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Low temperature rheological properties of asphalt mixtures containing different recycled asphalt materials

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Abstract

Reclaimed Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS) are valuable materials commonly reused in asphalt mixtures due to their economic and environmental benefits. However, the aged binder contained in these materials may negatively affect the low temperature performance of asphalt mixtures. In this paper, the effect of RAP and RAS on low temperature properties of asphalt mixtures is investigated through Bending Beam Rheometer (BBR) tests and rheological modeling. First, a set of fourteen asphalt mixtures containing RAP and RAS is prepared and creep stiffness and *m*-value are experimentally measured. Then, thermal stress is calculated and graphically and statistically compared. The Huet model and the Shift-Homothety-Shift in time-Shift (SHStS) transformation, developed at the École Nationale des Travaux Publics de l'État (ENTPE), are used to back calculate the asphalt binder creep stiffness from mixture experimental data. Finally, the model predictions are compared to the creep stiffness of the asphalt binders extracted from each mixture, and the results are analyzed and discussed. It is found that an addition of RAP and RAS beyond 15% and 3%, respectively, significantly change the low temperature properties of asphalt mixture. Differences between back-calculated results and experimental data suggest that blending between new and old binder occurs only partially. Based on the recent finding on diffusion studies, this effect may be associated to mixing and blending processes, to the effective contact between virgin and recycled materials and to the variation of the total virgin-recycled thickness of the binder film which may significantly influence the diffusion process.

Keywords: Reclaimed Asphalt Pavement (RAP); Recycled Asphalt Shingles (RAS); Thermal stress; Statistical comparison; Back-calculation; Binder blending

1. Introduction

Using recycled materials such as Reclaimed Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS) is a top priority in the pavement industry not only for reducing the construction costs but also for minimizing the environmental impact of road construction [1–3]. However, the aging condition and the associated brittleness of the asphalt binder contained in RAP and RAS may be a source of poorer low temperature performance for the final asphalt mixture and, eventually, affects pavement functionality and durability.

For these reasons, a number of research efforts were performed both in the U.S. and in Europe [4,5] to evaluate the effect of RAP on asphalt mixture properties with the conclusion that RAP content has a significant influence on the rheological and mechanical behavior of mixture. Spec-

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ifications were also developed in the US with recommendations for selecting RAP percentage based on traffic level up to a maximum of 40% by weight [6]. On the other hand, in Germany, several projects aimed to use much higher RAP content [7–9] with the objective of maximizing the benefits of recycled materials. More recent studies have centered their efforts in understanding and modeling the effective blending and the diffusion processes occurring at the interface between virgin and aged binder in the recycled mixtures [10,11].

Regarding the re-use of roofing asphalt shingles, two distinct byproducts are available in the market: Manufacturer Waste Scrap Shingles (MWSS) and Tear-off Scrap Shingles (TOSS), from old roofs have been exposed to solar radiation and high temperatures for extended periods of time. Both TOSS and MWSS, which are generally identified as RAS, contain a high amount of small aggregates and a much harder (i.e. stiffer) asphalt binder compared to that used in asphalt pavement mixtures. At 25 °C, the penetration values for asphalt binder in shingles ranges from 20 dmm to 70 dmm, while traditional paving binders range from 50 dmm to 300 dmm [12]. Most of the previous studies on RAS were devoted to identify the maximum amount of shingles that could be recycled in the new mixtures [12]. In the recent past, McGraw et al. [13] investigated the combined use of RAP and RAS showing the negative effect of TOSS on mixture's tensile strength and binder's critical cracking temperature. Recent European studies have also addressed the inclusion of shingles in the design of asphalt mixture [14,15]. In one of this research [15], both stiffness and fatigue properties of the recycled mixture were investigated showing an increase in mixture stiffness due to the inclusion of RAP and shingles (up to 5%).

The use of RAS in hot mix asphalt has seen increased acceptance from government agencies and road authorities, however this material poses significant challenges for pavement built in cold climates, such as northern US and northern Germany, where materials with good fracture resistance are required. This is particularly true for TOSS, which contain highly oxidized binders that are more prone to brittle failure. Similarly to RAP, specifications on the use of RAS are based on content limits (5%) with the provision that a specific percentage of new binder is used in the recycled mixture [6].

2. Research approach and scope

In this research, the addition of RAP and RAS (i.e. MWSS and TOSS) into asphalt mixtures used for pavement applications is investigated based on changes in mixture and binder low temperature properties. The experimental campaign consists of simple Bending Beam Rheometer (BBR) creep tests on asphalt mixture and corresponding extracted asphalt binder [16,17]. Creep stiffness, m-value and thermal stress of asphalt mixtures are then computed and graphically and statistically compared [18]. Then, the analogical Huet model [19–21] coupled with the Shift-Homothety-Shift in time-Shift (SHStS) transformation proposed by the research team of the École Nationale des Travaux Publics de l'État (ENTPE) [22] are used to evaluate the effect of recycled material on both asphalt binder and asphalt mixture creep stiffness. Back-calculation of the asphalt binder creep stiffness is performed using mixture creep stiffness data obtained with the Bending Beam Rheometer (BBR) [16].

The overall goal of the present research is to determine if changes in mixture behavior are due to the addition of recycled material and more specifically to the blending of new and old binder. This is obtained by comparing the back-calculated binder creep stiffness with the corresponding extracted binder obtained from the same mixture, which represents a condition of full blending. This also provides an indication of the degree of blending between the virgin binder and the aged binder present in the added recycled materials, RAP or RAS. Fig. 1 presents the schematic of the research approach followed in this study.

3. Material preparations and experimentation

Fourteen different asphalt mixtures (see Table 1) [23] were prepared for the present research effort. Three types of virgin aggregates were blended to prepare the mixtures: pit-run-sand, quarried ¾ in. (19 mm) dolostone, and quarried dolostone manufactured sand. The recycled material consisted of different amounts of RAP, TOSS and MWSS. [13]. Two plain asphalt binders having performance grade

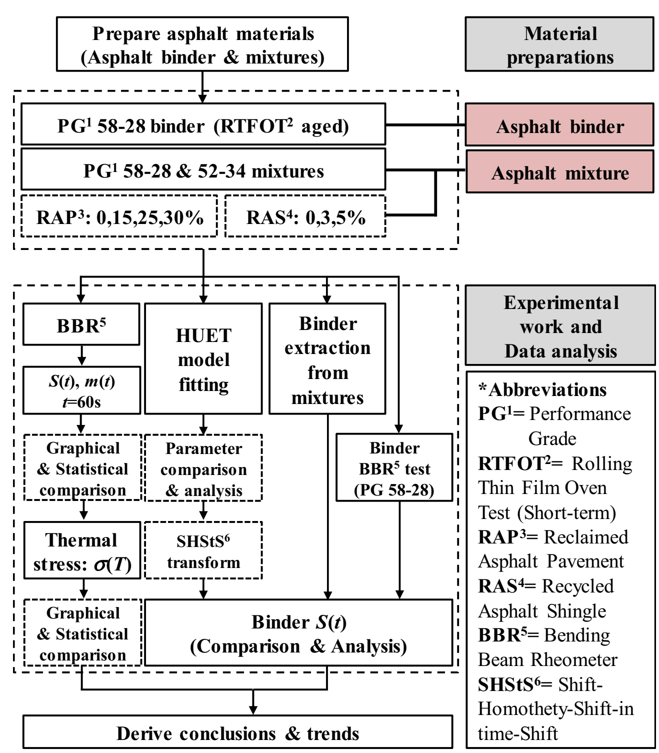

Fig. 1. Research approach.