Synopsis

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In the present work, various aspects of mix design of asphalt mix recycling in the context of hot-in-plant have been studied. In the asphalt pavement recycling process, reclaimed asphalt pavement material (RAPM), fresh aggregates, and virgin asphalt binder are mixed in certain proportions, and this recycled asphalt mix is used in pavement construction. Sometimes a suitable recycling agent (RA) is also added (primarily when a higher quantity of RAPM is to be utilized), to restore the properties of the aged RAPM binder (present in the RAPM). These recycling agents can be broadly classified as softening agents (those lower the viscosity of RAPM binder) and rejuvenators (those that recover the properties of RAPM binder and/or lower the recycling temperature). Therefore, RA could be considered as the fourth constituent in the constituent proportioning problem associated with asphalt recycling. While four constituents are possible, laboratory testing of the trial recycled asphalt mix samples made up of multiple possible combinations of the constituents, becomes a huge task. Thus, a judicious approach to estimate the constituent proportions is required that can reduce the number of experimental iterations.

At the binder level, blending of three components are involved, namely, virgin binder, RAPM binder, and the recycling agent. Limited literature is available on the ‘mixing formula’ for three-component binder blend that can be used to predict the resultant physical property of the blend, when the proportion and physical property of each of these three components are known. In the present work, a suitable three-component mixing formula based on empirical observations in the laboratory is explored. This work uses four different recycling agents separately (two softening agents and two rejuvenators), and the complex viscosity is taken as the physical property. Temperature and frequency are also included as variables to improve the robustness of the suggested equation. Subsequently, a generalized equation is developed for the prediction of complex viscosity at any given temperature and frequency.

Once the proportion of the binder components (virgin binder, RAPM binder, and RA) are estimated (using a binder mixing formulation); the proportions of the constituents (RAPM, virgin binder, fresh aggregates, and RA) of a recycled asphalt mix are obtained. The proportions (of constituents) are obtained through a set of equalities relating the known (individual properties of the constituents and the target properties of the mix/ blend) and unknown parameters (proportions of the constituents). The present study extends one of such formulations used for the conventional three-constituent mix to incorporate RA. This provides the preliminary constituent proportions.

The proportioning can be made further precise by incorporating the phenomenon of partial blending that happens between the binder components (RAPM binder, virgin binder, and RA) during asphalt recycling. For this, three cases of controlled blending situations (complete, partial, and insignificant/no blending) have been considered for the development of a scale in order to quantify the effect of blending on the strength of recycled asphalt mix. It is argued that the unavailable RAPM binder (in case of partial blending) should be accounted for in the total binder

content of the recycled asphalt mix. This correction (considering the phenomenon of partial blending) is incorporated in the binder mixing formulation. Subsequently, the final proportions are estimated using further laboratory trials (less in number than typically done in the conventional asphalt mix design) as the one giving the maximum strength. A strength-based mix design approach has been followed in the present study. Finally, the results are visualized by studying the proportions of constituents for a recycled asphalt mix against the strength of the recycled asphalt mix. The improved proportions are found to yield better results in terms of its strength. Thus, the present study proposes a systematic approach towards developing a recycled mix design method to obtain final constituent proportions efficiently.

After the recycled asphalt mix design is performed, the effect of physical parameters (namely, mixing temperature, mixing speed and duration) are studied as an experimental parametric study, and ranks are assigned. Further, the effect of material variability associated with RAPM (like amount of RAPM binder and RAPM binder viscosity) on pavement life is investigated through simulation study. This exercise enables a designer to foresee the effect of RAPM material variability.

Thus, the present study has proposed a few suggestions towards improvement of the mix design approach for in-plant asphalt recycling.

Keywords: Binder mixing rule, hot asphalt recycling, recycling agents, rejuvenator, softening agent, complex viscosity, partial blending, dynamic modulus, mixing temperature, mixing time, mixing speed, RAPM material variability, pavement analysis