ABSTRACT

Dense bituminous macadam (DBM) and bituminous concrete (BC) are commonly used bituminous layers in base and surface courses respectively in Indian Highways. Heavy commercial vehicles coupled with high pavement temperatures induce higher stresses in BC and DBM layers resulting in premature pavement distresses such as rutting or cracking. Efforts are being made in India to improve the performance of bituminous mixes through the use of different binders with higher stiffness/hard and more elastic for the construction of highways. Bituminous mixes with improved characteristics for the base course layer will help in addressing structural failures and also helps to achieve sustainability. Therefore, it is necessary to develop a binder that is stiffer and elastic in nature with improved performance that can be used to mitigate heavy axle loads and higher temperatures.

Since the last decade, several pavement research groups around the world are adopting "Enrobe' `a Module E'leve'", which are also referred to as "High Modulus Asphalt (HiMA)" mixes. The exceptional features of EME2 mixes are that they offer high resistance to fatigue cracking and rutting failures in addition to reducing thickness requirements of bituminous layer for given design life. However, HiMA mixes require hard binders with penetration of 10/15 or 15/25. In India, binders stiffer than viscosity grade, VG40, are not commercially available and the use of composite modification (more than single modifier/additive) to produce hard binder has been not explored as these would result in a binder with all with superior resistance against distresses such as fatigue, rut resistance and higher stiffness.

Keeping the above in view, the broad objective of the present study is identified as the development of High Modulus Asphalt (HiMA) mixes using hard binder suitable for hot climatic regions as well as heavy traffic conditions for Indian highways. To achieve the objective, binders using various additives/modifiers were prepared and evaluated with a specific focus on the rheological, chemical, and physicochemical characteristics for identifying superior performing hard binders. Based on the performance of binders, the best-performing binder was selected, used for the preparation of mixes, and evaluated with a target of producing HiMA mixes. A total number of fourteen modified binders were prepared in the laboratory by blending using three modifiers such as Gilsonite, Ethylene Vinyl Acetate (EVA) and a composite blend of Gilsonite and Styrene Butadiene Styrene (SBS) at different dosages to the base binder, VG 40. In

addition, three unmodified binders (VG40, hard pitch binder-HB obtained from propane deasphaltene (PDA) refinery process and laboratory oven aged binder-OB) were also included in the present study. Physical properties such as penetration, softening point, kinematic and dynamic viscosities of different unmodified and modified binders were carried out through basic conventional tests. Further rheological properties of binders in terms of permanent deformation and cracking were evaluated. Parameters such as complex modulus (G*), phase angle (δ), G*/sin(δ), rut resistance index, non-recoverable creep compliance (J_{nr}), percent recovery (%R) from Multiple Stress Creep and Recovery (MSCR) test, stress sensitivity analysis for permanent deformation characteristics, and linear amplitude sweep (LAS) test for fatigue characteristics etc were evaluated on all binders.

Chemical alterations of binders (HB, OB, and modified binders) in their functional groups were studied using Fourier Transform Infrared (FTIR) spectroscopy. Thermal oxidation characteristics of modified binders were also discussed. Physicochemical characteristics - surface free energy (SFE) of binders was calculated through the contact angles using the Goniometer. The relationship between the rheological, chemical and physicochemical characteristics was established for all the binders. Based on the rheological and physicochemical characteristics of all modified binders, a superior performing binder suitable for producing HiMA mixes was selected. Composite modified binder - G4S3 (Gilsonite: 4% and SBS modifier: 3% blended in VG40 binder) was selected for further mix studies.

In order to develop HiMA mixes with improved performance, bituminous mixes were prepared with two aggregate gradations (DBM gradation-II and EME2 gradation) and three binders (VG40 binder, hard pitch binder-HB), and composite modified binder - G4S3). Mechanical as well as durability characteristics of HiMA mixes were evaluated for all the mixes. HB binder was collected from the Propane deasphaltene (PDA) refinery process and considered for preparing HiMA mix as binder satisfies the requirements of hard binder adopted by other countries. Bituminous mixes were evaluated for indirect tensile strength (ITS), resilient modulus (M_r) and time lag values. A M_r of range between 4000 to 7200 MPa was achieved for mixes prepared with HB and G4S3 binders measured at temperatures at 35 °C and a frequency of 1 Hz whereas the target M_r of HiMA mix was 4000 MPa. Dynamic creep test was performed on mixes and results showed that mixes prepared with stiffer binders (HB and G4S3) were

superior in rut resistance compared to other mixes. Moisture resistance of mixes was evaluated through the Tensile Strength Ratio (TSR) parameter and abrasion loss was measured for the mixes. Significant resistance was found for mixes prepared with stiffer binders. Further, the fatigue resistance of the mixes was assessed by performing Indirect Tensile Fatigue test (ITFT) at 25 °C. Composite modification of binder resulted in improved fatigue characteristics of mixes despite being stiffer mixes. Pavement analysis with HiMA mixes showed that mixes prepared with composite modifier binder (G4S3) produced lower strains and longer fatigue lives leading to a 25% to 42% thickness reduction. Bituminous mixes prepared with HB binder was considered as target mix and conclusions were drawn based on the test results. From the limited laboratory study, comprehensive laboratory based HiMA tentative specifications for Indian highways was proposed. Bituminous mixes which satisfied proposed target requirements were recommended as HiMA mixes and further for field application.

Keywords: High Modulus Asphalt (HiMA) mixes, Modifiers, Fourier Transform Infrared Spectroscopy, Surface Free Energy, Resilient modulus, Dynamic creep test, ITFT test, Moisture damage, Abrasion loss, Thickness reduction