ABSTRACT

The transportation sector is the backbone of the country's economy as it facilitates the movement of people and commodities. The rapid growth in vehicular traffic demands superior performing pavements owing to which the consistent advancement in conventional road construction practices is the need of the hour. The stride rate of construction requires a massive amount of pavement materials, including fillers that constitute up to 12% of the total aggregates. This demand can be fulfilled by the exhaustive mining of reserves which causes the depletion of natural resources along with different environmental problems. In addition, strict restrictions on mining activities have made access to natural fillers a very challenging task. Also, the generation of waste from various sectors is enormous, which immediately requires an efficient disposal solution that can be tackled by utilizing waste in the form of fillers. The asphalt layer in the pavement is subjected to several types of distress, out of which fatigue is also one of the most common and severe pavement distress. It deteriorates the pavement's structural capacity and acts as a deteriorating medium for the ingression of water and other aggrasive agents. The combination of filler and binder, i.e., asphalt mastic, is often acknowledged as the actual binder which coats the aggregate skeleton in an asphalt mix as it affects the performance of mixtures against various distresses. Hence, the rheological characterization of asphalt mastics can better represent the performance of asphalt mixtures.

This study is focused on the fatigue characterization of the asphalt mastics and asphalt mixtures prepared with different fillers. A total of six different waste fillers, namely red mud (RM), marble dust (MD), limestone (LS), granite (GR), basalt (BA), and quartz (QZ) from different sectors and two types of binders viscosity graded (VG-30), polymer modified (PMB-40) were used to prepare the asphalt mastics. The fillers were characterized by different physical, chemical, and morphological tests such as Rigden voids (RV), specific gravity, particle size

distribution, specific surface area (SSA), X-ray diffraction, scanning electron microscope, etc. The mastics were fabricated at three filler volume concentrations of 10, 20, and 30%, followed by long term aging in the draft oven as per the western research institute (WRI) method. The rheological testing was done at three intermediate temperatures, 5, 15, and 25°C. The preliminary testing involves determining linear viscoelastic (LVE) limits corresponding to 95% of the initial complex shear modulus ($|G^*|$). The obtained LVE limits were compared with the Strategic Highway Research Program (SHRP) LVE criteria which were found to be inapplicable to the results of asphalt mastics.

Despite being acknowledged as one of the most accurate fatigue tests, the unpredicted testing durations during a time sweep (TS) test make it a non-feasible laboratory test method. Therefore, an alternate accelerated fatigue test known as the linear amplitude sweep (LAS) test was utilized to check its efficacy in simulating the TS test results. The dissipated energy ratio (DER) method was used as the fatigue failure criterion in the TS test, whereas the dissipated energy (DE) and pseudo strain (PSE) energy approach were used for defining the fatigue failure in the LAS test. In addition, the Superpave fatigue parameter ($|G^*|.\sin\delta$) was also compared with the results of the TS test. The TS and LAS test results were examined using correlational and ranking analysis. The power law regression was used to model the fatigue life from the TS test and the other three variables. The strong correlation and lowest discrepancy proved that the LAS test could effectively replace the conventional TS test with the PSE approach.

The drawbacks associated with conventional cylindrical parallel plate geometry motivate the researchers to search for a new geometry, due to which various alternate geometries have experimented to date. The hyperbolic geometry having a predefined failure location has been used in this study to assess its applicability as a superior alternative to cylindrical geometry. The evolution of pseudostiffness was used to examine the discrepancy in test results obtained from both geometries. The results obtained from hyperbolic geometry were more consistent, whereas abnormalities were observed in many cases with cylindrical geometry hence was adopted for the fatigue testing in this study.

This study integrated eight different variables to comprehensively understand the effect of the majority of possible factors on the fatigue performance of asphalt mastics. These factors include the type of filler, binder, filler-binder (F-B) ratio, testing geometry, temperature, type of test, analysis procedures, applied strain, etc. In addition, the efficacy of popular cracking resistance parameters known as the Glover-Rowe (G-R) parameter was also investigated. The effect of temperature was obvious because greater temperatures, regardless of any other variable, improved fatigue performance. With unmodified mastics, the influence of the filler-binder ratio was found to depend on the kind of filler, whereas the binder predominated in PMB based mastics. The filler ranking was roughly the same for both types of mastics except for RM filler. The magnitude of the applied strain significantly impacted the mastics' relative ranking since the materials' performance varied depending on the strain in the LVE, non- linear viscoelastic (NLVE), and failure region. The polymer modified binder outperformed the neat binder in terms of performance. The fatigue performance of asphalt mastics was primarily influenced by the three filler parameters fineness modulus (FM), SSA, and RV. The G-R parameter was found to be insufficient to describe the fatigue behavior.

The asphalt mixtures were prepared in accordance with Ministry of Road Transport & Highways (MoRTH-13) recommendations using dense bituminous macadam (DBM-2) gradation with the nominal maximum aggregate size (NMAS) of 26.5 mm. To avoid discrepancies in the filler content caused by the job mix formula or stockpiling method, the fractionation method was employed for the gradation. The DBM-2 recommends the filler content in the range of 2-8%; hence three filler contents, namely 3, 5, and 7%, were employed, representing low, average, and high filler content. Prior to the preparation of the mixture, the mixing and compaction temperatures of the virgin and polymer-modified binders were

measured using rotational viscometers and dynamic shear rheometer (DSR), respectively. The performance testing of the asphalt mixtures was done using the semi-circular bending (SCB) apparatus at two notch depths of 15 mm and 30 mm. The cracking resistance of the materials was quantified using the critical strain energy release rate (J_c) with a higher value referring to better performance. The similar ranking of the fillers obtained from the fatigue testing of mastics as well as mixes shows that the relative fatigue performance of the asphalt mixtures prepared with different fillers can be predicted from the LAS testing results of corresponding asphalt mastics using hyperbolic geometry. Also, the correlational analysis between the optimum filler dosage and the parameter FSR/$|G^*|.\sin\delta$ showed that the filler dosage in the asphalt mixtures could be obtained from the properties of fillers and binders, which may result in superior fatigue performance and lower optimum binder content.

Keywords: Asphalt mastic, Fatigue, Waste filler, Sustainability, Hyperbolic geometry, Dynamic shear rheometer, Linear amplitude sweep, Viscoelastic continuum damage, Semi-circular bending.