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Review

The use of rejuvenating agents in production of recycled hot mix asphalt: A systematic review

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HIGHLIGHTS

- Application of rejuvenating agents in production of HMA is reviewed.
- Recycling high amount of RAP is possible using rejuvenating agent.
- Importance of selecting rejuvenator type and dosage is highlighted.
- Rejuvenators must satisfy both short-term and long-term criteria.

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ABSTRACT

Extensive researches have been conducted on using reclaimed asphalt pavement (RAP) material in production of recycled hot mix asphalt. According to literature, the aged binder is the main obstacle to incorporate high amount of RAP into asphalt pavement which causes premature distresses such as fatigue failure and low temperature cracking in pavement structure. To overcome this problem, rejuvenating agent or rejuvenator is usually used to restore the RAP binder properties to a condition that resembles that of fresh asphalt binder. Different types of rejuvenators have been used previously. This study provides an overview on utilizing RAP, and the use of rejuvenators, type and dosage, in production of asphalt pavement.

Contents

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1. Introduction

Hot mix asphalt (HMA) is the most widely used paving material worldwide. During the years after construction of road pavement, the HMA deteriorates and needs to be removed from the road. Reclaimed asphalt pavement (RAP) is obtained as a result of the removal, milling, and crushing process of old pavement structures. The aged RAP can then be modified and reused in the construction of new pavement structures. The first application of RAP in construction of a new road structure was recorded in 1915 [1]; however, the wider application of RAP goes back to the 1970s when, as a result of the energy crisis, the cost of asphalt binder was dramatically increased [2]. Since that time the application of RAP has been increased due to improving road construction technologies. According to Chen et al., RAP is now one of the most recycled materials in the world [3]. Currently, 100% of RAP material can be recycled [4]; however, not more than 40% of RAP is allowed to be used in mixtures by many state agencies [5]. There are four common methods that can be used to incorporate RAP in new pavement construction. These methods are hot recycling at the asphalt plant, hot-in-place recycling, cold-in-place recycling, and full depth reclamation [6,7].

RAP binder is highly oxidized and has high viscosity (stiffness) compared to fresh asphalt binder. Rejuvenating aged asphalt binder is a common practice to restore the aged asphalt binder properties to a condition that resembles that of fresh (virgin) binder. Rejuvenating agent, or rejuvenator, is one of the recycling agents and is suitable for either highly oxidized mixtures or mixtures containing a high percentage of RAP (more than 25% RAP) or recycled asphalt shingles (RAS) [8]. In the production of recycled pavement, type and amount of rejuvenator need to be properly determined so that the low temperature properties of the mixture can be improved while the properties at higher temperatures are not adversely affected [6].

This paper provides an overview of reusing RAP and applications of rejuvenating agents in the construction of recycled pavement structures in three steps. The first step briefly describes advantages, disadvantages, and limitation of using RAP, followed by a general view of the RAP application procedure. The second step focuses on the RAP fractions including RAP aggregate as well as binder. The final step studies rejuvenation methods along with the effects of different rejuvenators (types and dosages) on the aged binder and mixture characteristics.

2. Advantages of using RAP

Using RAP in constructing new pavements offers two main advantages, including economical advantage as well as environmental benefit [9]. First, reusing aggregate and asphalt binder available in RAP material contributes to significant reduction in pavement construction cost. Second, recycling asphalt pavement using RAP offers different environmental benefits.

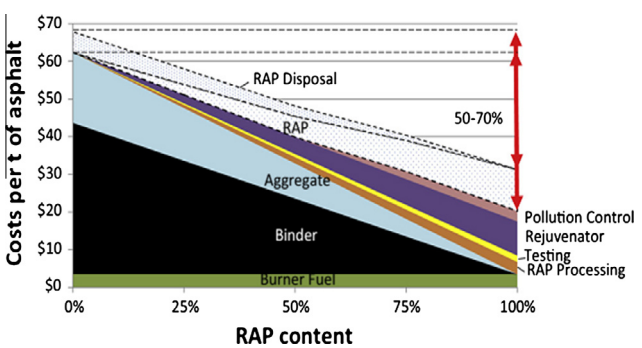

Fig. 1. Costs of materials in hot mix recycling [11].

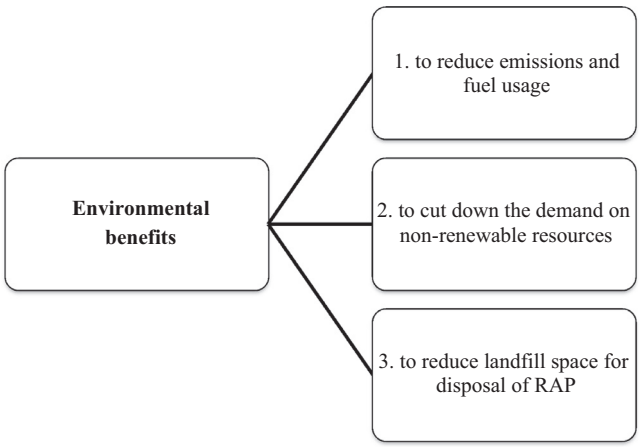

Fig. 2. Environmental benefits of using RAP in construction of new pavement structure.

2.1. Cost analysis

In 2014, Martins Zaumanis et al., compared the costs of conventional asphalt mixtures to those of asphalt mixtures containing RAP. In their study, different percentages of RAP (0–100%) material were considered, as is shown in Fig. 1. The asphalt binder has the highest portion of the cost in constructing conventional asphalt mixtures at almost $40 per ton. This is followed by aggregate cost which is roughly $20 per ton. Using 50% RAP materials resulted in decreasing the construction cost by almost $20 per ton from $70 to less than $50. This value is slightly different than the earlier study which suggested that using RAP between 20% and 50% would save the construction cost between 14% and 34% [10]. Besides, as Fig. 1 shows, the cost types in recycled mixtures are more attributed to costs of RAP processing, testing, using rejuvenator, pollution control, and cost of RAP material. Overall, by utilizing 100% RAP material the construction cost was reduced by 50–70% which is a considerable amount [11].

2.2. Environmental benefits

As can be seen in Fig. 2, there are three different environmental benefits of reusing RAP. Reusing RAP in recycled pavements is an alternative solution to reduce waste road construction materials by incorporating them in new road construction projects. This causes savings in raw materials (asphalt binder and aggregate particles). Additionally, previous studies have reported that energy consumptions and emissions were reduced by using RAP materials in road pavements construction [11–13] which can be related to the extraction and transportation of virgin materials. Among the pavement materials production of binder causes the highest energy consumption and emissions. By using RAP, the amount of required binder decreases which eventually results in less energy consumption and fewer emissions [11,14,15]. As another environmental benefit, the landfill space required for disposal of RAP is reduced [16].

3. Disadvantages of using RAP

In spite of the fact that using RAP materials in pavement construction offers many advantages, it might have some disadvantages which are mostly attributed to the complexity of mix