ABSTRACT

Asphalt pavements are highly susceptible to thermal degradation and oxidative aging, which lead to increased stiffness, reduced flexibility, and premature cracking during service life. To improve the durability and performance of asphalt binders, natural polymer modification has become an important alternative due to its environmentally friendly characteristics and potential to enhance rheological and viscoelastic behaviour. In this study, the aging performance of Pen 60/70 asphalt modified with Natural Rubber Liquid (NRL) at four concentration levels, 0%, 3%, 5%, and 7%, was evaluated through physical, rheological, viscoelastic, and chemical testing. Physical characterization showed that the incorporation of NRL decreased penetration and ductility and increased softening point, indicating improved stiffness and thermal stability. Rheological analysis revealed that NRL substantially enhances rutting resistance in both unaged and RTFO-aged conditions, with the 7% NRL binder achieving the highest G*/sin δ values. Under long-term PAV aging, however, excessive stiffness in the 7% mixture reduced fatigue resistance, whereas the 5% NRL binder provided the most balanced performance by maintaining G*·sin δ values below Superpave fatigue limits. Viscoelastic analysis indicates that the incorporation of NRL reduces both the complex modulus (G*) and phase angle (δ) in the unaged binder, suggesting enhanced elastic response and flexibility. However, oxidative aging induced by RTFOT and PAV progressively increases binder stiffness, as reflected by higher G* values, while simultaneously reducing elastic behavior due to molecular hardening. Aging ratio, Rheological Aging Index, and Aging Effect analysis confirmed that 3% NRL provides the best resistance to short-term aging, while 5% NRL offers superior durability against long-term oxidative aging. Overall, NRL modification significantly improves asphalt performance, with 5% NRL identified as the most optimal composition for achieving balanced long-term performance, 3% for short-term aging resistance, and 7% for maximizing high-temperature rutting resistance.

Keywords: Pen 60/70 asphalt, natural rubber liquid, aging performance, rheological properties, viscoelastic behavior, DSR, FTIR, oxidative aging