Laboratory Tests, Results and Analyses

Triaxial Shear Strength Tests

The triaxial shear strength tests were conducted for the control and FRAC mixtures. Tests were carried out on cylindrical specimens, 100 mm in diameter and 150 mm in height at 54.4 °C (NCHRP 465, 2002). Unconfined and two confining pressures were used: 138 kPa and 276 kPa. Two replicates were used at each confinement level. The specimens were loaded axially to failure at a strain rate of 1.27 mm/mm/min. Figure 1 presents a comparison example of the tests conducted for both mixtures at the 138 kPa confinement level. The plots represent before and after peak stress development during the test. For the FRAC mixture, it was observed that the peak stress developed and the time of its occurrence were higher when compared to those of the control mixture, a behavior that was attributed to the influence of the fibers in the mix. The fibers provided this additional reinforcement to the asphalt mix in resisting permanent deformation and retard the occurrence of shear failure. In addition, cumulative areas under the curve for the tested mixtures are indicative of the mixes' residual energy in resisting crack propagation post peak stress. In all tests, the fiber reinforced mixture showed higher residual energy than the control mixture.

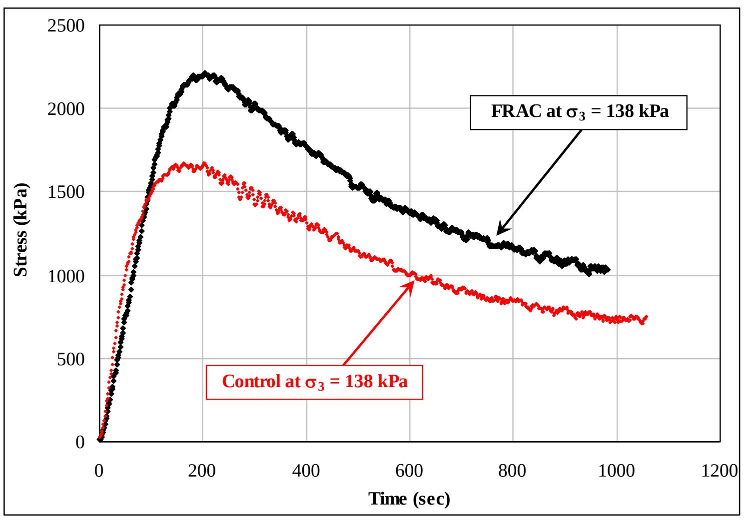

Figure 1. Comparison of Stress-Time Plots at 138 kPa Confinement Level.

E Dynamic Modulus Test*

The E* Dynamic Moduli of control and FRAC mixtures were determined per AASHTO TP 62-03 standard (AASHTO TP 62-03). For each mix, three specimens, 100 mm in diameter and 150 mm in height, were tested at -10, 4.4, 21, 37.8 and 54.4 °C, and 25, 10, 5, 1, 0.5, and 0.1 Hz loading frequencies. Figure 2 shows direct comparisons of E* values for selected test temperatures 4.4, 37.8 and 54.4 °C and a loading frequency of 10 Hz. It is observed that the moduli for the FRAC mixtures were higher than the control mixture, and therefore play a positive role in resisting deformation.

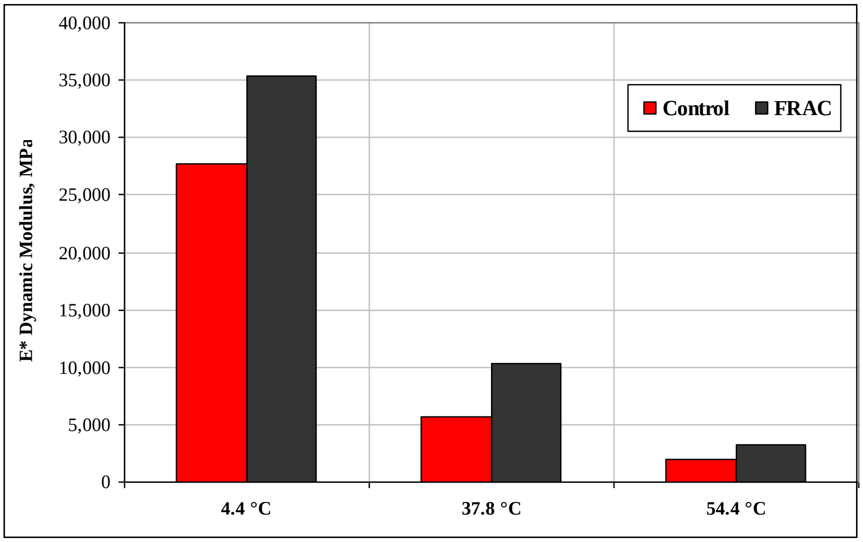

Figure 2. Comparison of Measured Dynamic Modulus Values at 10 Hz.

Crack Propagation - C Line Integral Test*

C* is an energy rate or power integral test property. C* can be calculated using a power rate interpretation as follows (Abdulshafi, 1983, Abdulshafi and Kaloush, 1988):

$$C^* = -\frac{\partial U^*}{\partial a}$$

Where U* is the power or energy rate defined for a load p and displacement u by:

$$U^* = \int_0^u p\,du$$

Disc specimens were prepared from gyratory plugs. For each disc, a right-angle wedge was cut into the specimen to accommodate the loading device as shown in Figure 3 (a). Tests were conducted at 21.1 °C. The load applied at a constant displacement rate and the crack length over time was measured for each test specimen. The displacement rates used were 0.127, 0.254, 0.381, 0.508, and 0.635 mm/min for both the control and FRAC mixtures. The data was used to determine the load as a function of displacement rate for various crack lengths. The power of energy rate input, U*, was measured as the area under the load displacement rate curve. The energy rate, U*, was then plotted versus crack length for different displacement rates and the slopes of these curves constituted the C*-integral. The C*-integral was plotted as a function of the displacement rate. Finally, the C* integral data were plotted as a function of the crack growth rate as shown in Figure 3 (b). In this figure, it is observed that the FRAC mixture has much higher C* and slope values compared to the control mixture. This is an indication that the FRAC mixture has much higher resistance to crack propagation. A unique observation of the FRAC mix specimens after the test was that the samples never split and they were difficult to split them apart by hand; whereas most of the control mixture samples split at the end of the test.

Pavement Thickness Design and Consideration

The results of the laboratory study were used as input into the Mechanistic Empirical Pavement Design Guide (MEPDG) computer program (Guide for MEPDG, 2004). This was done to predict field performance per the MEPDG, and to evaluate the impacts on varying pavement design thicknesses. A total of 10 runs were performed for each of the control and FRAC mixtures for the following conditions.

- Two traffic levels, 1500 and 7000 Annual Average Daily Traffic (AADT), representing an intermediate and high traffic levels.
- Five Asphalt Concrete (AC) layer thicknesses, 50 to 150 mm over a constant thickness base of 200 mm.
- Climatic conditions: Phoenix, Arizona, USA
- Design life: 10 years

The distresses evaluated as output were rutting and fatigue cracking. Distress versus thickness trends for the two traffic levels were very similar but with different magnitude. Figure 4 (a) shows the relationship between total rutting and thickness for both mixtures at the 7000 AADT (~50 million ESALs). It can be observed that for a rutting criterion not to exceed 10 mm during the design period of 10 years, the control mixture AC pavement thickness needed is 140 mm; whereas the FRAC layer thickness needed would be 90 mm; a saving of about 50 mm in the total AC layer thickness. Figure 4 (b) shows the fatigue cracking predicted by the MEPDG. The results show similar trends, in that lower fatigue cracking is predicted for the FRAC mixture. The results, as shown, are also dependent on the AC layer thickness. This agrees with observations in the MEPDG manual, where for very thin AC layer pavement system, fatigue cracking may not be of a concern due to the compressive nature of strains throughout the AC layer (Guide for MEPDG, 2004).

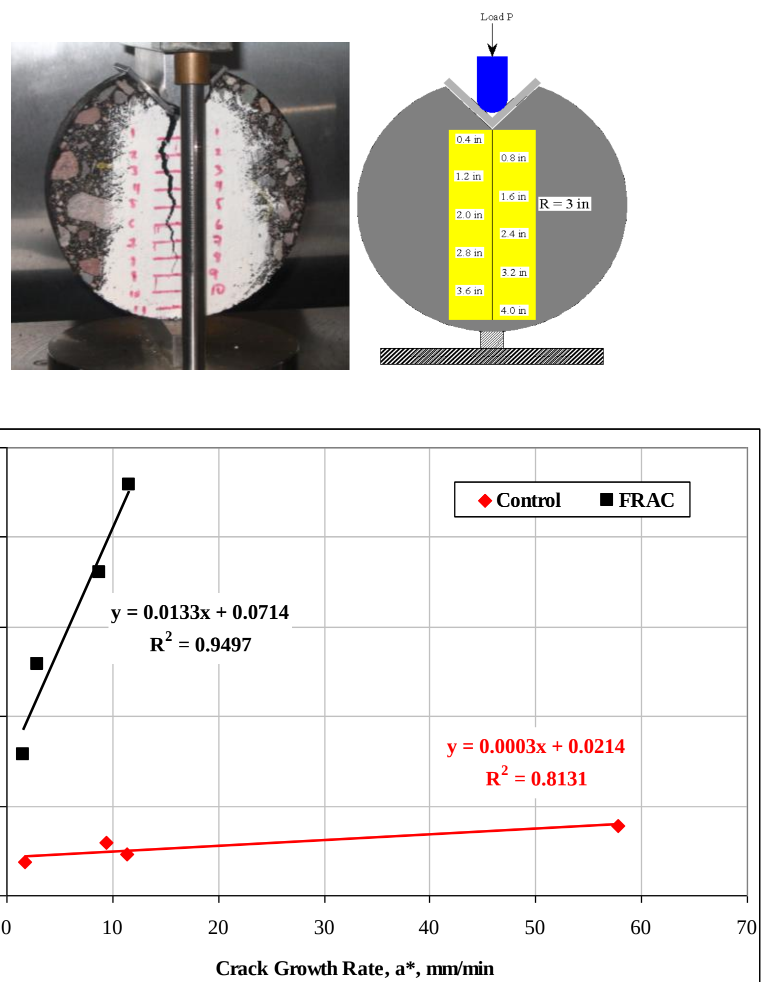

Figure 3. (a) Typical C* Test Setup (b) C* Line Integral versus Crack Growth Rate.

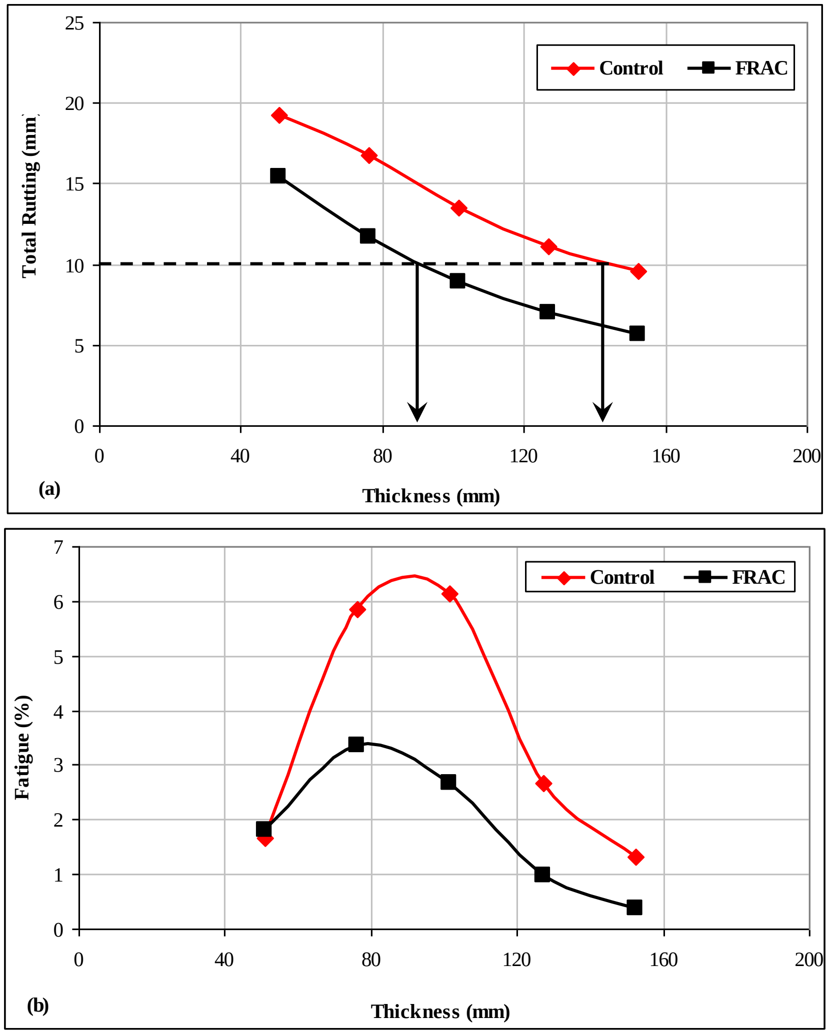

Figure 4 (a) Pavement Rutting Evaluation using the Mechanistic-Empirical Pavement Design Guide (b) Pavement Fatigue Cracking Evaluation using the Mechanistic-Empirical Pavement Design Guide.

Conclusions

The laboratory test results in this study showed that the use of polypropylene and aramid fibers blend in the asphalt mixture improves the mixture's performance in several unique ways. The FRAC mixtures showed better resistance to shear deformation. The measured Dynamic Modulus E* values were higher for the FRAC mix. At 54.4 °C, the increase in modulus was 50%. **The relationships between crack growth rates and C* line integral values showed that the FRAC mix had about 40 times higher resistance to crack propagation than the control.** The pavement design analysis showed that a reduced AC layer thickness of about 30 to 40% can be achieved when using the FRAC mixture. This value will vary slightly depending on the traffic level used in the analysis.

References

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2. Abdulshafi, O., (1983). “Rational Material Characterization of Asphaltic Concrete Pavements,” Ph.D. Dissertation, the Ohio State University, Columbus, OH, 1983.
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5. Witczak, M. W., Kaloush, K. E., Pellinen, T., El-Basyouny, M., & Von Quintus, H. (2002). Simple Performance Test for Superpave Mix Design. *NCHRP Report 465*. Transportation Research Board. National Research Council. Washington D.C.