Construction and Building Materials 170 (2018) 547–556

Contents lists available at ScienceDirect

Construction and Building Materials

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

Usage of two biomass ashes as filler in hot mix asphalt

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HIGHLIGHTS

- The feasibility of using rice husk ash and date seed ash as alternative filler in hot mix asphalt was investigated.
- The use of RHA and DSA enhanced the Marshall stability and stiffness of asphalt mixtures.
- The usage of RHA and DSA fillers improved the rutting performance of asphalt mixtures.
- Asphalt mixtures with RHA and DSA showed better fatigue resistance compared to control mixtures.

ARTICLE INFO

Article history:
Received 4 August 2017
Received in revised form 12 March 2018
Accepted 13 March 2018

Keywords:
Hot mix asphalt
Date seed ash
Rice husk ash
Mechanical properties
Stiffness modulus
Rutting resistance
Fatigue

ABSTRACT

Today, waste materials have been increasingly utilized as alternative raw materials in asphalt mixtures in order to decrease construction costs, conserve natural resources and reduce environmental problems. The main purpose of this research is to investigate the potential of using two biomass ashes, which are agricultural waste/byproducts namely rice husk ash (RHA) and date seed ash (DSA), as filler material in hot mix asphalt (HMA) by replacing conventional filler at different percentages. The percentages of DSA and RHA separately used in the mixtures were: 0%, 25%, 50%, 75% and 100%. The effects of DSA and RHA fillers on mechanical properties of asphalt mixtures were assessed using Marshall stability, MQ, indirect tensile stiffness modulus, wheel track and four point bending fatigue tests. Furthermore, the asphalt mastics were produced to evaluate the effect of fillers on mastic viscosity. Based on the results, asphalt mixtures with DSA and RHA fillers showed higher stability and stiffness modulus in comparison with the control mixture. Also, using biomass ashes improved the thermal sensitivity of mixtures and the adhesive force between asphalt and aggregates, which caused an enhancement in rutting resistance and fatigue life of HMA mixtures.

1. Introduction

Growing traffic volume and the increase in allowable axial loads necessitates the enhancement of the road paving materials. Providing economical, safe and durable pavements is the aim of highway authorities to bear the anticipated loads [1].

Asphalt mixture is the most widely used material in road pavement due to its superior in-service performance. Asphalt mixture is a combination of aggregate, asphalt binder and filler. Filler is an important component because asphalt mastic, a fundamental dispersed system in asphalt mixture, is formed by combination of asphalt binder and filler. The physico-chemical interactions between asphalt and filler in asphalt mastic have direct and significant impact on the performance of HMA. Also, Filler can fill the voids in asphalt mixture that affects the stability and improves the ability of the mix to resist plastic deformation under high temperatures [2]. Using filler in hot mix asphalts contributes to enhancing the fatigue performance, rutting behavior and moisture damage resistance [2–4].

In recent years, it can be seen that the growth in the mining industry and the raised consumption of raw materials have caused a rapid limitation in available natural resources [5,6]. The high volume of resource extraction and shortage of raw materials lead to developed waste recycling and management [7]. Besides, one of the main concerns of many countries is solid waste, which has been continuously increased, should be managed because the amount of waste materials in most landfills near large cities has got oversaturated. Utilization of waste materials can be promoted in asphalt roadways and the properties of asphalt pavements containing waste materials should be examined [8,9]. Owing to increasing environmental and economic concerns, many research-

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https://doi.org/10.1016/j.conbuildmat.2018.03.102
0950-0618/

ers have tried to evaluate the feasibility of reusing wastes in asphalt industry in order to save limited resources, reduce construction costs and tackle environmental pollution.

Fly and bottom ashes are byproducts produced directly during the combustion of solid biomass in combustor facilities. Heat produced during the combustion process is converted into electrical power that is increasingly used by factories. The produced biomass ashes remain as solid waste and require disposal and, consequently lead to environmental and economic issues. So, in order to evaluate the feasibility of using these ashes in as construction materials, the chemical and physical properties of different ashes were investigated and it was suggested to use them in bituminous and cementitious mixtures [10].

Xue et al. [11] examined the performance of stone matrix asphalt using municipal solid waste incineration ash as filler. They found that using this type of ash could increase the moisture damage resistance of asphalt mixtures. Also, the results showed significant improvement in fatigue life of mixtures with municipal solid waste incineration ash. The effects of four types of fly ashes on asphalt mastic and asphalt mixture were studied by Sharma et al. The study concluded that the rheological properties of asphalt mastics were enhanced by using fly ashes. Besides, to evaluate the performance of different asphalt mixtures, Marshall stability, retained stability, tensile strength ratio, and static creep tests were carried out. The results demonstrated that four groups of fly ashes could be used in asphalt mixtures and asphalt mixtures with fly ash showed superior performance in comparison with the control sample [12]. Other researchers suggested that using fly ash in asphalt mixtures improved mixes strength against permanent deformation [13].

Date is regarded as one of the oldest known plants which has been grown in North Africa and the Middle East [14] Date trees are cultivated in dry and semi-dry regions such as United Arab Emirates, Egypt, and Iran. Also, in the United States (California and Arizona) 16,500 tons of date is produced in 2005 (ranked 10th worldwide) [15]. It has reported that in 2013, about ten million tons of dates were produced globally. From these, 1.2×10^6 tons were produced in Iran [16]. About 11–18% of date weight is its seed, meaning that approximately more than 1 million tons of date seeds are wasted worldwide annually [17]. Therefore, in 2016, the usability of date seed, an agricultural waste, in asphalt pavement was investigated. In this study, date seed ash was used as mineral filler and its effects on moisture susceptibility of HMA were evaluated with help of surface free energy method. The results indicated that date seed ash could enhance the adhesion between aggregate and asphalt mastic that led to better moisture damage resistance of modified asphalt mixes [16].

Rice husk is another agricultural byproduct obtained from milling processes of rice paddy. The combustion of rice husk waste in combustor facilities produced RHA which is regarded as agro-industry waste [18]. The world production of rice paddy has exceeded 678 million tons that causes generation of 149 million tons of rice husks. The combustion of this volume of rice husks produces 37 million tons of RHA [19]. The fuel of most rice milling plants has been supplying by combustion of rice husk. This considerable volume of rice husk ash is useless and sent to landfill, leading to considerable environmental contamination. In consideration of these important issues, many researchers have studied characteristics of rice husk ash and concluded that it can be used as a pozzolanic material for cement replacement in concrete that gives properly improvement in durability and strength of concrete [19–21].

Also, some efforts into the application of RHA as asphalt pavement material were made, however, is comparatively limited. In 2016, the effects of RHA as filler on Marshall stability and moisture susceptibility of asphalt mixtures were investigated. The results of the study showed that using RHA could increase the stability of mixes by 65%. Furthermore, asphalt mixes with RHA exhibited better indirect tensile strength and moisture damage resistance compared to conventional mixes [22]. Another research was performed by Arabani and Tahami [5] in 2017 on modification of asphalt binder with RHA. The research outcomes indicated that addition of RHA could increase the viscosity of asphalt binder. Also, RHA could be effective in reducing thermal susceptibility of asphalt binder that resulted in better performance of modified asphalt mixture at high temperatures. Furthermore, based on dynamic shear rheometer test the RHA modified asphalt binders had better elastic behavior than base asphalt binder.

2. The statement and objectives of the present study

Hundred million tons of rice paddy and date fruit are consumed each year, which produce a huge amount of agricultural waste. Burning these wastes and dumping them in landfill is the most common way used today. Utilizing these waste materials as alternative raw materials in asphalt pavement can be promising method to reduce environmental pollution, decrease consumption of natural recourses and lessen construction costs. However, there are a few researches on the effects of using rice husk ash and date seed ash, especially as filler, on asphalt pavement. So that, the objective of this research is to evaluate further mechanical properties of asphalt mixes containing RHA and DSA. For this purpose, RHA and DSA were used in HMA mixtures as filler. The stone dust filler (conventional filler) of asphalt mixtures was substituted with 25, 50, 75% and 100% RHA and DSA powders, and various tests including Marshall stability, indirect tensile stiffness modulus, wheel track and four point fatigue tests were performed to assess the performance of different HMA mixtures.

3. Materials and experimental design

3.1. Aggregate

In this study, crushed and sharp-edged aggregates were utilized to prepare HMA mixtures. Table 1 reports the physical properties of the aggregates. Gradation of aggregates, which is obtained from the continuous type IV scale of the AASHTO standard, is provided in Table 2.

3.2. Asphalt binder

The asphalt binder of 60/70 penetration grade was used in this study. The physical properties of asphalt binder were determined by conducting laboratory tests, which are listed in Table 3.

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