ABSTRACT

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Degree:	Ph.D.	Department:	Civil Engineering
Thesis title: Blending of asphalt binders during recycling – a microscopic study			
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Month and Year:		February, 2023	

The present study deals with the microscopic investigation of the blending of asphalt binders. Such a blending generally happens due to diffusion and mechanical agitation during the asphalt recycling process, where virgin asphalt binder is mixed with reclaimed asphalt pavement materials (RAPM). The overall objective of the present study is to understand the blending occurring in the recycling process at the microscopic level – that is, to estimate the binder concentration at any given location and after blending has been allowed to occur for a given duration.

To achieve the above objective, different microscopic and spectroscopic techniques are employed, including, atomic force microscopy (AFM), Fourier transform infrared microscopy (FTIR), FTIR-attenuated total reflection (ATR), and confocal laser scanning microscopy (CLSM). Through preliminary trials, parametric descriptors are selected (for AFM, FTIR, FTIR-ATR and CLSM) that can distinguish between virgin asphalt binder and the aged binder (that is, binder present in RAPM). Subsequently, calibration charts are developed, for each of these probing tools, by preparing blends (with 100% blending) for known proportions of virgin asphalt binder and the binder obtained from RAPM. These calibration charts are used later to estimate the binder concentration for various experiments.

To study the blending process, three experimental setups (namely, Experiments A, B, and C) are designed, as mentioned in the following.

- In Experiment A, a setup is developed where RAPM samples, placed within the virgin binder, are stirred. High mixing temperatures and longer mixing times are allowed so as to create favorable conditions for blending to occur. In this experiment, blending occurred both due to diffusion and mechanical agitation. The extent of blending is estimated using FTIR spectroscopy. From this study, it is

concluded that even though maximum favorable conditions is provided for blending to occur, the binders could only blend partially.

- In Experiment B, a RAPM piece is placed on a glass slide with virgin binder put on both its sides, and the setup is kept at an elevated temperature for a fixed duration. In this experiment, blending occurred only due to diffusion. AFM and FTIR-ATR are used as probing tools to estimate binder concentration at different locations away from the RAPM piece. The coefficient of diffusion is estimated from the experimental results by matching it with the theoretical models for the geometry that corresponds to the experimental setup. It is found that the coefficient of diffusion increases with the increase in temperature during diffusion.
- In Experiment C, blending occurring on a laboratory-prepared recycled asphalt mix is studied. The RAPM samples, virgin aggregates, and virgin binder are mixed at elevated temperatures. In this experiment, blending occurred both due to diffusion and mechanical agitation. The recycled samples are fixed on the glass slide as thin slices for ease in observation. AFM and CLSM are used as probing tools to estimate binder concentration at different locations away from a RAPM piece. The binder concentrations at different locations are estimated. The coefficient of diffusion is estimated at those isolated locations where pure diffusion is deemed to have occurred.

While fitting a theoretical model in the blending study due to diffusion, the RAPM binder film thickness is required. Hence, a separate study is initiated, in which a micro-CT apparatus is used to estimate the effective and the adsorbed asphalt binders of the single RAPM samples (that is, for non-agglomerated RAPM samples). The results are calibrated using the volumetric studies done on RAPM samples of similar size and source. This study establishes the application potential of micro-CT in evaluating the adsorbed and effective binder contents (of single RAPM samples). The finding of the study suggests that although the effective and adsorbed binder contents depend on RAPM size, the binder film thickness is independent of the RAPM size.

The following are the contributions arising out of the present study:

- The application potential of the AFM (mechanical-based method), FTIR (chemical-based method), and CLSM (imaging-based method) are established individually for analysing binder concentration values during the blending process (due to diffusion

and/or mechanical mixing) between the aged binder (present in RAPM) and virgin binder added externally. Appropriate calibration techniques are suggested to estimate the concentration of binder at any given location for each of these probing tools. Accordingly, coefficient of diffusion values are estimated wherever applicable.

- Experimental configurations are developed to study binder blending (due to diffusion and/ or mechanical mixing) for RAPM samples and laboratory-recycled asphalt mix. With such configurations (where RAPM is used directly) possible changes in the chemistry of the binder could be avoided (which otherwise would have happened while using an artificial aging method or solvent extraction method of asphalt binder as adopted by the past researchers).
- The experimental geometry of the approaches developed is closer to the realistic scenario, and the binder present in RAPM is allowed to participate directly in the blending process.
- Experimental approach is developed to use the micro-CT technique for the direct estimation of adsorbed and effective binder film of the binder present in the RAPM.

Keywords: Asphalt recycling, virgin binder, RAPM, RAPM-binder, blending, mechanical mixing, diffusion, effective binder, adsorbed binder, binder film, AFM, FTIR, FTIR-ATR, CLSM, micro-CT.