of rice husk ash and found that rice husk ash can be used as a supplementary cementitious material in concrete for enhancing the mechanical properties and durability of concrete [19–21]. Recently, some attempts have been made by researchers to study the feasibility of using rice husk ash in asphalt pavement. In this regard, a research was conducted by Sargin et al. [22] on using RHA as filler in asphalt mixtures. The application of rice husk ash as a replacement of virgin filler in the rate of 25%, 50%, 75%, and 100% was evaluated by Marshall stability test. It was found that asphalt mixtures containing the combination of 50% limestone powder and 50% RHA as filler exhibited the best performance in terms of Marshall stability and Marshall flow. In a research, rice husk ash was added to asphalt binder, and the effects of RHA on chemical properties of asphalt binder were analyzed by Fourier Transform Infrared Spectroscopy, and it was observed that there is no chemical interaction between asphalt binder and RHA. Furthermore, the physical properties of binder were improved by addition of RHA. Besides, the storage stability of asphalt binders modified with RHA was stable [23].

2. Problem statement and objectives

Iran is located in West Asia where there are many rice agricultural lands, hence causing the high production of rice, which subsequently produces rice husk in large volume at rice mill factories. This volume of produced rice husk is used as fuel in factories, resulting in generating large amount of rice husk ash. This leads to many problems such as disposal and environmental problems. Although rice husk ash is widely applied in many fields such as concrete construction, the application of rice husk ash in asphalt mixtures is still in the early stages. Many aspects of using rice husk ash in asphalt mixtures were not studied. In this study, two steps were considered in order to assess the effects of rice husk ash on asphalt binder and mixture. As the first step, various laboratory tests for asphalt binder properties such as penetration grade, softening point, ductility, rotational viscosity (RV) and dynamic shear rheometer (DSR) were conducted to examine the rheological characteristics of modified asphalt binders. As the second step, the performance tests including Marshall stability, indirect tensile stiffness modulus (ITSM), repeated load axial (RLA) and indirect tensile fatigue (ITF) were used to study the mechanical properties of HMAs.

3. Materials and experimental design

3.1. Aggregates

In this study, crushed and sharp-edged aggregates were used for preparation of HMAs. Table 1 presents the physical properties of the aggregates. The aggregates grading for asphalt mixtures was obtained from the continuous type IV scale of the AASHTO standard [24] which is listed in Table 2.

3.2. Asphalt binder

The asphalt binder 60/70-penetration grade from Isfahan Mineral Oil Refinery was used in this study. The laboratory tests were carried out in order to assess the conventional rheological properties of asphalt binder. The test results of the asphalt binder used in this study are summarized in Table 3.

3.3. Rice husk ash

Rice husk was collected from a local rice mill plant from Guilan Province in the northern part of Iran. Fig. 1 shows rice husk and prepared rice husk ash used in this study. The RHA used for this investigation was produced by burning rice husks at 650 °C in the furnace for 2 h. The ash was ground in a ball mill for 15 min and then was passed through the sieve size 0.075 mm. It was reported that the combustion condition affects the specific surface area of rice husk ash. Therefore, producing maximum reactivity of ash depends on temperature and environment [25]. The highest amount of reactivity is obtained by burning rice husk at the temperature of about 500–700 °C [26]. The chemical compositions of the RHA which was determined by X-ray fluorescence spectrometry (XRF) are presented in Table 4.

3.4. Sample preparation

The asphalt mixtures were prepared using the standard Marshall mix design procedure with 75 blows on each side of the cylindrical specimens. The optimum asphalt content was found to be 5.6% for the control mixture. In this study all HMA samples were made with 5.6% asphalt content in order to maintain consistency throughout the research. For each test (Marshall, stiffness modulus, repeated axial load and fatigue test), three samples were fabricated and tested.

For modification of asphalt binder with RHA, asphalt binder was heated at around 160 °C. Then, RHA was blended with asphalt binder at a speed of 2500 rpm for 30 min to obtain the required homogeneity. Five RHA contents were used: 0%, 5%, 10%, 15% and 20% in terms of total asphalt binder weight.

Table 1
Properties of aggregates.

Test	Specification	Result
Coarse aggregates		
Bulk specific gravity (g/cm^3)	ASTM C 127	2.633
SSD specific gravity (g/cm^3)		2.641
Apparent specific gravity (g/cm^3)		2.663
Fine aggregates		
Bulk specific gravity (g/cm^3)	ASTM C 128	2.638
SSD specific gravity (g/cm^3)		2.645
Apparent specific gravity (g/cm^3)		2.664
Abrasion loss (%) (Los Angeles)	ASTM C 131	24.1
Flat and elongated particles (%)	ASTM D 4791	17.2