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Effectiveness of Linear Amplitude Sweep (LAS) asphalt binder test in predicting asphalt mixtures fatigue performance

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HIGHLIGHTS

- The discrepancy between G*sinδ and the LAS test rankings was fairly high.
- LAS and FBB ranked the asphalt binders and asphalt mixtures exactly the same.
- G*sinδ parameter is not an effective indicator of mixtures' fatigue performance.
- Binder test should be conducted at the corresponding strain levels of the mixture.

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ABSTRACT

In this research, Linear Amplitude Sweep (LAS) test was conducted on several asphalt binders modified by different percentages of gilsonite and Styrene-Butadiene-Styrene (SBS) polymer. Asphalt mixtures were also made from some of the study binders and tested for fatigue resistance using Four-point Bending Beam (FBB) fatigue test. The results showed that a strong correlation exists between LAS and FBB rankings at all the tested strain levels. Also, SHRP binder fatigue index (G*sinδ), as a traditional binder fatigue index, was evaluated which did not show a strong correlation with either LAS or FBB tests. It was concluded that LAS test seems to be an effective binder fatigue test in predicting asphalt mixtures' fatigue performance.

1. Introduction

There are three main defects in asphalt pavements namely, moisture susceptibility, rutting, and fatigue cracking [1–4]. Fatigue cracking is one of the major distresses of flexible pavements which usually appear in the form of alligator cracking on the surface of pavement caused by repetitive stresses and strains due to traffic loading and environmental factors [3,5–7]. Fatigue behavior of asphalt mixtures is affected by many factors such as loading, environmental conditions, mixtures characteristics, binder and aggregate characteristics, etc. It is reported that from the mixture components, binder plays the most important role in fatigue behavior of asphalt mixtures [8–11]. Hence, it is important to find a promising test method for evaluation of asphalt binder fatigue performance.

The search for finding a time and cost-effective method for evaluating asphalt binder fatigue performance is an on-going effort. The G*sinδ fatigue index, which was introduced as an asphalt binder fatigue criterion during SHRP program, has received considerable criticism as it does not account for the traffic and pavement structure [10,12]. During the NCHRP 9–10 Project, the time sweep test, at which specimen is subjected to a repeated cyclic loading using Dynamic Shear Rheometer (DSR) until a specific criterion such as stiffness level is met, was introduced. Although time sweep test was proved as a reliable test method for asphalt binder fatigue evaluation, it was questionable due to its long-lasting testing time [10,13,14]. In response to this issue, additional investigations started to find a more time effective asphalt binder fatigue test method which led to the Linear Amplitude Sweep (LAS) test [15]. The LAS test was introduced by Bahia and his associates as a

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promising time-saving test to estimate the binder fatigue performance [16]. Moreover, the results of the LAS test have correlated fairly well with Long-Term Pavement Performance (LTPP) field fatigue cracking data [17].

The LAS test results are analyzed using Viscoelastic Continuum Damage (VECD) model principles. The VECD model has been successfully used for characterizing fatigue performance of asphalt mixtures by many researchers [18–25]. This method predicts the damage growth in asphalt mixtures based on Schapery's elastic-viscoelastic correspondence principle and the work potential theory [17]. However, the use of this model for predicting asphalt binders fatigue performance has encountered a number of problems such as duration of test methods as well as difficulties in analyzing the results when modified binder is used. These problems were solved in the LAS testing method [17].

Although many researchers have investigated the asphalt binder fatigue test methods, a few numbers of literature have compared the effectiveness of G*sinδ fatigue index and LAS test in estimating the mixture fatigue performance. In addition, asphalt binders with a wide range of stiffness were not always used in these studies. In 2013, Zhou et al. [12] investigated the G*sinδ parameter, elastic recovery, Multiple Stress Creep Recovery (MSCR), LAS, and the Double Edge Notch Tension (DENT) asphalt binder fatigue tests on six different binders and compared the results with the push-pull asphalt mixture fatigue test of corresponding mixtures. They confirmed the poor performance of G*-sinδ parameter and also claimed that neither the MSCR nor the LAS test methods show good correlation with asphalt mix fatigue performance. However, the DENT and elastic recovery test methods could provide the same ranking as the asphalt mix fatigue test [12]. In 2012, Clopotel et al. [26] employed the LAS and the Single-Edge Notched Beam (SENB) tests to investigate the correlation between the binder and mixture fatigue behavior at intermediate and low temperatures and found a fairly good correlation between them.

In this research, to study the effectiveness of LAS test in predicting fatigue behavior of asphalt mixtures containing binders with a wide range of stiffness, neat binders as well as SBS and gilsonite modified binders were employed and the correlation between LAS and G*sinδ as binder fatigue parameters was investigated. In addition, FBB test was conducted on selected asphalt mixtures and the correlations between binder fatigue parameters with FBB test results were studied to better understand their effectiveness in predicting the fatigue behavior of asphalt mixtures.

2. Materials

2.1. Binder

In this study, neat PG 58-22 and PG 64-22 binders were used as base binders. The base binders were then modified with 4%, 8%, and 12% of gilsonite, and 3% and 5% of SBS to provide 12 different binders. Table 1 shows the physical properties of the neat binders.

Table 1
Properties of neat asphalt binders.

Test	Standard	PG 64-22	PG 58-22
Viscosity Test at 135 °C (cSt)	ASTM D113	376	291
Penetration Test (0.1 mm)	ASTM D5	66	94
Ductility Test (cm)	ASTM D113	100	100
Softening point (°C)	ASTM D36	49	45
Flash point (°C)	ASTM D92	332	334
Specific Gravity	ASTM D70	1.02	1.01
Soluble in trichloroethylene	ASTM D 2042	99.8	99.7

2.2. Additives

Gilsonite and SBS polymer were used for binder modification in this research. Gilsonite is a natural resinous hydrocarbon that has been used as a modifier in asphalt binders and mixtures. It exists in great volume in some countries such as Iran, USA, Trinidad, etc. Gilsonite modified binders are usually stiffer than the neat binders with low penetration and high viscosity. It either can be blended with hot asphalt binder or be blown directly into the mixer with aggregates [27]. It is reported that using gilsonite as an additive in asphalt binders can improve its high and intermediate temperature performance [28,29].

Table 2 shows the physical and chemical properties of the gilsonite used. To produce gilsonite modified binders, first, the neat binder was heated to 140 °C then the predetermined amount of gilsonite was added to the binder and mixed at 150 rpm for 15 minutes with a high shear binder mixer. Next, the speed increased up to 4500 rpm for 30 minutes to make the binder more homogeneous. Gilsonite modified binders were produced at gilsonite contents of 4%, 8%, and 12% by weight of the binder. Fig. 1 shows the gilsonite used in this study.

The other binder modifier used in this study was SBS which is a triblock copolymer that is usually used for improving the engineering properties of asphalt binders. SBS modified binder has shown enhanced properties at high, intermediate, and low temperatures [30–32]. In this study, in order to obtain a homogeneous binder, 3% and 5% of solid SBS copolymer were mixed with the binder at 170 °C using a high shear stirrer at 3000 rpm for 2 hours [33].

Table 2
Properties of gilsonite used in this study.

Test	Standard	Gilsonite
Carbon content (%)	ASTM D5291	22/85
Hydrogen content (%)	ASTM D5291	43/6
Nitrogen content (%)	ASTM D5291	77/0
Oxygen content (%)	ASTM D5291	59/1
Sulfur content (%)	UOP 864	09/3
Solubility in CS2 (%)	ASTM D4	99
Moisture content (%)	ASTM D3174	0
Specific gravity @ 25 °C (g/cm3)	ASTM D3289	05/1
Ash content (%)	ASTM D3174	24/2
Color		Brown

Fig. 1. Gilsonite used in this study.