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Evaluation of warm mix asphalt containing recycled asphalt shingles

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HIGHLIGHTS

- Field production of recycled asphalt shingles (RAS) with warm mix asphalt (WMA).
- Distress surveys on 18 pavement sections performed yearly after construction.
- Moisture susceptibility comparison for WMA/RAS mixtures.
- Beam fatigue testing to measure fatigue properties when RAS and WMA are used.
- Low temperature tests imply similar thermal cracking between the mixtures studies.

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ABSTRACT

Advances in asphalt materials have led to the incorporation of higher amounts of recycled asphalt materials in mixtures that can be produced at reduced temperatures. Two demonstration projects were constructed to assess the performance of mixtures that use warm mix asphalt (WMA) and recycled asphalt shingles (RAS) at reduced temperatures. WMA mixes were produced at 120 °C. Eighteen pavement sections were monitored each year after construction. Performance tests were conducted on all mixes to measure material properties at a range of temperatures. Additional tests were conducted for one of the field projects to show the influence of increasing RAS on moisture susceptibility. Results indicate that WMA can successfully be used with a RAS mixture. Benefits of adding additional RAS include improvement in rutting, stripping inflection point (SIP), and higher or similar dynamic modulus values at increased test temperatures.

1. Introduction and background

The use of sustainable materials and practices in asphalt paving has garnered significant interest over the past decade. Modifying asphalt mixes with recycled asphalt shingles (RAS) diverts materials from landfills and reduces liquid asphalt costs. The increased use of warm mix asphalt (WMA) technologies has reduced mixing and compaction temperatures of hot mix asphalt (HMA). The benefits of WMA include temperature reductions leading to reduced fuel costs, reduced compaction effort, and lower emissions [1]. Combining the use of warm mix asphalt technology with RAS will provide the contractor with benefits of using both technologies while creating a more sustainable product. Asphalt shingles typically have 20–30% asphalt by weight of the shingles and utilization of this waste product presents an economic opportunity, particularly when virgin asphalt binder prices are high. Using WMA technologies or processes with RAS provides economic value due to virgin binder cost reduction, utilization of materials that would otherwise be landfilled, reduction of HMA plant temperatures by approximately 30 °C, saving fuel, and achieving improved field compaction. Two mixes were studied, one from Indiana and one from Iowa, both use variable amounts of recycled asphalt pavement (RAP) and RAS as well as incorporate WMA technology. The Indiana mixture compares HMA–RAP, HMA–RAS, and WMA–RAS produced from an asphalt plant foaming process. The Iowa mixture uses a chemical additive WMA technology, RAP, and increasing amounts of RAS. The mixes were evaluated based on performance testing and pavement surveys.

The use of RAS in HMA has been studied and used in asphalt pavements for the past twenty years. The vast majority of research on RAS has been focused on post-manufacturer asphalt shingles and its use in HMA historically. Over the last seven years, the focus on research has moved to post-consumer asphalt shingles due in

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part to the limited availability of post-manufacturer asphalt shingles, the rise in asphalt prices and the success in the use of post-manufactured RAS in HMA pavements. It has been estimated that more than 10 million tons of asphalt shingles are landfilled every year and over sixty percent are post-consumer asphalt shingles [2]. The environmental incentive of diverting large quantities of asphalt shingles from landfills combined with the economic value of replacing virgin asphalt, aggregate, and fibers, has brought this research to the forefront for state environmental and transportation engineers.

Research has shown that the composition of RAS provides both economic value and mix properties that can enhance the performance of asphalt pavements [3]. The continuing challenges in utilizing RAS are found to be the quality control and quality assurance of the final product along with identifying mix designs that meet the requirements of specifying agencies which includes the volumetric properties of RAS for their inclusion in HMA volumetric properties. Some of the earliest published literature on the use of post-manufacturers' recycled shingles in HMA was done by Emery and MacKay [4] and although it included other recycled materials it accurately identifies the limiting factors to utilizing RAS in pavement construction today: material variability; collection, storage and processing costs; lack of technical guidance and specifications; environmental constraints; and agency conservatism. Research completed on post-manufacturer recycled shingles has found the material to perform as well or better than HMA mixes not containing post-manufacturers' RAS [5–8].

Implementation of WMA has become widespread over the past decade as more contractors utilize the technologies to take advantage of reduced mixing and compaction temperatures, reduced fuel consumption and better compatibility. There are four main categories of WMA technologies which include: chemical additives, wax additives, foamed asphalt mix-additives and foamed asphalt-plant modifications. For this study, a chemical additive derived from the forest products industry and a foamed asphalt-plant modification were studied. It is recommended that the forest products chemical additive be added at rate of 0.5% by weight of binder [9]. Foaming asphalt began in the 1950s but has more recently increased in popularity. Foaming systems use nozzles to deliver small droplets of water to foam the asphalt.

Research in the area of warm mix asphalt has found overall favorable results with its use. One area of concern for WMA is moisture sensitivity. Multiple research studies have shown that in cases where the WMA additive does not contain an anti-stripping agent, there is a reduction in tensile strength ratios in WMA compared to HMA samples. A recent study investigated the mechanical properties of plant-produced warm-mix asphalt mixtures. This study found that the WMA dosage, production temperature and binder properties all significantly affected the performance test results of the dynamic modulus and Hamburg wheel tracking tests (HWTT). Stripping inflection points (SIP) for foamed asphalt and a Fischer–Tropsch wax were found to be lower than the HMA control mixtures [10]. This reinforces the findings of earlier studies that WMA is susceptible to moisture conditioning [9,11]. In 2011, a survey sent out to the state agencies asking about the current use of WMA. The published results showed that approximately 87% of the respondents indicated that WMA was used in their state. The final question asked respondents if any moisture damage related field distresses were observed in WMA mixes and no respondents answered "yes" [12]. WMA field sections have also shown to perform well compared with HMA sections in other published literature [13–15].

Low temperature semi-circular bending (SCB) tests will be important for developing a full profile of WMA–RAS material behavior. Disk-shaped compact tension (DCT) testing is also commonly used for low temperatures. One published study showed that fracture energy measured in the SCB and DCT at low temperatures showed no significant differences by mix at the same test temperatures [16]. Another study tested samples at intermediate temperatures and correlations show that SCB is a viable way of testing WMA samples and can be correlated to other tests [17].

Many studies have proven the successful use of RAS and WMA independently of each other but only a limited number of studies investigate the performance of RAS and WMA pavements when both technologies are used within the same mix. A state-of-the-art review of the Fischer–Tropsch wax technology [18] discusses several studies in which the use of RAS and WMA have shown to provide satisfactory results in low volume roads [19,20] and in stone matrix asphalt pavements [21]. The use of WMA and RAS together can potentially decrease the amount of virgin liquid asphalt and reduce the carbon footprint by lowering production temperatures. This will lead to decreased costs while developing more sustainable highway materials. The objectives of this research are to evaluate the performance of plant produced WMA containing various levels of RAS, investigate the influence of RAS and WMA technologies on performance test results, and document pavement performance over several years of service.

2. Material information and sample preparation

Two demonstration field projects from two different states are included in this study to evaluate the use of RAS with WMA technologies at reduced temperatures. The first was an Indiana DOT demonstration project constructed on US Route 6 in August 2009. For the demonstration project, 1.5 inches of the HMA was milled and replaced with 1.5 inches of one of three experimental mix designs: an HMA control section with 15% RAP (0% RAS), an HMA test section with 3% RAS (0% RAP), and a WMA test section with 3% RAS (0% RAP). The WMA was produced using an asphalt plant modification that foamed the asphalt. Each mix design was a dense-graded 9.5 mm Superpave mixture. Aggregate proportions in the 15% RAP mix design were slightly adjusted to create a 3% RAS mix design with the same gradation as the 15% RAP mixture. The 3% RAS–WMA mixture was the same design as the 3% RAS–HMA mixture; the only difference between the two RAS mixtures was the plant temperature for the WMA mix, The average laydown temperature was lowered approximately 30°F (reduced from 300°F to 270°F) during plant foaming process. Post-consumer RAS with a 26.8% asphalt content and a high performance grade (PG) of 134.2 was used for the mix designs. A polymer modified PG 70-22 was used as the binder. A summary of the aggregate gradations and mix design properties are presented in Tables 1 and 2, respectively.

The second project was a demonstration project constructed on US 61 between Muscatine and Blue Grass, Iowa in 2010. The project was construction of new asphalt shoulders along existing Highway 61. This project used three mix designs: a 20% recycled asphalt pavement (RAP) mixture (designated as IA-0) to achieve 21% virgin asphalt binder replacement, 13% RAP and 5% RAS (designated as IA-5) to achieve 32% virgin binder replacement, and 6% RAP with 7% RAS (designated as IA-7) to achieve 29% virgin asphalt binder replacement. Production of the mixes utilized a WMA technology derived from the forest products industry and all three mixtures were produced at the reduced temperature of 121 °C (250°F). The compaction temperature for reheating samples in the laboratory was 121 °C. The aggregate gradations for each mixture are presented in Tables 1 and 2, respectively.

Laboratory performance testing was conducted on laboratory compacted samples of loose mix collected in the field during the demonstration projects. For the Iowa mixtures, the loose mix was reheated to compaction temperatures, 149 °C (300°F) for HMA samples and 121 °C (250°F) for WMA samples, split into properly sized samples and compacted using a Superpave gyratory compactor. The foamed asphalt in the Indiana mixture was reheated at HMA compaction temperatures because it is assumed the benefit of the foam is diminished for reheated asphalt mixtures. All samples were compacted to the exact dimensions needed for testing. Indirect tensile strength and HWTT analysis of the Iowa demonstration project also included core samples that were taken from the field after one year of service. Core samples were saw cut to the correct dimensions for testing.

3. Test methodology

3.1. Mix testing

Five performance tests were conducted to analyze and evaluate the performance of using RAS with WMA. High-temperature tests to evaluate the mix for rutting include flow number and HWTT. Dynamic modulus evaluates the stiffness of the mixture over a