Effect of Various Nanoclay on the Reological Behavior of Bitumen

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Abstract

In this research bitumen has been modified with adding different nanoclay by melt blending with montmorillonite nanoclay (MN), expanded vermiculite nanoclay (VN) and organic rectorite nanoclay (RN). The morphology of the nanocomposites was characterized by X-ray diffraction (XRD).The binders were aged according to the thin film oven test (TFOT) and pressure aging vessel (PAV). The effect of nanoclays on the physical and aging properties of the bitumen was investigated. XRD shows that RN and MN modified bitumen's form the intercalated nanostructures, while the VN modified bitumen forms the exfoliated nanostructure. The addition of nanoclay to the bitumen increases both softening point and viscosity of the bitumen. Compared with RN and VN modified bitumen's, the MN modified bitumen shows the higher increase in softening point and viscosity as well as the low temperature ductility. As a result of TFOT and PAV aging, the mass change rate and viscosity aging index of the bitumen are decreased due to the introduction of nanoclay, indicating the good aging resistance of nanoclay-bitumen nanocomposites. MN has more pronounced improvements in aging resistance of bitumen in comparison with RN and MN modified bitumen's due to the formation of exfoliated structure.

Keywords: modified bitumen, reological behavior, nanoclay, nanocomposites, aging.

1. Introduction

Bitumen has been widely used as the binder of aggregate in road pavement due to its good viscoelastic properties (Loeber et al., 1998). However, the increasing demands of traffic on road building materials in recent years have resulted in a search for binders with improved performance relative to normal penetration grade bitumens. Furthermore, bitumen is prone to become hard and brittle from volatilization of light ends, oxidization, and possibly polymerization when exposed to heat, oxygen, and ultraviolet light during production and storage of pavement mixtures, and during their transportation to the construction site and during subsequent placement of the mixture in the pavement (Lamontagne et al., 2001; Zhang et al., 2005; Wu et al., 2009).

Consequently, more and more modified bitumens are used in road pavement. For more than 15 years, polymer/layered silicate (LS) nanocomposites have attracted the interest of polymer and materials scientists in filled polymers. The main clay include montmorillonite (MN), rectorite (RN), vermiculite (VN) and kaolinite clay. Indeed, with tiny amounts (usually less than 5 wt%), the addition of clay and its ultimate dispersion as 1 nm-thick nanolayers in a polymer matrix allow many properties, such as stiffness, fire resistance, fluid and gas barrier properties, to be increased (Peeterbroeck et al., 2005). However, the interlayers of layered silicate are hydrophilic, and the interlayer spacing is small. This makes the polymer chains insertion into its interlayers difficult (Ahmed and Nehal, 2005.). To increase the ease of insertion, layered silicate is commonly exchanged with organic cations, particularly alkylammonium ions, making the layered silicate become lipophilic, and the interlayer spacing is enlarged. This results in easy insertion (Gultek et al., 2001). It has been found that the nature of the organic modifiers has an obvious effect on the morphology and properties of the nanocomposites (Wan et al., 2003).

Recently, nanoclays have been used to modify bitumen. More attention of the researchers has been paid to MN modified bitumen. It has been found that physical properties, rheological behaviors and aging resistance of bitumen and polymer modified bitumen could be obviously improved due to barrier properties of MN (Yu et al., 2007; Polacco et al., 2008; Zhang et al., 2011; Jahromi and Khodaii, 2009). However, there is a little report on the effect of different nanoclays on the properties of bitumen. In this paper, three