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Relationship between Elastic Recovery and Linear Amplitude Sweep as Asphalt Binder Fatigue Tests

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ABSTRACT

Elastic recovery is a new performance test that shows the fatigue behavior of pure and modified binders. Results of Researches show a strong correlation between elastic recovery test and other fatigue tests on asphalt binders and mixes. This test requires great precision in sample preparation, timing and temperature control during the test. Many researches have been done to simulate and predict the fatigue performance of binders. In this paper, the relationship between the Linear Amplitude Sweep (LAS) and elastic recovery test results was studied. For this purpose, four types of pure and ethyl vinyl acetate (EVA) modified binders were used as laboratory specimens. The LAS test outputs were analyzed using the viscoelastic continuum damage method and compared with the results of elastic recovery test. The results showed the LAS test could be employed as a more accurate and less time consuming test in order to predict the fatigue performance of the asphalt binders.

KEYWORDS: Elastic Recovery Test, Linear Amplitude Sweep Test, Fatigue, Performance Test, Binder.

1. INTRODUCTION

These days as the technology develops, researchers are looking for more accurate and less time consuming tests to predict the performance of asphalt binders and mixtures. Elastic recovery is a newly developed binder test for evaluation the binder fatigue life and many researchers have employed this test to investigate the fatigue performance of neat and polymer modified binders [1-3]. Extensive researches have been done to investigate the correlation between the Elastic recovery and other binder fatigue tests and a strong correlation between Elastic recovery and other fatigue tests has been reported [4-6]. This test requires much accuracy on time and temperature monitoring during test procedure and the time required for the test is 2 hours.

Due to the developments achieved in determining the rheological properties of binders using the Dynamic Shear Rheometer (DSR), trying to get a new test to simulate the fatigue behavior with use of this device is in progress. Clopotel and Bahia in 2012 introduced a new test method to simulate the bitumen elastic recovery test. The results indicated a strong correlation between the tests with a R^2 value of 0.999 [7]. The LAS is a newly developed test method that predicts the fatigue behavior of binders with a good correlation [4]. The time required for conducting the LAS test is about 10 minutes.

In this study four different binder types (60-70, 85-100, 60-70 EVA modified and 85-100 EVA modified) were used to investigate the correlation between the LAS and elastic recovery tests.

2. ATERIAL AND METHODS

2.1. Binder

In this study, the 60-70 and 85-100 penetration graded binders were provided from Pasargad Oil Company. The properties of binders are presented in tables 1.

2.2. Binder additive

Ethyl Vinyl Acetate (EVA) is a copolymer of Ethyl and Vinyl acetate. This polymer performs like elastomers in terms of softness and flexibility and performs like thermoplastic materials in terms of workability. The properties of EVA used in this research are presented in Table 2. According to the manufacturer recommendations 4% EVA was mixed with pure bitumen at the temperature of 180°C using low shear mixer. The mixture was blended for 2 hours.

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. **Table 1.** Properties of 60-70 and 85-100 penetration grade binders

Test	Standard test	60-70	85-100
Specific gravity (gr/cm^3)	ASTM D70	1.019	1.01
Kinematic Viscosity (cSt)	ASTM D88	349	244
Penetration Test (dm)	ASTM D5	61	87
Ductility Test (cm)	ASTM D113	>100	>100
Softening point (°C)	ASTM D36	50.2	46.8
Solubility in Trichloroethylene (%)	ASTM D2042	99.53	99.89
Flash point (°C)	ASTM D92	288	263
RTFO aged penetration (dm)	ASTM D5	40.1	74.8

Table 2. Properties of EVA

VA content (%)	Density (g/cm^3)	Melt Index (g/10min)	Melting Point (°C)	Vicat Softening Point (°C)	Tensile Strength At Break (Kg/cm^3)	Elongation at Break (%)
19	0.940	150	81	44	74	800

3. Experimental Program

3.1. Rolling Thin-Film Oven (RTFO) test

The RTFO test was conducted on the specimens produced with neat and EVA modified binders according to AASHTOO T-240. The aged binders then were used to conduct elastic recovery and the LAS tests.

3.2. Elastic recovery test

The elastic recovery test was conducted according to AASHTO T-301-99 on aged binders using the ductility test devise at 25°C. The specimens were pulled apart at a rate of 5 cm/min and held after a specified elongation. The specimens then were kept at constant temperature for 1 hour to recover. After completing the test the length of the binder was measured and recorded. The recovery percentage was calculated using equation 1.

Recovery percentage $= \frac{20-x}{20} \times 100$ (1)

Where

x is the final length of the binder (cm)

3.3. The LAS test

The LAS test was conducted on RTFO aged binders using the Dynamic Shear Rheometer (DSR) apparatus according to AASHTO TP-101. The samples are prepared using a 8-mm parallel plate geometry with a 2-mm gap setting. The LAS test consists of 2 phases. Firstly, a frequency sweep test is employed at constant stress level of 0.1% to obtain information about undamaged material properties. This phase includes applying oscillatory shear loading at constant amplitude over loading frequencies of 0.2, 0.4, 0.6, 0.8,1,2,4,6,8,10,20 and 30 Hz. The rheological information of binder including G^* and δ are recorded at each frequency. The α parameter which is related to undamaged material characteristics is then calculated by equation 2. In the second phase, an amplitude sweep test is conducted immediately after the nondestructive frequency sweep test in first phase. This test is run at the selected temperature at frequency of 10 Hz. The loading scheme consists of 10-s intervals of constant strain amplitude. Each interval consists of 100 load cycles and the strain amplitude at first interval is 1%. The strain amplitudes increase by 1% at each consecutive interval until the strain amplitude reaches 30%. The test results are analyzed using viscoelastic continuum damage theory (VECD) which is extensively used for characterizing the binder and mixture fatigue performance [8]. The damage characteristics of the materials are measured to predict the fatigue performance parameter of the binder using equation 3. The time required for preparing the test devise and conducting both tests is about 10 minutes.

$\alpha = 1 + \frac{1}{m}$ (2)

$N_f = A(\gamma_{max})^B$ (3)

Where: α is the undamaged material parameter; m is the slope of the best-fit straight line that is applied to a plot with log ω (frequency) on the horizontal axis and log G'(ω) (storage modulus) on the vertical axis; N_f is the fatigue performance parameter; A and B are binder fatigue performance parameters and γ_{max} is the maximum expected binder strain for a given pavement structure (%).

4. RESULT AND DISCUSSION

4.1 Elastic recovery and the LAS test results

Elastic recovery test was conducted on RTFO aged and unaged binders. Two tests were conducted for each binder type and the averages of the results are presented in Table 3.

As presented in table 4, the elasticity of the binders enhances by adding EVA. This performance is due to the crystallization of three-dimensional networks within the EVA modified binder [9]. The same trend is seen for aged binders. It is also seen that the recovery percentage of the softer 85-100 binders are higher that stiffer 60-70 binders.

The results of the LAS test conducted on RTFO aged binders at 25℃. The results calculated for 2 strain values (2.5% and 5%) are presented in table 4. The VECD method was used to analyze the results. It is seen that the results of the LAS test are quite compatible with the results of Elastic recovery test. The fatigue performance of EVA modified binders are higher than neat binders and it is also seen that the effect of EVA on 85-100 penetration binders is much more than 60-70 penetration binders.

Table 3. Elastic recovery test results

Specimen	60-70 neat	85-100 neat	60-80 modified	85-100 modified
Recovery for unaged binder (%)	0. 11	0.17	0.41	0,54
Recovery for aged binder (%)	0,05	0.07	0.31	0.38

Table 4. The LAS test results

Specimen	60-70 neat	85-100 neat	60-80 modified	85-100 modified
A Value	1.546E4	1.546E4	1.009E5	3.851E5
B Value	-2.857	-2.999	-3.365	-3.664
$(N_f)_5$	194	333	449	1058
$(N_f)_{2.5}$	1315	2664	4626	13415

4.2. The correlation between tests

Figure 1 shows the results of elastic recovery for aged binders versus the logarithm of the fatigue parameter resulted from the LAS test. The fatigue performance parameter was calculated for different strain levels in order to make a better estimation of the correlation between the tests. The strain levels were chosen according to the changing procedure of the R^2 value. As it is shown in Figure1 and table 5, there is a significant correlation between the LAS and elastic recovery test results and as the LAS test is more accurate and less time consuming, it can be a better method to predict the fatigue performance of asphalt binders. It is noteworthy that the R^2 value increases by decreasing the strain level used for calculating the fatigue performance parameter.

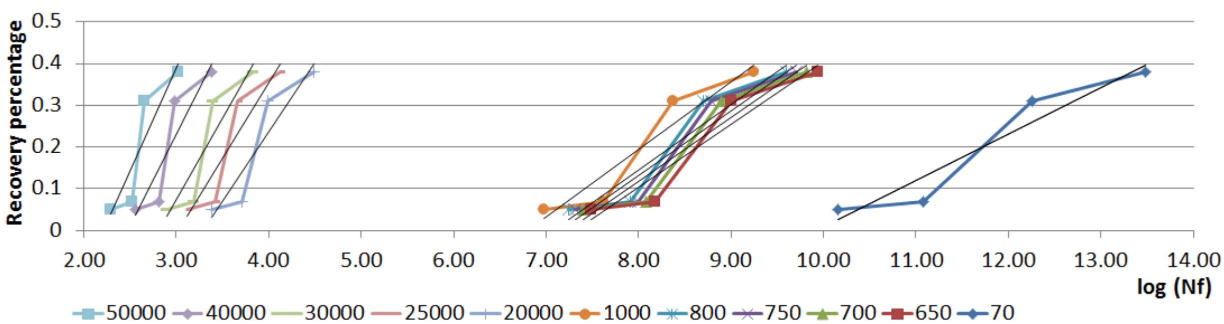

Figure 1. Elastic recovery test results for aged binders versus the LAS test results

Table 5. Relationship between elastic recovery and the LAS test results calculated for different strain levels

Strain Level used in calculation of N_f	Fitted line equation	R^2 value
5000 microstrain	y = 0.4884x - 1.078	0.8078
4000 microstrain	y = 0.4398x - 1.0871	0.8262
3000 microstrain	y = 0.3893x - 1.0944	0.8438
2500 microstrain	y = 0.3627x - 1.0974	0.8525
2000 microstrain	y = 0.3345x - 1.1001	0.8614
1000 microstrain	y = 0.1624x - 1.1053	0.9072
800 microstrain	y = 0.1564x - 1.1052	0.9086
650 microstrain	y = 0.1512x - 1.1051	0.9097
70 microstrain	y = 0.1112x - 1.1036	0.9184

5. CONCLUSION

Linear amplitude sweep test is a new test for characterizing the fatigue performance of binders. The test is accurate and its procedure is automatic. The sample preparation is also accurate and quick and the test is conducted in high precision temperature control. The analysis of the LAS test results using VECD clearly shows the damage growth in binders and also the fatigue behavior of asphalt binders.

In this research four different types of binders were chosen to investigate the relationship between elastic recovery and the LAS tests. The LAS test results were calculated using different strain levels and for each strain level a regression relationship between the LAS and elastic recovery tests was introduced. The results indicated that there is a significant correlation between the LAS and elastic recovery tests and the LAS test can be used as a more accurate and less time consuming test for characterizing the fatigue behavior of asphalt binders instead of elastic recovery test.

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