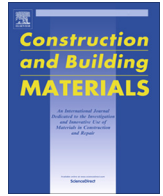




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Effect of granular polymers on rutting performance of SMA with respect to modification process

Reza Imaninasab

Civil and Environmental Engineering Department, University of Wisconsin-Madison, Madison, WI, USA

HIGHLIGHTS

- ECB does not improve rutting performance when directly added to SMA mixture.
- Rheofalt improves rutting performance when directly added to mixture SMA.
- Blending Rheofalt with bitumen is more efficient than direct addition to mix.
- Rheofalt and SBS modified binders have almost the same rutting performance.
- Rheofalt and SBS have greater rutting performance enhancement than ECB.

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ABSTRACT

The aim of this research is to investigate the effect of two types of modification processes for granular polymers, Polymer Modified Bitumen and direct addition of polymer into mix, on rutting performance of Stone Matrix Asphalt (SMA). In this research, granular polymers including Rheofalt and Ethylene-Copolymer-Bitumen (ECB), namely Lucobit, were used and their impact on rutting resistance improvement were compared with SBS modified and unmodified mixtures. Results of performing dynamic creep test revealed that, with respect to both modification types, Rheofalt modified mixtures resulted in significantly greater rutting resistance than ECB modified ones. Moreover, it was found that although ECB modified bitumen is effective to rutting enhancement, there is no improvement as a result of direct addition of it into mixtures. On the other hand, results showed that Rheofalt is influential in direct addition into mixtures but not as efficient as introduction of Rheofalt modified bitumen into mixes. Finally, investigating resilient modulus vs. cycle curves, it was revealed that SBS with elastomeric property predominance resulted in resilient modulus reduction as the content increases while Rheofalt and ECB showed reverse trend with their content increase.

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1. Introduction

Stone Matrix Asphalt (SMA) is a gap-graded hot mix asphalt composing of coarse skeleton and mastic. The mastic contains high filler content, some fine aggregates, cellulose fiber and asphalt binder [1,2]. SMA was first developed in 1960s to reduce damages of studded tire which was common in Germany. The expensive materials and costly construction of SMA as well as prohibition of studded tire led to production decline in this type of asphalt mixture. However, it became popular in some other countries such as Sweden because of its high rut resistance properties [2]. And, later, was introduced to the United States after European Asphalt Study Tour in 1990 [3].

Rutting is one of the predominant load-associated distresses and accumulates with load repetition. It is of major concern for the following reasons [4]:

1. water trapping that results in drainage capacity decrease
2. bleeding along rut path
3. fatigue cracking due to reduction in thickness of asphalt layer
4. steering difficulty as the rut develops in depth

Providing stone on stone contact, SMA is rut resistant hot mix asphalt, in which applied loads are borne by coarse skeleton making up approximately over 70 percent of aggregate weight [1,2,5,6]. Coarse aggregates are identified the retained aggregate on sieve #4 or #8, depending on Nominal Maximum Aggregate Size (NMAS) [2]. A lot of field-related researches have been carried out on rut depth of SMA mixture that proves its high rut resistance potential

E-mail address: Imany_reza@civileng.iust.ac.ir

[5–8]. However, only some of the laboratory tests were found to be able to evaluate the performance of SMA mixtures versus dense-graded ones. These include confined creep and gyratory shear tests that both are indicator of rutting resistance [8,9].

When comparison of SMA with other mixture types such as HMA is not intended, to evaluate the mastic impact on permanent deformation, confining pressure is not essential. In the unconfined condition, the permanent deformation of SMA mixtures is mostly influenced by the plastic flow of mastic [2]. Introduction of elastomer, thermoplastic and elastomer-thermoplastic polymers into SMA has positive effect on performance of mastic and, subsequently, the performance of SMA.

The elastomer polymers make deformations recoverable and maintain flexibility at low temperatures. On the other hand, not only do the thermoplastic polymers improve workability while mixing and paving, but they also stiffen binder content at in-service temperatures [10]. Resilience and stiffness increase of mastic contribute to the preservation of coarse skeleton cohesion and, as a result, permanent deformation decreases.

There are two types of asphalt modification approaches with polymers including using Polymer Modified Bitumen (PMB) and direct addition of polymers into asphalt. While the first process is very common and applicable for all types of polymers, the second is restricted to granular polymers with low melting temperature. A Fischer Tropsch wax, namely Sasobit, is a widely used Warm Mix Asphalt (WMA) additive [11,12] that can be applied with both processing types because of its low melting temperature [10].

There have been several researches about the effect of various PMBs on rutting performance of asphalt mixes. SBS has been found one the most influential polymers regarding rutting resistance improvement of SMA and, subsequently, reducing asphaltic layer thickness [13,14,16–18]. Moreover, Rhefalt at concentration of 10% was proved to be almost as effective as SBS with respect to rutting [15]. On the other hand, cellulose fiber, which is widely used in SMA to avoid draindown, has no significant effect on rutting performance [13]. Recently, direct introduction of Rhefalt into asphalt mixes was investigated and found effective regarding resilient modulus and rut depth reduction [19].

Despite many studies on PMB modified SMA, there have been lack of researches on efficiency of direct addition of granular polymers into asphalt mixes. This is mainly due to scholars' interest to follow sophisticated laboratory protocols regarding polymers evaluation rather than employing off-standardized approaches. This paper focuses on the effect of two thermoplastic polymers on rutting performance with employing two recommended methods for modified asphalt production. Furthermore, elastomer-thermoplastic polymer of SBS was used to assess the effectiveness of the thermoplastic polymers used in this study.

2. Objectives

The objectives of this research are:

- To evaluate rutting resistance of ECB and Rhefalt with respect to two applicable processes for granular polymers to produce polymer modified asphalt with comparing them to unmodified and SBS modified SMA mixtures
- To evaluate the effectiveness of adding Fischer Tropsch wax, thermoplastic resin and Vinyl-Acetate (elastomeric portion of EVA) into the thermoplastic polyethylene in direct addition of polymer into mixture regarding rutting resistance.
- To investigate resilient and creep modulus vs. cycle curves obtained from dynamic creep test to find relation between these curves and polymer properties.

3. Materials

In this study, aggregates, asphalt binder, stabilizing additives and mineral fillers were selected to meet Iran Highway Paving code specifications [20]. Using high quality coarse aggregates are required for SMA since they are the load-bearing structure of this type of asphalt mixture. Table 1 presents chemical elements of siliceous aggregate used in this research, which were determined by XRD testing and analysis. The Properties of fine and coarse aggregate are also given in Table 2. Used bitumen is 60/70 penetration bitumen whose properties are listed in Table 3.

The additives used in this study are SBS, Rheoflat, which is combination of EVA with a thermoplastic resin and a Fischer Tropsch wax, Ethylene-Copolymer-Bitumen (ECB), namely Lucobit, and cellulose fiber. The properties of Lucobit, Rheofalt, SBS and cellulose fiber are listed through Table 4–7, respectively. As presented in Table 4, ECB is a mixture of ethylene copolymer and bitumen in form of masterbatch. According to the instruction of the producing company, direct addition into the mixture is applicable for this thermoplastic polymer containing polyolefines [21]. In addition, as presented in Table 5, Rheofalt has lower melting temperature than ECB due to EVA combination with a Fischer Tropsch wax (refined hydrocarbons). This combination leads to production temperature reduction and makes Rheofalt applicable for direct addition into the mixture as this processing type is also recommended by the manufacturer instruction [22].

4. Research approach

4.1. Gradation and optimal asphalt binder content

Proposed SMA gradation limits depend on NMAS. At least three trial preliminary gradations within the limits are required to be evaluated for desired gradation selection. Gradation with closest VCA ratio (VCA_{mix}/VCA_{DRC}) to 1, which meets minimum VMA of 17 percent and has void of coarse aggregate in mix (VCA_{mix}) less than the one determined by the dry-rodded technique (VCA_{DRC}), is selected as the desired gradation. The inequality $VCA_{mix} \leq VCA_{DRC}$ is checked to ensure stone on stone contact establishment. To find desired gradation, first, minimum binder content was determined according to NCHRP report 425 using the aggregates bulk specific gravity [1–3]. 12 samples (3 identical for each gradation) were then compacted by 50 Marshall hammer blows per side for volumetric properties determination and 4 uncompacted samples were fabricated for theoretical maximum density calculation. Trial and desired gradations of this research are shown in Fig. 1.

After the desired gradation was chosen, samples were prepared in different binder contents to determine optimal binder content, which is supposed to result in 3–4% air void content. For warmer region it is advisable to choose approximately 4 percent air void, and, for cooler region, closer to 3% is recommended. For each bitumen percentage, 3 identical compacted samples and 3 uncompacted samples were prepared to calculate air void content and

Table 1
Chemical element of aggregate.

Chemical element	Percent
Calcite	29.5
Quartz	25.9
Feldspar	20.9
Dolomite	18.4
Clay	5.4

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