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Rheological investigation of asphalt binder modified with nanosilica

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Abstract

The study investigates the use of nanosilica as a potential binder modifier. Nanosilica can be produced from rice husk and silica fumes and therefore is a cost-effective and environment-friendly modifier. Different percentages of nanosilica (0%, 0.5%, 1% and 3% by weight of asphalt binder) were added to VG-10 binder in a high-speed mixer. The influence of temperature, strain rate and frequency on viscosity was evaluated. Different rheological tests like time-temperature sweeps, Superpave rutting parameter ($G^*/sin\delta$), Multiple Stress Creep and Recovery (MSCR) Test, Creep tests, and Zero shear viscosity (ZSV) tests were performed on base asphalt binder and nanosilica modified asphalt binders. The addition of nanosilica enhanced the rutting potential of the asphalt binder. Fatigue evaluation using Linear Amplitude Sweep test showed that incorporation of nanosilica arrests the micro crack nucleation and therefore enhanced the fatigue performance of asphalt binder. Nanosilica particles act as a potential heating barrier and protect the host polymeric chains of the asphalt binder, thus improving its aging resistance. Nanosilica modified binders also showed an enhanced self-healing capability.

Keywords: Nanosilica; Shear thinning behaviour; Superpave rutting parameter; MSCR; ZSV; Self-healing; Linear amplitude sweep

1. Introduction

The pavements experience diverse kinds of distresses; amongst which high-temperature rutting, intermediate temperature fatigue and low temperature cracking are the most important from the design standpoint of flexible pavements. The type and extent of these distresses are influenced by loading, axle configurations, temperature variations, mixture parameters and rheological properties of the asphalt binders. There arises a need to overcome various distresses to make the pavements more durable. There have been continuous efforts to make pavements more durable against different types of failures by using diverse kinds of asphalt modifiers [1-6]. Besides the conventional modifiers, the use of different nanomaterials like nanoclays, nanotubes, nano alumina, as asphalt binder modifiers is being explored [7-11]. High specific surface area, high functional density, and high strain resistance make nanomaterials viable alternatives for binder modification [12]. The addition of nano-sized additives improves the performance of the asphalt binder and overcomes the drawbacks of the conventional polymers such as phase separation problems, storage instability problems, low resistance to heat, oxidation and higher costs. Organo-montmorillonite (OMMT) modified asphalt binders showed higher a resistance against thermo-oxidative aging [13]. Aging resistance of CL-30B nanoclay modified binders measured by means of rheological aging index showed that addition of CL-30B nanoclay enhances the aging resistance of the asphalt binders [14]. The addition of nanoclay significantly enhances the storage stability of the polymer modified asphalt binders [15]. Improvement in aging and storage stability of asphalt binders was enhanced after the addition of nanosilica [16]. A significant improvement in the aging resistance of the SBS modified asphalt binder was observed after the addition of carbon nanotubes [17]. Carbon nanotube modified asphalt binders showed an improvement in aging resistance and storage stability [18].

Adding nanosilica to asphalt binder had a positive effect on the physical and rheological properties of the asphalt binder. The available literature has mostly concentrated on evaluating the rutting resistance of the nanosilica modified asphalt binders by utilizing Superpave ($G^*/sin\delta$) rutting parameter. Previous research based on Superpave rutting parameter($G^*/sin\delta$), showed that the addition of nanosilica enhanced the rutting resistance asphalt binders. The addition of nanosilica improves the storage modulus and elasticity of the asphalt binder, besides an improvement in aging resistance [19]. It makes the asphalt binder stiff and improves temperature susceptibility as shown by decrease in penetration and increase in softening point. An enhancement in the PG grade of the asphalt binder is also observed after the addition of nanosilica [20]. Nanosilica improves the self-healing capacity of the asphalt binders and mixes, therefore making the pavements more durable and lasting [21]. An improvement in the elastic behaviour of the asphalt binder leading to an improvement in

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