ABSTRACT

For several decades, researchers have been striving to develop new pavement materials and improve the specifications of paving mixes and their constituents. The development of high modulus (performance) asphalt mixes (HiMA) which typically have high stiffness (modulus) values and are designed to have better rutting and fatigue performance than conventional mixes, was a major step in this direction. The binders used in these mixes are stiffer than conventional binders and are called hard grade binders (HiMA binders) and the mixes are identified as "Enrobé à Module Elevé (EME)"/ HiMA mixes. Because of their superior performance, EME mixes have the ability to reduce the thicknesses of bituminous layers for a design life.

The present study was taken up to develop and evaluate the laboratory and field performance of HiMA mixes. One hard binder (HB) produced from Propane De Asphalting (PDA) refining process and different modified binders, produced by modifying viscosity grade bitumen (VG40) using single (Ethylene Vinyl Acetate (EVA)-18) and composite (EVA-18+EVA-28) polymers, were considered for developing HiMA mixes. The rheological properties and performance of binders were evaluated by conducting temperature-frequency sweep, Multiple Stress Creep and Recovery (MSCR) and Linear Amplitude Sweep (LAS) tests using Dynamic shear Rheometer (DSR). The effect of single as well as composite EVA polymer modification on the chemical composition of binders was evaluated in this study. The thermal and aging characteristics of the binders were investigated by conducting Differential Scanning Calorimetry (DSC) and Fourier transform infrared (FTIR) spectroscopy, respectively. The bituminous mixes prepared with some of the high-performance binders were evaluated for mix characterisation and performance. Some of the HiMA mixes developed in the laboratory were used in the construction of base layers of different test sections of National Highways NH18 and NH49 and the structural performance of the field test sections was periodically monitored using Falling Weight Deflectometer (FWD). The specifications of HiMA binders and mixes developed in France were used for identifying appropriate binder and mix specifications taking into consideration the differences between the material test protocols followed in India and France.

Addition of EVA-18 or EVA-18+EVA-28 polymers to VG40 bitumen improved the stiffness and elastic nature of the binders. The peak modification index values were observed at temperatures which are smaller than the melting point temperature of EVA-18 polymer. The single and composite modified binders and HB binder had significantly better rutting resistance characteristics compared to VG40 binder. The fatigue life of the HB binder was less than that of VG40 due to the presence of higher asphaltene content in the HB binder. The fatigue life of single and composite polymer modified binders increased with increase in polymer content. Three binders: EVA-18 modified binder (7%), EVA-18 (1%) + EVA-28 (3%) modified binder and HB, were selected as high-performance binders on the basis of different performance indicators.

The heat of fusion (ΔH_f) and degree of crystallization (F_c) increased with increase in EVA-18 polymer content. Good correlations were observed between DSC test parameters and different rheological properties of binders. The polar components were found to be higher in HB binder compared to VG40. With the addition of EVA-18 and EVA composite polymers in the base binder VG40, non-polar fractions decreased and polar fractions increased. Colloidal stability of bitumen increased with the addition of EVA-18 and EVA composite polymers in base binder VG40. The colloidal stability of the binders was found to correlate with the recovery properties and fatigue lives of the binders. Further, single, and composite EVA polymer modified binders yielded two additional unique peaks in the FTIR spectra at 1240 cm^{-1} and 1740 cm^{-1} wave lengths when compared to that of base binder VG40.

The polar components of the binders were found to correlate with Indirect Tensile Strength (ITS) and Resilient Modulus (M_r) of mixes. Good correlations were observed between time lag values of mixes with binder properties such as viscosity, phase angle, fatigue life, and polar components of binders. The HiMA mixes had longer fatigue lives at all strain levels when compared to conventional mixes prepared with VG40 binder. The fatigue lives of mixes had fair to good correlation with fatigue lives of the binder, colloidal stability, Crack Tolerance Index (CT_{Index}) and time lag value of mixes. The HiMA mixes had better rutting resistance compared to the mixes prepared with conventional binder VG40. The rut depth measured using wheel tracking device had fair to good correlation with softening point, Superpave rutting parameter ($G^*/\sin\delta$), Non-recoverable creep complaince (J_{nr}) of binders, and the time lag values of mixes.

Deflection bowl parameters were found to correlate well with the backcalculated moduli values. The equivalent modulus of the combined bituminous layers obtained from the cores collected from the test sections in the different seasons were found to correlate with the backcalculated bituminous layer modulus. Based on the laboratory and field evaluation of binders and mixes, specifications were recommended for high performance/high modulus binders and mixes.

Keywords: *High Modulus Asphalt Mixes, Rheological characteristics, Ethylene Vinyl Acetate, Differential Scanning Calorimetry, Fourier Transform Infrared Spectroscopy, Indirect Tensile Strength, Crack Tolerance Index Resilient modulus, Falling Weight Deflectometer, Specifications of HiMA binders and mixes*