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Effects of a surfactant-wax based warm additive on high temperature rheological properties of asphalt binders

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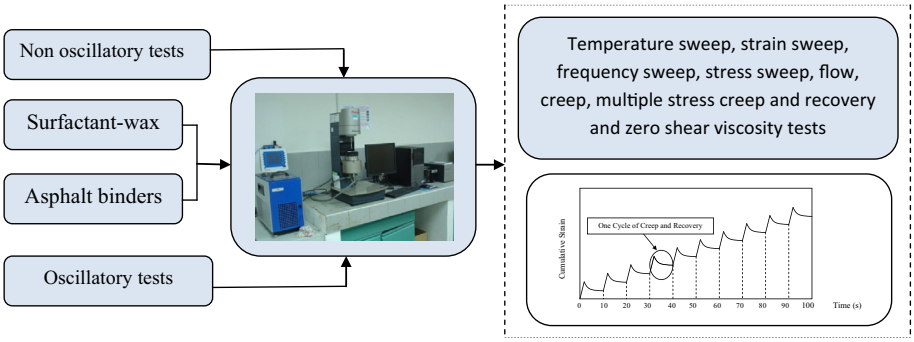
HIGHLIGHTS

- Binder type affects the performance of surfactant-wax warm additive.
- Some of DSR tests show different results for surfactant-wax warm binders.
- Trust in one type of rheological test at high temperatures is questionable.

GRAPHICAL ABSTRACT



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ABSTRACT

Asphalt binders and mixtures are more susceptible to permanent deformation at high temperature. The Dynamic Shear Rheometer (DSR) test results have been extensively used to evaluate the effects of wax and foamed warm additives on asphalt binder properties at elevated temperature. Wax based additives improve the rheological properties of the binders at high temperatures, while foamed based additives exhibit no significant effects on binder rheology. However, the literature reports contradictory effects of surfactant-wax warm additive named Rediset, on binders and mixtures propertiesat high temperatures. Some studies reported positive effects, while others found otherwise. This paper evaluates the effects of binder type, additive content and loading type on high temperature properties of warm asphalt binders incorporating Rediset on temperature, strain, frequency and stress sweep tests as well as flow, creep, multiple stress creep and recovery and zero shear viscosity test results. The results showed that the effects of Rediset depended on binder type, additive content and loading type. It implies that the chemical composition of different dosage of this warm additive with various binder types, directly affect the performance of binders subjected to various loading types at high temperatures. Hence, simply relying on one type of shear loading in the DSR test for evaluating the high temperature properties of binders incorporating a surfactant-wax additive, can lead to erroneous conclusions.

1. Introduction

The DSR test results that evaluates the effects of Rediset on the properties of asphalt binders at high temperatures appears conflicting. According to Shi et al., Doyle et al. and Xiao et al., addition of Rediset improves binder dynamic viscosity, Superpave rutting

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factor ($G^*/\sin\delta$) and Superpave high failure temperatures, respectively [1–3]. On the other hand, Zaumanis and Haritonovs, Benert et al. and Kim et al. reported no significant effects of Rediset on high temperature binder properties [4–6]. Also, Tsai and Lai, Mcbroom and Hainin et al. reported the negative effects of Rediset on the DSR test results [7–9]. The inconsistent results were more evident when it comes to the softening point tests results [10]. On the other hand, several studies and experience on the performance of asphalt pavements showed that the Superpave system needs improvement for better characterization of modified binders [11]. According to Marasteanu et al., the use of DSR test results to determine the Superpave rutting factor may not be accurate for prediction of permanent deformation of asphalt mixtures [12]. Hence, a detailed characterization of asphalt binders' properties containing various amount of Rediset at high temperature under different shear loads is necessary. Since warm mix asphalts (WMA) are more prone to rutting deficiency at high temperatures, it is believed that the results of this study can provide useful information on prediction of the real performance of WMA. The results can also be used as a database for future works to upgrade and develop new warm additives to suit high temperature conditions. The study aims to evaluate the changes in properties of asphalt binders incorporating Surfactant-wax additive named Rediset at high temperature when subjected to several shear loading conditions using the DSR as highlighted in Fig. 1.

2. Materials and methods

2.1. Materials

A 80/100 penetration grade asphalt binder with Superpave high failure temperature equal to 64 °C and a 60/70 penetration grade asphalt binder with Superpave high failure temperature equals to 76 °C, were selected for blending with a surfactant-wax warm additive. The 80/100 binder was an unmodified conventional binder, while 60/70 binder was a polymer-modified asphalt binder using styrene butadiene styrene (SBS). Some engineering properties of binders are shown in Table 1. Rediset WMX 8018 from AkzoNobel was chosen as a chemical warm surfactant-wax additive. This additive is a combination of surfactants and organic additives [10]. As adhesion promoter, surfactants can improve the aggregate surfaces wetting potential with binder, while the other components help to reduce binder viscosity. Some physical and chemical properties of the Rediset are presented in Table 2. Hamzah and Golchin found out that Rediset WMX 8018 can also decrease the mixing and compaction temperatures of asphalt mixtures [13].

Table 1
Properties of Asphalt Binders.

Aging condition	Properties	Asphalt binder	
		80/100	60/70
Un-aged binder	Viscosity at 135 °C (Pa.s)	0.38	1.66
	Softening point (°C)	45	69
	Penetration (0.1 mm)	80	60
	Ductility (cm)	>100	90
	Flash point (°C)	331	344
	$G^*/\sin\delta$ at 64 °C (Pa)	1653	–
	$G^*/\sin\delta$ at 76 °C (Pa)	–	2374
Short-term aged binder (RTFO)	$G^*/\sin\delta$ at 64 °C (Pa)	2442	–
	$G^*/\sin\delta$ at 76 °C (Pa)	–	3968
Long-term aged binder (RTFO + PAV)	$G^*(\sin\delta)$ at 25 °C (MPa)	2.58	5.41

Table 2
Physical and chemical properties of the additive [10].

Properties	Value/description
Physical state	Solid
Color	Brown
Odor	Amine like
Composition	Long chain aliphatic hydrocarbon structure and an $-NH3^+$ group
Solubility in water	Insoluble in cold water
Flash Point	>150 °C
Melting point	85 °C

2.2. Sample preparation

Asphalt binders, 80/100 and 60/70 were respectively heated to 130 °C and 180 °C for blending with warm additive. Warm additive at 0, 1, 2, 3 and 4% was blended into the binders using a propeller mixer for 30 min at 60 rpm. Rediset is easily dissolved in the hot asphalt binders [10]. Temperature sweep, strain sweep, frequency sweep, flow, creep, stress sweep and zero shear viscosity tests were performed on unaged asphalt binder samples with 1 mm thickness using the DSR. Parallel plates with 25 mm diameter were used for performing the tests. The multiple stress creep and recovery tests were conducted on short-term aged asphalt binders according to ASTM D7405 procedures [14]. The procedures mentioned in ASTM D2872 were used for short-term aging of asphalt binders [15].

2.3. Test procedures

High temperature properties of binders can be evaluated using the DSR machine based on parameters such as dynamic modulus

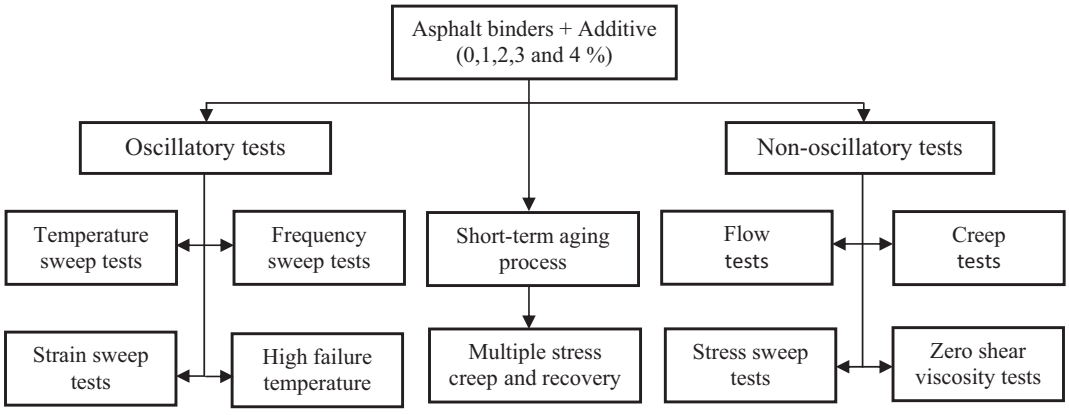

Fig. 1. Flowchart of Reserch.