Effect of Using FORTA Fibers in Base Asphalt Layers to Mitigate Bottom-Up Fatigue Cracking

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Introduction

The action of repeated loading caused by traffic induces tensile and shear stresses in the Asphalt Concrete (AC), which cause a loss of the structural integrity of the AC pavement. This loss in integrity will eventually lead to the development of fatigue cracking as the traffic-induced tensile and shear stresses approaches the strength of the material. There are two types of fatigue cracking in HMA pavements; bottom-up (alligator) cracking and top-down (longitudinal) cracking. Of these two the bottom-up mode is the most well-known form.

For several years, the mitigation of bottom-up fatigue cracking in Hot Mix Asphalt (HMA) pavements has been one of the main issues for the construction of long lasting or perpetual pavements. There are two main options that can be used to mitigate bottom-up cracking of HMA pavements. For the first option, the-traffic induced stresses at the bottom of the AC layer are reduced by increasing the depth of that layer. For the second option, the strength of the base course layer is improved by altering the mix design specifications to produce less fatigue susceptible mixtures. These specifications may include the use of higher asphalt contents, inclusion of modifiers such as polymers, synthetic/crumb rubber, fibers, and etc. The main objective of this white paper is to discuss the effectiveness of using FORTA fiber with base course mixtures with respect to improving bottom-up fatigue cracking resistance.

Analysis and Results

The analysis presented in this paper is based on the conclusion that the addition of FORTA Fiber into asphalt mixture increases the laboratory fatigue life (N_f) by three times compared to the control asphalt mixture (concluded based on the combined and average laboratory performance of 12 national and international fiber studies). The N_f parameter is used in Mechanistic Empirical pavement analysis, such as the AASHTOWare Pavement ME, to determine the cumulative damage using Miner's law as shown in Equation (1).

$$D = \left[\sum_{i=1}^{12} \sum_{j=1}^{5} \sum_{k=1}^{K} \sum_{l=1}^{L} \sum_{m=1}^{M} \left(\frac{n}{N_f} \right)_{i,j,k,l,m} \right] \times 100 \qquad (1)$$

Where;

- D = cumulative damage,
- n = actual number of axle-load applications within a specific analysis period,
- $N_{f,}$ = allowable repetitions under conditions prevailing within a specific time period,
- i = month,
- j = time of day (quintile),
- k = axle-load type (single, tandem, tridem, quad, or special axle configuration),
- l = load level for each axle type,

m = traffic path, assuming a normally distributed lateral wheel wander.

Based on the laboratory observations regarding a factor of three improvement in fatigue cracking, it can be seen that the damage in the pavement with fiber reinforced asphalt will be 1/3rd of that from the non-fiber alternative. The cumulative bottom-up fatigue damage, D, is then used to calculate the bottom-up fatigue cracking, $F.C.$ as a percentage of lane area by using the transfer function shown in Equation (2).

$$F.C. = \left(\frac{6000}{1 + e^{(C_1' + C_2' \times \log(D))}} \right) \times \left(\frac{1}{60} \right) \tag{2}$$

Where;

C_1' = C_2',

C_2' = $-2.40874 - 39.748 \times (1 + h_{ac})^{-2.856}$, and

h_{ac} = total thickness of asphalt layer (in).

Equation (2), shows that the relationship between damage, and thus the laboratory based fatigue performance is not one-to-one. Because of this difference, it cannot be concluded that the observed factor of three improvement in fatigue life from laboratory tests will translate to an equivalent increase in bottom-up fatigue performance. However, since the damage factor for fiber reinforced pavements is known to be 1/3rd of that of the non-fiber case, comparisons between the predicted fatigue cracking of the two alternatives can be calculated. Figure 1 shows the comparison of the predicted bottom-up cracking for fiber reinforced and non-fiber reinforced cases. The improvement from the fiber reinforcement is clearly demonstrated by the fiber conditions being below the line of equality. The Fatigue Cracking Improvement Factor (FCIF) was calculated by dividing the control fatigue cracking by the fiber fatigue cracking at different damage levels. Its value ranges from 1.0 to 3.4 depending on the cumulative amount of cracking in the non-fiber reinforced case, shown in Figure 2.

Conclusion

Laboratory fatigue results from twelve national and international fiber studies showed that the addition of FORTA Fiber into asphalt mixture increases the laboratory fatigue life (N_f) by **<u>three times</u>** compared to the control asphalt mixture. This improvement in fatigue life was translated into an equivalent decrease in bottom-up fatigue cracking by a factor of **<u>1.0 to 3.4</u>** depending on accumulated damage level compared to the control case. This finding is independent of pavement structural, traffic level, and climate.

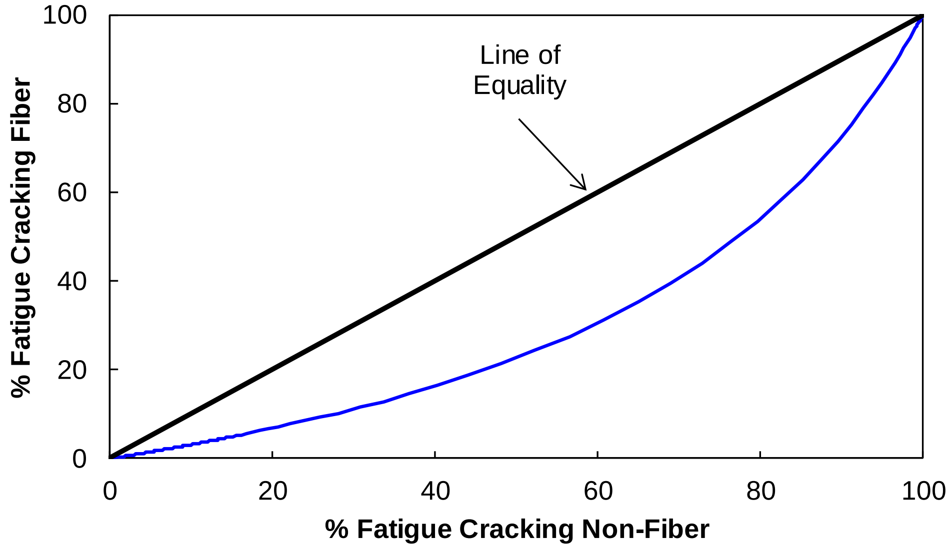

Figure 1 Comparison of fiber and non-fiber reinforced bottom-up fatigue cracking.

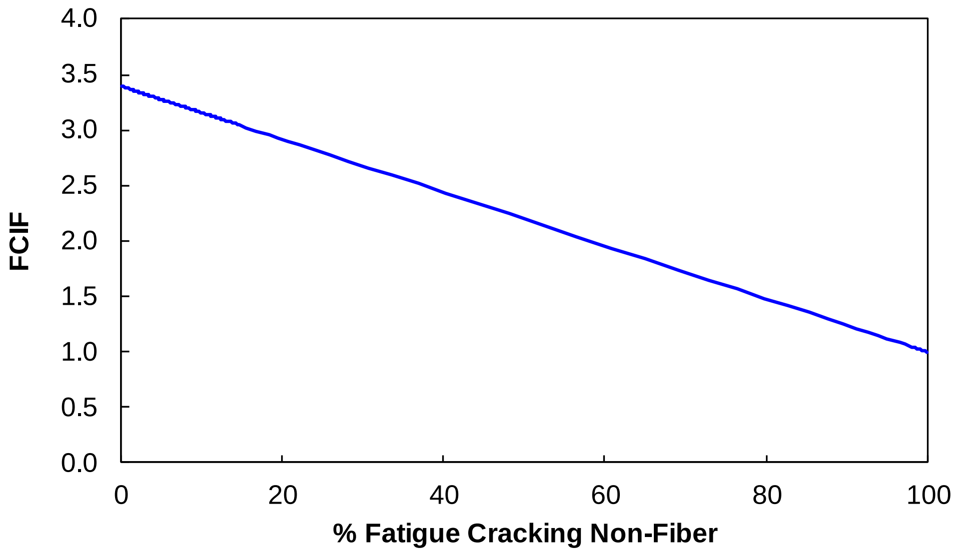

Figure 2 Improvement in fatigue cracking from fiber reinforcement.