Construction and Building Materials 178 (2018) 551–561

Contents lists available at ScienceDirect

Construction and Building Materials

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

Review

Effects of additives on the mechanical performance in recycled mixtures with bitumen emulsion: An overview

Pooyan Ayar

Civil Engineering School, University of Granada, Dr. Severo Ochoa St., Granada 18071, Spain

HIGHLIGHTS

- Effects of additives on the mechanical performance in Recycled Mixture with Bitumen Emulsion (RMBE) have been reviewed.
- Fatigue response of RMBE containing cement could be affected by strain levels.
- The use of modified bitumen emulsion could improve rutting resistance of RMBE.
- Waste pozzolan can be used as a substitute for traditional additives in RMBE.
- The mechanisms of interaction between lime and bitumen emulsion need more clarification.

ARTICLE INFO

Article history:
Received 22 December 2017
Received in revised form 21 May 2018
Accepted 22 May 2018

Keywords:
Recycled mixture
Bitumen emulsion
Performance
Modified emulsion
Waste pozzolan
Additive

ABSTRACT

Cold recycling technology has been recognized as an efficient, cost-effective, and environmentally friendly method to rehabilitate asphalt pavements. Based on previous experiments, some solutions such as using additives (e.g. cement, lime, and waste pozzolans) and modifying bitumen emulsion have been proposed to enhance the performance, as well as to improve the sustainability of Recycled Mixture with Bitumen Emulsion (RMBE) as a cleaner product. Although some studies have evaluated the laboratory protocols to design RMBEs, there still remain many unclear issues related to the use of additives. Therefore, this article tries to review the general criteria for additive selection, and also to assess the different functional aspects of RMBEs (e.g. physical, durability and mechanical characteristics), paying attention to the impacts of additives. Additionally, key points concerning the use of modified bitumen emulsion in RMBEs were assessed. Finally, a series of important lines for further investigations in this field have been presented.

Contents

E-mail address: payar@correo.ugr.es

https://doi.org/10.1016/j.conbuildmat.2018.05.174
0950-0618/

1. Introduction

According to recent data, Europe and the U.S. produced 265.4 and 319.0 million tons asphalt mixtures in 2014 respectively [1]. It is clear that the production of asphalt mixes is accompanied by a remarkable emission of greenhouse gases [2] and during the manufacturing, construction and maintenance processes involved in asphalt pavements, the adverse effects of energy consumption, bitumen production, and extraction of natural aggregates should be taken into consideration [2,3]. Given these critical issues, highway agencies have attempted to cut down the environmental and the economic impacts of pavements through different efforts such as reducing the temperature of production and construction processes, as well as reusing existing materials [4–6]. One of these important efforts emerges in cold recycling technology, which is a combined measure to reduce the manufacturing temperature and reuse of the existing pavement materials.

Cold recycling technology as a rehabilitation method can be used to modify distresses that involve both surface and base courses in a pavement system [7]. Furthermore, placing and paving cold mixes at ambient temperature could reduce the stiffening effects originating from initial aging [8] and also working at lower temperatures is considered as the main advantage of employing this technology in rehabilitation projects [9–11]. Additionally, cost-effectiveness superiority and sustainability of cold recycling technology compared with the traditional rehabilitation methods have been previously reported [10,12,13].

Concerning the implementation steps of cold recycling technology, when the whole recycling processes including milling, mixing Reclaimed Asphalt Pavement (RAP) materials with agents and also paving are performed in-place, the method is called Cold In-place Recycling (CIR), whilst when the recycled mix is prepared in a plant and then is conveyed to the project site for paving, the method is called Cold Central Plant Recycling (CCPR). Although CCPR allows a better control of the mix properties, the CIR eliminates transporting the recycled mixtures to the project site, resulting in less fuel consumption [7,12,14] and compared to other rehabilitation methods, CIR technique possesses less environmental impacts [14,15]. Referring to this issue, Fig. 1 is depicted to reflect presented data by Chappat and Bilal [16], shows that CIR's energy consumption is much less than other asphalt products. In CIR method, the treatment depth of pavement is 50–100 mm when the recycling agent is only a bitumen emulsion. However, higher depths of treatment (125–150 mm) can be applied when chemical additives are used to improve the performance [17]. Conventionally, cold recycled layer can be used as a surface course for secondary roads and if a protective wearing surface is placed over, it can also be implemented as a base course for high-quality pavements [12,18,19].

Since 1970s, bitumen emulsion was used as the most common recycling agent in cold recycled mixtures. Owning to its liquid form at ambient temperatures, bitumen emulsion can disperse all over the mix. In addition to improving the cohesiveness and load bearing capacity of the cold recycled layer, the bitumen emulsion could help in rejuvenating and softening the aged bitumen of the RAP materials [7,20,21].

According to the earlier experiences, Recycled Mixture with Bitumen Emulsion (RMBE) was exposed to problems such as excessive plastic deformation (i.e. rutting), low initial strength, weak adhesiveness and inappropriate dispersion of bitumen. These problems were more obvious at initial times of service due to long curing period. Thereupon, the idea of using additives (i.e. active fillers) in RMBEs was introduced to overcome these problems [7,22,23]. Nonetheless, utilizing additives is not the unique way to improve the performance of RMBEs, and the use of modified bitumen emulsion can also be considered as another solution [7]. Commonly, cement and lime are employed as conventional additives in RMBEs [7,24,25], as well as waste additives (e.g. waste pozzolans) have been used in some experiments [7,26]. Moreover, in comparison with additives, normal fillers (i.e. stone powder) does not have a remarkable effect on the performance of RMBE [27]. It is important to bear in mind that additives have a significant impact on RMBE's performance [28–30] and several factors can affect the selection of their types and dosages [18,21,26].

Although researchers tried to synthesize different protocols related to the preparation and evaluation of RMBEs [25], a tangible gap can be seen in former experiments concerning combined effects of additives and bitumen emulsion on the service performance [31]. In fact, when additives and bitumen emulsion are to be used at the same time, the mechanical behavior could be strongly influenced by the dosage and characteristics of these agents [32]. Accordingly, this article aims at reviewing and analyzing the role of additives in the performance of RMBEs, as well as evaluating other solutions to improve the sustainability of these types of mixtures (e.g. using modified bitumen emulsion). Moreover, current article provides some technical recommendations to choose the type and optimum dosage of additives in RMBEs based on various studies with respect to physical, mechanical and durability characteristics.

2. Additives

2.1. Additives incorporated in the mixture

2.1.1. Lime

Lime has been widely used as an additive or a filler in bituminous mixtures to improve durability [33] and likewise hydrated

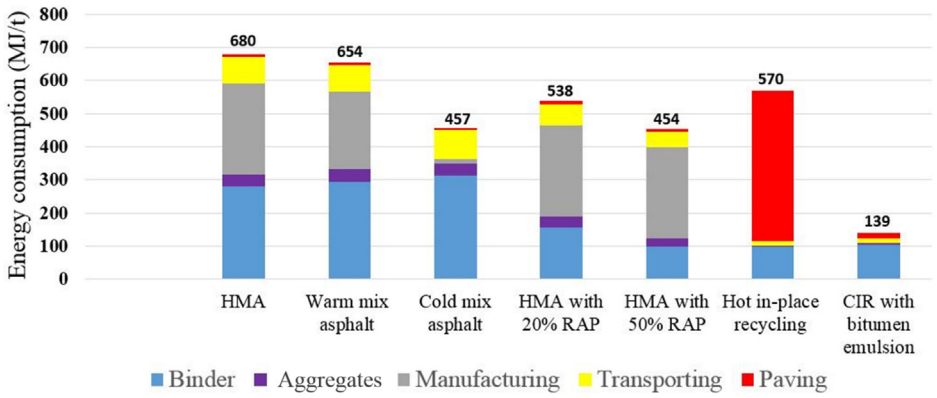

Fig. 1. Comparing the energy consumption of different asphalt products, depicted based on presented data by (Chappat and Bilal, 2003 [16]).