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Effect of Rest Period on the Fatigue Life of Asphalt Concrete

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ABSTRACT: *Fatigue damage is caused by the repeated traffic-induced horizontal strain at the bottom of Asphalt Concrete (AC). In laboratory, this damage is simulated by applying sinusoidal loading without any gap between loads. However, in real highways, there is always some gap between loadings. Investigating the fatigue behavior of AC at different rest periods is essential to understand the effect on gap between traffic in highway. This study investigates the fatigue life of AC under different rest periods using Four-Point Bending (4PB) test apparatus. Beam fatigue tests were conducted at 600 micro strains at 20 °C at a loading frequency of 10 Hz, and fatigue lives were determined. Results show that fatigue life increases (in other words, fatigue damage decreases) polynomial with rest period because of the healing capacity of asphalt material. This result can be used to model the healing function of asphalt concrete.*

Keywords: *Asphalt concrete; Fatigue damage; Rest Period; Stiffness*

I. INTRODUCTION AND PROBLEM STATEMENT

Fatigue cracking is one the most common forms of distresses in flexible pavement. It happens due to the repeated tensile strain at the bottom of Asphalt Concrete (AC) caused by the traffic loading. The integrity of the asphalt concrete material starts losing with the initiation of microcracks upon applying repeated traffic loading. These microcracks coalesce to form macrocracks under further traffic loading and finally lead to pavement failure. The fatigue behavior of hot-mix asphalt (HMA) has been characterized by Four-Point Bending (4PB) fatigue test in the laboratory by many researchers in the past [1–2]. In this test, an AC beam is subjected to repeated bending in strain-controlled mode until the stiffness is decreased by 50% of its initial stiffness, which is the traditional failure criteria. There are several factors which might affect the test results in the fatigue test. The effect of loading pattern (haversine and sinusoidal) and rest period between loading of the fatigue test has been widely explored in the literature [1–6].

American Association of State Highway Transportation Officials (AASHTO) defines fatigue failure as the number of cycles at which stiffness of material decreases by 50% [7]. Initial stiffness of a beam is measured at the 50th cycle of loading to account for the initial setting of the beam. However, one might expect stiffness reduction from the first cycle itself especially at higher strain amplitude. Other researchers have used dissipated energy to model fatigue behavior [8–10]. Dissipated energy is defined as energy lost to the system during each cycle of loading. Energy loss is due to damping, viscoelastic effects and damage growth. On the other hand, the Viscoelastic Continuum Damage (VECD) approach has shown promising results in terms of robustness and efficient utilization of available resources [11–12]. In addition, the test is typically performed at several temperatures to evaluate the effect of stiffness on the fatigue life, since the stiffness of AC is largely affected by temperature.

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The above discussion clarifies that the fatigue damage of AC has been widely explored by the researchers. The loading pattern, failure criteria and the effect of temperature are well known. However, the effect of rest period between loadings is still an unknown issue. However, there is gap between traffic in our highways. Therefore this study investigates the fatigue life of AC for different rest periods.

II. LABORATORY TESTING AND RESULTS

Plant produced asphalt mixture was used to prepare the samples and the mix was collected from a construction site in cooperation with New Mexico Department of Transportation (NMDOT). This is a widely used dense graded Superpave (SP) mix, type SP-III with the maximum aggregate size of 25 mm. The mixture contained 35% Reclaimed Asphalt Pavement (RAP) materials. Performance Grade (PG) binder, PG 76-22 was used an amount of 4.4% by the weight of the mixture. About 5% of materials passed through the No. 200 sieve size (0.075 mm).

Fig. 1 shows the preparation of the beam sample in the laboratory. As a first step, beam slabs of 450 mm x 150 mm x 75 mm were prepared using kneading compactor as shown in Fig. 1(a). Prior to the compaction, the mixture was oven heated for less an hour. Then, each slab was cut into two beams of 380 mm x 63 mm x 50 mm using a laboratory saw as shown in Fig. 1(b). The air voids of the samples ranged from 5.1% to 5.6% with an average value of 5.3%.

(a) Compacted mixture

(b) Cutting the slab to prepare beam sample

Figure 1. Sample preparations

Beam fatigue tests were conducted using a sinusoidal waveform with no rest period at different strain levels, temperatures and frequencies. The support conditions and the geometry of the sample followed the requirements of AASHTO T 321-07 test protocol [7]. The test program is shown in Fig. 2(a) where a sample has been clamped for testing. The middle two clamps are loading frames which apply downward and upward force to attain the predefined strain in sample. Using the deflection history, the maximum strain and stress in specimen can be calculated using Eq. 1 and Eq. 2 respectively.

$$\varepsilon = \frac{12\,h\,\delta}{3L^2 - 4a^2} \qquad (1)$$

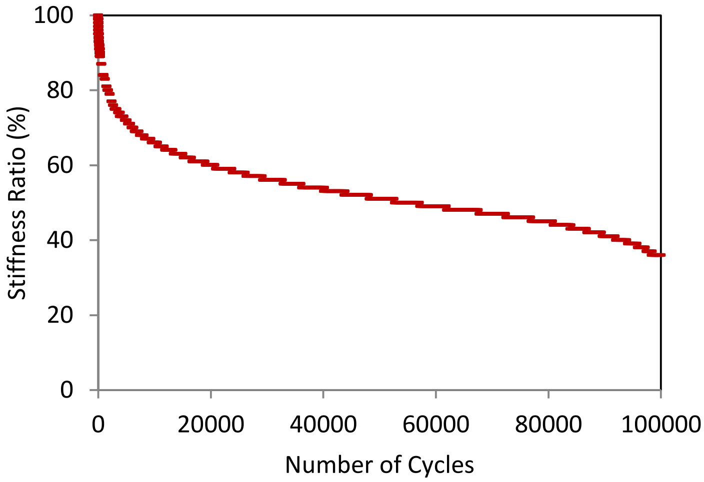
$$\sigma = \frac{P\,L}{b\,h^2} \qquad (2)$$

where ε = maximum strain, σ = maximum stress, P = load applied by actuator at time t, b = average specimen width and h = average specimen height, δ = deflection at center of beam at time t, a = distance between inside clamps and L = distance between outside clamps.

Sample flexural stiffness is then calculated using σ and ε data recorded from each cycle.

$$E = \frac{\sigma_t}{\varepsilon_t} \qquad (3)$$

where *E* = flexural stiffness.



a) Test setup b) Test result

Figure 2. Flexural stiffness test

Fig. 2(b) shows a typical test result where the Stiffness Ratio (SR) (current cycle's stiffness divided the initial stiffness) decreases with cycle of loading due to microcrack formation. According to the AASHTO T 321-07 test protocol, the stiffness at the 50th cycle of loading was considered the initial stiffness and the number of cycles at 50% reduction in stiffness was considered the failure of beam following AASHTO T 321-07 test protocol [7].

The strain-controlled test was conducted at 600 micro strains sinusoidal load at 20 °C and at 10 Hz of frequency. The initial modulus of all beam samples was between 4,200 ksi and 4,500 ksi. The fatigue life with the rest period is presented in Figure. The fatigue life with no rest period is 10,600. The lives are 12,600, 33,700, 101,900 and 133,900 at 0.5 sec, 1.0 sec, 2.5 sec and 5.0 sec of rest period between loadings. In real highways, there are always some gap between traffic. Therefore, whatever fatigue life achieved in laboratory does not exactly simulate the field conditions. While designing asphalt pavement a shift factor of 400 is normally used to transfer a laboratory model to a field model.

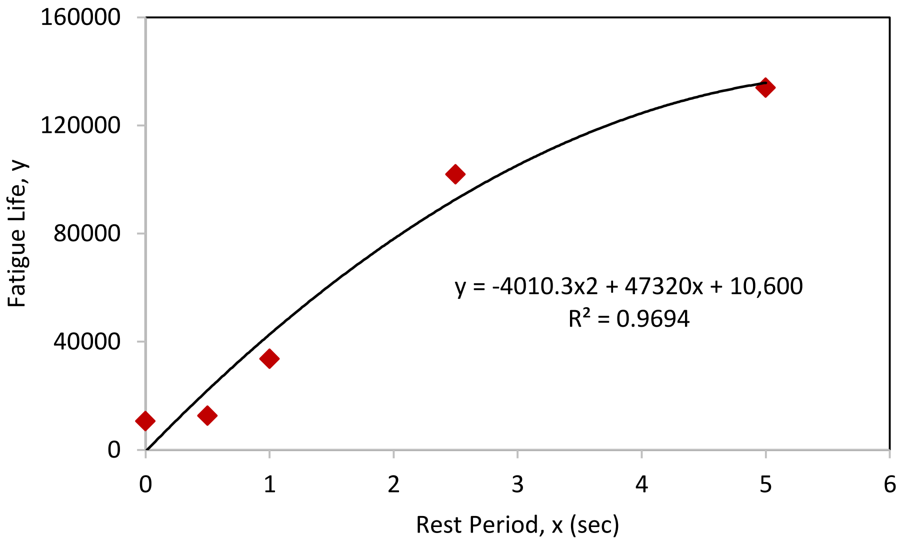


Figure 3. Variations of fatigue life with rest period

III. CONCLUSION

Based on the study, it can be said that fatigue life increases polynomial with the increase of rest period between loadings. A single asphalt mixture has been used in this study. Therefore, the result may not be exactly valid for other mix. However, the fatigue life pattern is expected to be similar.

IV. RECOMMENDATIONS

A more rigorous analysis with more mix variable could be performed as a recommendation for future studies. Real-world validation is another scope.

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