Tribological and Performance Assessment of Binders Modified with Warm Mix Asphalt Additives

वार्म मिक्स डामर एडिटिव्स के साथ संशोधित बाइंडरों का ट्राइबोलॉजिकल और कार्य मूल्यांकन

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By

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CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Preamble

The present study assessed the mixing and compaction temperature of WMA technology using tribological approach. Along with this, the study also focuses on the influence of lower mixing and compaction temperatures on the performance of WMA modified binders. Two base asphalt binders (VG30 and PMB40), and four WMA additives categorized under organic and chemical technology were used to prepare the WMA modified binders. Initially, the production temperatures of WMA modified binder have been determined using tribology approach and validated using workability test, coating ability test, and compactibility test. Thereafter, the performance of WMA modified binder was analysed and compared with their respective base asphalt binders through different experimental investigations (such MSCR test, LAS test, and BBS test). Finally, the study also focuses on the selection of WMA additives and their optimum dosages according to the performance requirement of particular project or location. Four objectives were defined in this direction of the study. This chapter presents the conclusions drawn from different phases of the work, the main contributions, and applications of the study. The chapter also includes the scope and recommendations for future studies.

8.2 Conclusions

8.2.1 Physical Properties of WMA Modified Binders

- Physical properties showed that organic additives increase the stiffness of base binders while no change in stiffness is observed in case of chemical additives.
- The addition of Organic additives to VG30 binder bumps the PG grade by two intervals (from PG 70 to PG82) whereas Chemical additives do not change the grade of the binder. In case of PMB 40, organic additives bump the PG grade by one

- interval (from PG82 to PG88) whereas chemical additives do not change the grade of base binder. However, the true failure temperature for chemical additives were found to be higher than base binders.
- The FTIR spectra allows the classification of chemical additions into two groups: amine-silane based chemical additives and amine-based chemical additives. On the other hand, organic additives can be classified into two groups: wax type organic additives and amine-based organic additives.

8.2.2 Production Temperatures Using Conventional Approaches

- Viscosity based approach works well for viscosity graded binders. It fails to characterize WMA modified and polymer modified asphalt binder.
- The use of these lower MT and CT may lead to insufficient densification (field density) of the asphalt mixture, resulting in the pavement's failure.
- MT and CT of all PMBs obtained from phase angle method were appropriate and implementable in field and consistent with past studies.
- Phase angle method fails to characterize the MT and CT of organic and chemical additives.
- Criteria based on the viscosity of asphalt binder are not sufficient to describe the mechanism of WMA technology involved in reduction of production temperatures.

8.2.3 Tribology of WMA Modified Binders

- The normal load of “1N” and sliding speed of “0.3 m/sec” was found to be appropriate for characterization of WMA technology in ball-on-three plates tribology test.

- CoF was found to be a function of various tribological parameters like normal load, sliding speed, the surface roughness of plates, and temperature.
- WMA modified binders reduces the CoF indicating better lubrication as compared to base binders.
- The temperature ranges corresponding to the CoF values of 0.26 ± 0.021 and 0.33 ± 0.023, were referred to as mixing and compaction temperatures, respectively.
- The tribological approach was sensitive to WMA additives and their dosages. Chemical additives showed the maximum reduction in MT and CT (around 25^{o}C) as compared to organic additives.
- The MT and CT determined from the tribological approach were well correlated and validated with the workability approach.
- Workability study showed that the addition of WMA additives improved the workability of base asphalt binder at lower temperatures.
- WMA additives showed better coating and compactibility at lower temperatures than base binder.

8.2.4 Performance of WMA Modified Binders

- WMA technology reduces the MT and CT which reduces the aging of asphalt binders
- FTIR test results showed that WMA modified asphalt binders have lower values of carbonyl and sulfoxide indices. Thus, increases the aging resistance of asphalt binder. PMB 40 showed higher aging resistance.
- The asphalt binder with the addition of organic additives showed reduced J_{nr} value and increased recovery value (%R), thus improving rutting resistance of asphalt binder. Whereas, addition of chemical additives showed high J_{nr} value and low

recovery value, signifying adverse effect on rutting performance of asphalt binder. But combination of PMB 40 and WMA technology gives enhanced rutting performance. Despite reduced aging temperatures, all the WMA modified asphalt binders were suitable for extremely heavy traffic conditions at 40ºC and 50ºC, and showed better or equivalent grading as that of base asphalt binders at higher temperatures.

- The response of stress-strain curve of the organic-modified asphalt binders were sharper than those of the neat binders, indicating a stronger strain dependency. Conversely, chemical additives showed a lower strain dependency as indicated by broader peaks.
- The LAS test results showed that the inclusion of Rediset and Iterlow enhanced fatigue performance compared to Sasobit, Asphaltan A and neat asphalt binders. Although the increase in dosage of organic additives lowered the fatigue life, its application was still worthwhile as the cycles to failure were more than base binders at all the test conditions. It is believed that the better fatigue life of the WMA modified asphalt binders is due to their lower aging temperature.
- The bond strength was observed to be a function of aggregate type, base binder, WMA additive and its dosages.
- The bond strength results showed that adding organic additives (Sasobit and Asphaltan A) increased the bond strength due to the crystallization effect of the wax, whereas chemical additives (Rediset and Iterlow) showed negligible change, probably due to the emulsifying and surfactant action.
- The bond strength was higher for organic additives as compared to chemical additives. Considering the aggregate type, Dolomite resulted in higher bond strength, whereas Sandstone showed lower strength.

- Among all the WMA additives, Asphaltan A, Rediset and Iterlow performed better against moisture damage as the BSR value was close to 1 in most cases. Comparing different aggregate types, Sandstone showed a higher potential for moisture damage due to a higher percentage of silica (approximately>40%).
- The threshold of BSR was found to be 0.82, corresponding to 93.2% reliability. This value can be used as a pass/fail criterion for moisture damage assessment at the binder level.
- The statistical analysis showed that temperature and WMA type has significant impact on the rutting and fatigue performance parameters whereas the effect of dosages was found to be insignificant on these parameters as p-value >0.05.
- The statistical analysis for BBS test parameters showed that the aggregate type, WMA types and their dosages significantly impact dry POTS, wet POTS and BSR ($p<0.05$). The effect of aggregate type was found to be more dominant on these parameters. This indicates that the mineralogical characteristics of the aggregates greatly affect the interfacial bond between the aggregate and asphalt binder; hence, aggregate type should be chosen wisely.

8.2.5 Dosage Optimisation and Selection of WMA Additives

- Optimum dosage determined was found to be different for both the base binders as the interaction of base binders were found to be different with WMA additives.
- For VG30 as base binder S3, A2, R0.6, and I0.4 are found to be optimum dosages. On the other hand, PS2, PA2, PR0.6, and PI0.5 are found to be optimum dosages for PMB40.
- Organic additives exhibit higher ranking when rutting is primary distress whereas chemical additives exhibit higher ranking when fatigue cracking is primary distress.

For moisture damage, the WMA additive with antistripping properties exhibits higher ranking.

- In the ranking analysis, the lower rank does not mean that the additive is poor. It means that such additives should not be prioritize when better options are available.

8.3 Application of the Study

- The current guideline, IRC SP 101-2019, on the use of warm mix asphalt (WMA), is also silent on fundamental quantification of mixing and compaction temperatures. In this study, a tribology-based approach was proposed which can be successfully used to determine the production temperatures (mixing and compaction temperatures) for WMA. It is recommended to use the procedure outlined in this study as a part of IRC SP 101 for the evaluation of production temperatures of WMA.
- It is recommended to use the current tribology-based approach for determination of mixing and compaction temperatures of polymer modified binders.
- Proposed limiting values of bond strength ratio (BSR) can be used for the acceptance/rejection of asphalt binders and WMA modified binders.
- Results of the present study can be used to select appropriate WMA type and dosage for pavement construction, depending on the environment, aggregate source and base asphalt binders.

8.4 Future Recommendations

- It is recommended to used tribology-based approach for the determination of MT and CT of crumb rubber modified binder and other types of modified binder.

- The present study evaluated the performance of WMA additives at binder level. However, validation being a concern, a comprehensive mixture level and field study is essential to understand the long-term effectiveness of WMA additives.
- The effectiveness of WMA additives with reclaimed asphalt pavement materials using tribological and performance characteristics can be studied in future.
- Since WMA modified asphalt binders are exposed to reduced aging, which may also affect their low-temperature performance, thus exploring the consequences of reduced aging on the low-temperature behaviour of WMA modified asphalt binders is recommended. It is well known that the chemical functional groups of asphalt binders influence mechanical performance, especially rutting and fatigue characteristics. Future studies should also focus in this direction to correlate these performances with chemical properties of WMA modified binders.
- The present study emphasized understanding the effect of aggregate mineralogy on the bonding mechanism between aggregate and WMA modified asphalt binders. Past studies have shown that the chemical composition of asphalt binders plays an important role in the bonding mechanism. Thus, there is a need to investigate the effect of the chemical composition of base binder and WMA additives on the bond strength.
- For the future work, it is also recommended to conduct an environmental impact assessment study on the incorporation of WMA additives in different types of asphalt mixtures. This study should include calculating the carbon footprints of various mixtures and construction methods to accurately quantify the impact of WMA usage on reducing carbon emissions.