Development of Optimum Fractionation Method for High-RAP Mixtures
By Sieve-by-Sieve Analysis of RAP Materials

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ABSTRACT

The main objective of this research is to examine the effects that different methods of RAP stockpile fractionation have on the volumetric mix design properties for high-RAP content surface mixes, with the goal of meeting all specified criteria for standard HMA mix designs. To determine the distribution of fine aggregates and binder in RAP stockpile, RAP materials were divided by each sieve size. The composition of RAP materials retained on each sieve was analyzed to determine the optimum fractionation method. Fractionation methods were designed to separate the stockpile at a specified sieve size to control the amount of fine RAP materials which contain higher amounts of fine aggregates and dust contents. These fine RAP materials were used in reduced proportions or completely eliminated, thereby decreasing the amount of fine aggregate materials introduced to the mix. Mix designs were performed using RAP materials from three different stockpiles and the two fractionated methods were used with high-RAP contents up to 40% by virgin binder replacement. By using an optimum fractionation method, a mix with 40% RAP was successfully designed while meeting all Superpave criteria and asphalt film thickness requirement by controlling the dust content from RAP stockpiles.

INTRODUCTION

The main objective of this research is to examine the effects of different methods of RAP stockpile fractionation on the volumetric mix design properties of high-RAP content surface mixes. Fractionation methods were designed to separate the stockpile at predetermined sizes to isolate RAP materials within the stockpile that contained higher amounts of fine aggregate and negatively impacted the volumetric properties of the HMA mix design. Mix designs were performed for a low-volume (300,000 ESAL), ½” mix-size surface mixture with RAP contents accounting for replacement of up to 40% of the total mixture’s asphalt binder. The resulting properties of each mix design were compared to determine the volumetric improvements attributed to the fractionation methods.

RAP MATERIAL COMPOSITION ANALYSIS

Samples of three RAP materials were obtained from stockpiles at a local, eastern-Iowa contractor’s asphalt plant facility. Each stockpile was unique with respect to the combination of the original pavement’s source, the recycling methods used and the recycled material’s properties. A detailed analysis was conducted on each RAP material to investigate the material composition. The milling operation seemed to influence the amount of ‘Coarse RAP’ and ‘Fine RAP’ materials produced. Slower, deeper milling passes seemed to break down the pavement so that almost all of the millings will pass the maximum top size; however, the extensive material degradation will increase the amount of ‘Fine RAP’ and dust content (Stockpile A). Faster and shallow depth milling seemed to produce more ‘Coarse RAP’ materials and less dust content (Stockpile C); however, ‘Oversize RAP’ materials that was screened out and processed at the plant seemed to better represent the aggregate gradation of the original mix design (Stockpile B). The gradation of recovered fine aggregates from the ‘Coarse RAP’ category was very consistent and the dust content was low whereas that of recovered aggregates from ‘Fine RAP’ category...
was highly variable and the dust content was high. As expected, the Fine RAP materials exhibited higher recovered asphalt binder content.

**DESIGN OF FRACTIONATION METHODS**

The composition analysis of all three stockpiles confirmed that a significant aggregate degradation has occurred during the milling and crushing process. The excessive amounts of fine aggregates produced from milling and crushing process pose a challenge in meeting Superpave criteria such as the combined aggregate gradation, dust-binder ratio and film thickness. Therefore, the main purpose of this research is to design RAP stockpile fractionation methods that would help meet the Superpave criterion with high RAP contents up to 40%. The following two methods named ‘Fractionated RAP’ and ‘Optimum FRAP’ were designed to produce the acceptable high-RAP mix design that would meet the Superpave criteria with a minimum disposal of fine RAP materials.

The ‘Fractionated RAP’ method removes all of RAP material passing the No. 30 sieve size (Stockpile A and B) or the No. 16 sieve size (Stockpile C) from the stockpile. This method resulted in significant fine aggregate reduction and minimal material discarded from each original stockpile. The ‘Optimum FRAP’ method splits each original RAP stockpile at the No. 4 (Stockpile A and B) or 3/8” sieve size (Stockpile C) to produce a ‘Coarse FRAP’ stockpile (RAP materials retained a specified sieve) and a ‘Fine FRAP’ stockpile (RAP materials passing a specified sieve). The percentage of ‘Coarse FRAP’ was increased to bring the combined aggregate gradation to the middle of the fine aggregate gradation control points. Mix designs were performed for high-RAP content mixtures using RAP materials included as the ‘Traditional RAP’ method, the ‘Fractionated RAP’ method and the ‘Optimum FRAP’ method. Results of these mix designs were then compared to determine the effects of the fractionation methods on the volumetric properties of high-RAP mix designs.

**HIGH-RAP MIX DESIGN**

Currently, the maximum amount of RAP material currently allowed in the surface course by the Iowa DOT is limited to 30% of the virgin binder replacement by Classified RAP materials. For this study High-RAP mix designs were created for inclusion of 40% RAP material (measured by amount of virgin binder replaced) from each original RAP stockpile (Stockpile A, B and C) as well as the fractionated RAP stockpiles (‘Fractionated RAP’ and ‘Optimum FRAP’).

To meet Iowa DOT’s mix design criteria, fraction methods (‘Fractionated RAP’ and ‘Optimum FRAP’) were developed for High-RAP mixes with 40% replacement of the mixture’s virgin binder. Comparison of the results from these High-RAP mix designs showed that the volumetric properties are highly dependent on the material composition of the original RAP stockpile. Stockpile A contained very high dust content resulting in a low asphalt film thicknesses and a high ratio of dust content to effective asphalt binder. The ‘Fractionated RAP’ and ‘Optimum FRAP’ methods were effective in reducing the aggregate surface area of the high-RAP mixture; however, improvement of mixture’s volumetric properties was also influenced by the optimum asphalt content of each mixture. For Stockpile B, the aggregate structure improvements by the
fractionation methods were offset by reductions in the optimum asphalt content resulting in a lower asphalt film thickness than the minimum requirement. For Stockpile C, the only ‘Fractionated RAP’ method met Iowa DOT’s mix design criteria.

SUMMARY

While reclaimed asphalt pavement (RAP) materials are widely used around the country, their usage has been limited due to a difficulty in meeting the required volumetric properties for high-RAP content mixtures. The original aggregate structure of the existing pavement is changed during the milling and processing operations resulting in the creation of excessive amounts of fine aggregate. In order for RAP materials to be used in higher amounts, these volumetric properties must be improved to meet the mix design criteria.

Various fractionation methods were designed and applied to three different stockpiles for up to 40% RAP binder replacement. The component analysis of three different RAP stockpiles identified the distribution of aggregates and binder associated with RAP materials retained on each sieve. This sieve-by-sieve analysis helped identify the critical sieve to divide the stockpiles and its impacts on the resulting fractionated mix designs. The component analysis confirmed that asphalt content varied depending on the size of RAP materials with very little asphalt content in minus 200 RAP materials. Fine aggregates were stuck with nearly all RAP materials and it is very difficult to remove them. It is concluded that the fractionation methods were effective in improving volumetric properties of the HMA mixture with a high RAP content.

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