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Rutting and Fatigue Properties of Plant Mixes from AE Stone

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16. Abstract

Loose mix from A.E. Stone, Inc. in Egg Harbor Township, NJ was supplied to the Rutgers Asphalt Pavement Laboratory (RAPL) for evaluation. Three different plant mixes were supplied for permanent deformation (rutting) and flexural fatigue testing; 1) A.E. Stone ¼" Mix, 2) I-4 HD, and 3) I-5 HD. To evaluate the rutting resistance properties of the different HMA mixes, the samples were tested in the Asphalt Pavement Analyzer (APA). Meanwhile, to compare the fatigue properties the different HMA mixes, the Flexural Fatigue Device (FFD) was used. A brief description of each the testing devices are provided below.

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WORKPLAN

Loose mix from A.E. Stone, Inc. in Egg Harbor Township, NJ was supplied to the Rutgers Asphalt Pavement Laboratory (RAPL) for evaluation. Three different plant mixes were supplied for permanent deformation (rutting) and flexural fatigue testing; 1) A.E. Stone ¼" Mix, 2) I-4 HD, and 3) I-5 HD. To evaluate the rutting resistance properties of the different HMA mixes, the samples were tested in the Asphalt Pavement Analyzer (APA). Meanwhile, to compare the fatigue properties the different HMA mixes, the Flexural Fatigue Device (FFD) was used. A brief description of each the testing devices are provided below.

Asphalt Pavement Analyzer (APA) – AASHTO TP63

The APA is a second-generation loaded wheel tester (Figure 1). It has the capability of testing compacted brick or pill samples under various environmental conditions to evaluate the HMA mix's rutting potential. The device can also be linked to a computer and data acquisition system so the user can measure the rutting of the HMA for each load cycle.

A moving wheel load is applied at a rate of about one cycle per second to a ¾ inch pressurized hose that rests atop the HMA samples (Figure 2). This simulates (on a small scale) the traffic loading that occurs in the field. The major benefit of using the device is as a comparative tool for mixture selection (i.e. one would select the mix that ruts the least from the APA testing).

The Asphalt Pavement Analyzer (APA) test was conducted at a test temperature of 64^{o}C, with hose pressures and wheel loads of 100 psi and 100 lbs, respectively. A data acquisition system recorded the APA rutting out to 20,000 loading cycles. The total APA rutting at 8,000 cycles was used for comparative purposes. Four 77-mm tall gyratory samples having air void contents of 4% (±0.5%) and 7% (±0.5%) were used for comparison between the different mixes.

To evaluate whether the APA rut performance was good or poor, a 5mm rut depth criteria was used. The 5mm rut depth has been proposed by a number of researchers/state agencies as a means of ranking the rutting resistance: < 5mm = Good Rut Resistance; > 5mm = Poor Rut Resistance (1, 2, 3) for APA samples that are compacted to 7% air voids only. The APA test results for the 4% air void samples were conducted to evaluate how the various mixes compared at the design air void level, unfortunately there does not exist performance-related criteria for this air void level. Therefore, the APA performance criteria should only be used for the 7% air void samples.

Figure 1 – Asphalt Pavement Analyzer

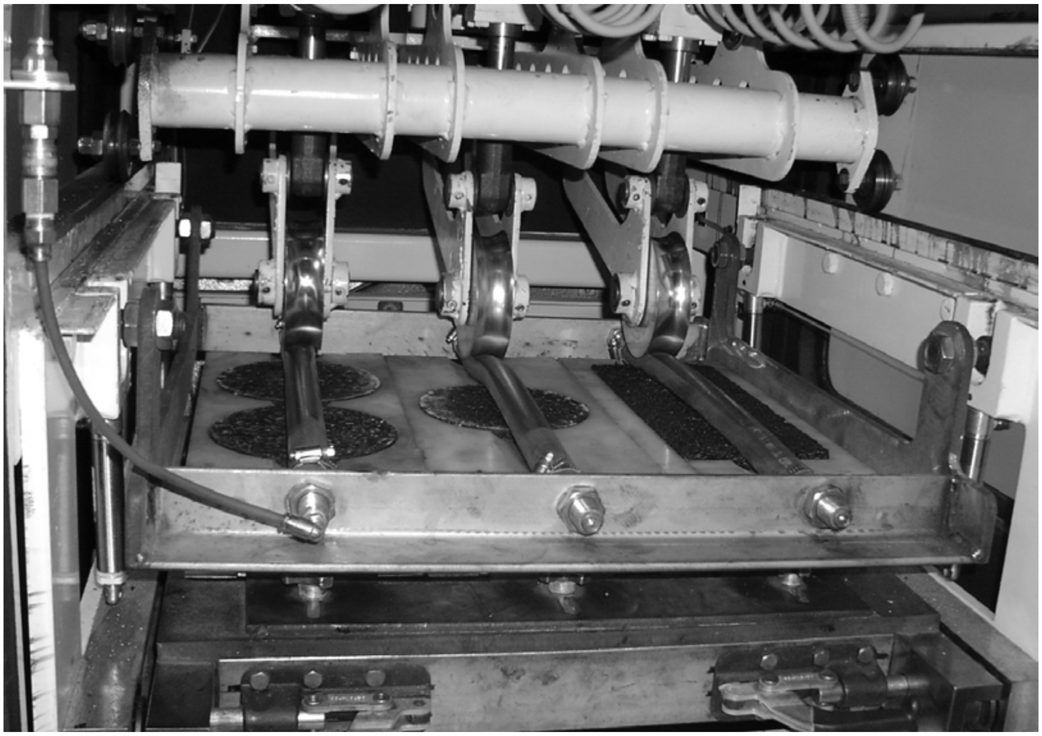

Figure 2 – Inside the Asphalt Pavement Analyzer

Flexural Beam Fatigue Device – AASHTO T321

Load associated fatigue cracking is one of the major distress types that occurs in flexible pavement systems. The action of repeated loading caused by traffic induced tensile and shear stresses in the bound layers initiates cracking in the asphalt material. To evaluate how different HMA materials resist fatigue cracking, many researchers have recommended the use of the Flexural Fatigue Device (FFD). Materials that will obtain a higher number of loading cycles in the FFD before failing in fatigue will most often have a longer fatigue life in the field.

Figure 3 shows a picture of the testing device used for the flexural beam fatigue testing at RAPL. The device is placed inside an environmental chamber to control the temperature prior and during testing.

Throughout the test, the flexural stiffness of the sample is calculated and recorded. The stiffness of the beam is plotted against the load cycles and the resulting data is fitted to an exponential function as follows:

$$E = E_i e^{bN} \qquad (1)$$

where,

E = flexural stiffness after the n load cycles;
E_i = initial flexural stiffness;
e = natural algorithm to the base e

b = constant from regression analysis
N = number of load cycles

Equation (1) is then modified to determine the number of loading cycles to achieve 50% of the initial flexural stiffness.

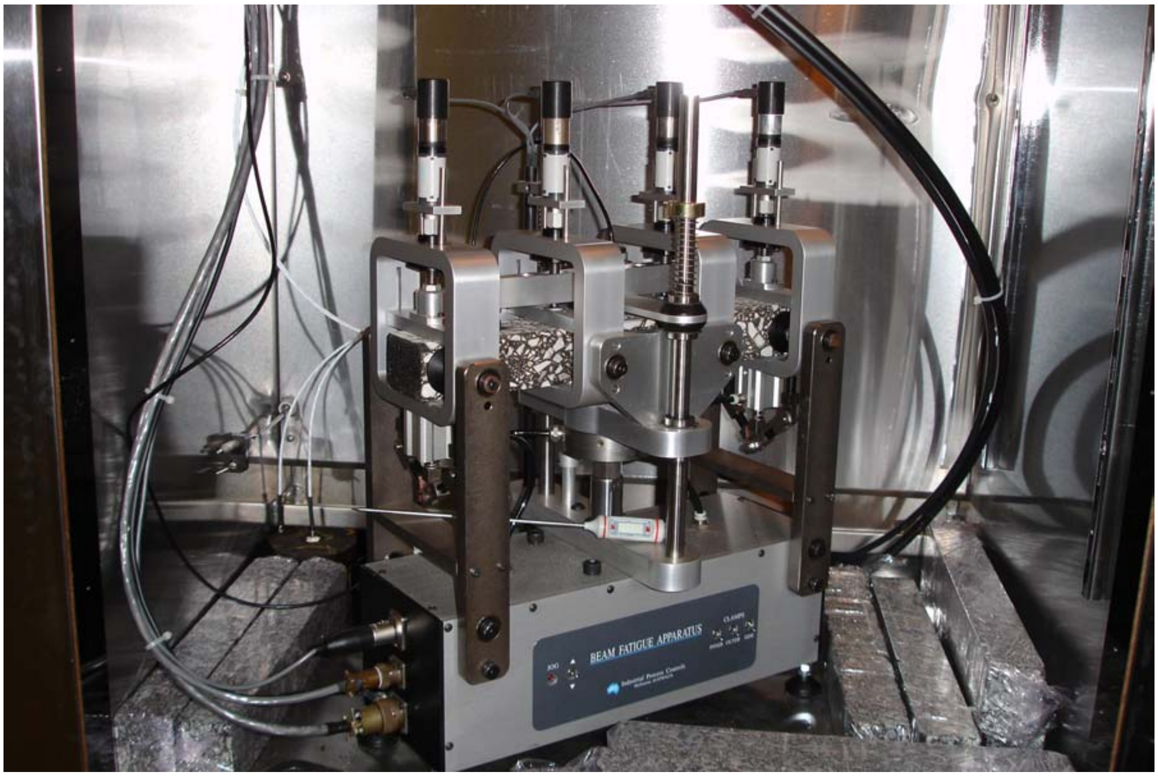

Figure 3 – Flexural Beam Fatigue Device

Due to the unusual specimen size required for the FFD (380mm in Length x 65mm in Width x 50mm in Height), FFD samples can not be compacted using the gyratory compactor. Instead, the vibratory brick compactor at RAPL was used to first compact an oversized sample and then the final FFD required dimensions were obtained by trimming with a wet saw (Figure 4).

Although testing is typically conducted under a wide range of applied tensile strain conditions, only a 1,000 micro-strain level was selected for testing. This is a high level of bending for most HMA samples to withstand and HMA that is susceptible to fatigue-type cracking will fail extremely fast under this loading condition. The FFD test protocols used in this study were as follows:

- Test temperature = 15^oC (59^oF)
- Loading Frequency = 10 Hz (0.1 second load duration)
- Strain-controlled test/Sinusoidal loading
- Applied tensile strain = 1,000 micro-strains

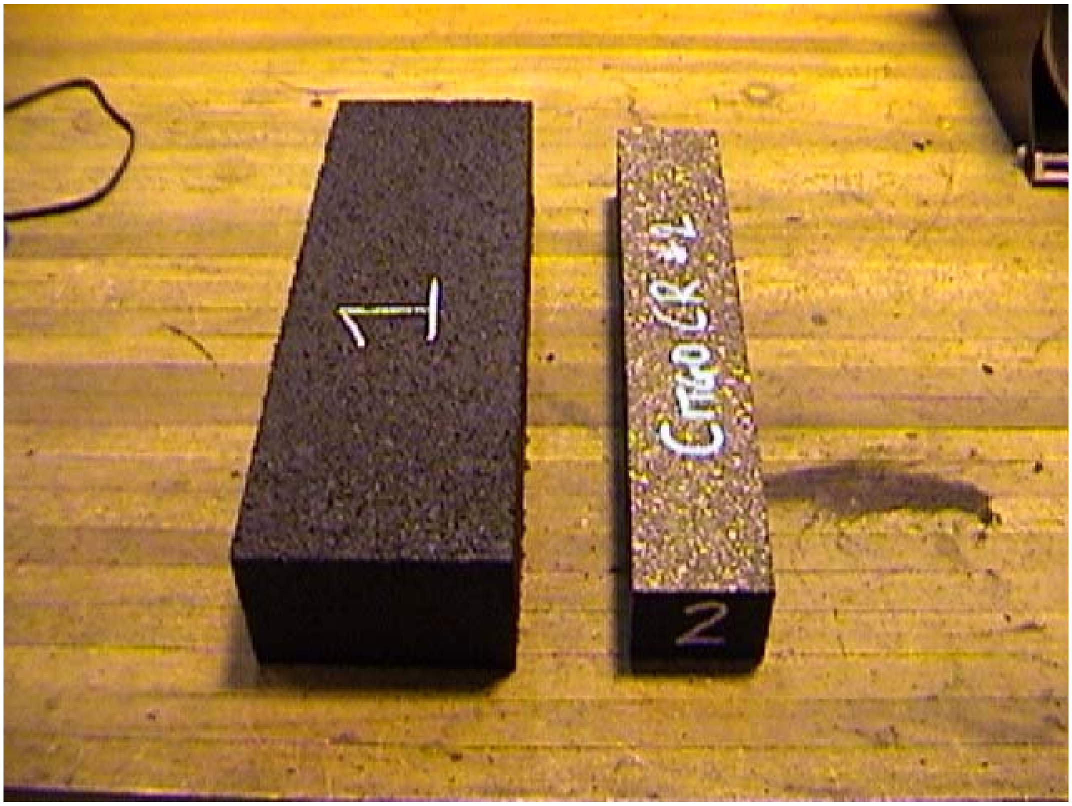

Figure 4 - Compacted and Cut Samples for Beam Fatigue Testing

TEST RESULTS

<u>Asphalt Pavement Analyzer (APA)</u>

The test results for APA are shown in Figures 5 and 6. In both figures, the A.E. Stone ¼" Mix is compared to either the I-4 HD or the I-5 HD.

<u>I-4 HD vs A.E. Stone ¼" Mix</u>

The APA rutting comparison between the I-4 HD and the A.E. Stone ¼" Mix is shown in Figure 5. The results show that for the mixes compacted to 7% air voids, the I-4 HD has an APA rut depth of 6.36mm, while the ¼" Mix has an APA rut depth of 4.31mm. Based on the criteria discussed earlier, the I-4 HD may be susceptible to rutting while the ¼" Mix should be able to withstand rutting in the field. More importantly, it should be emphasized that the ¼" Mix obtained only 2/3 the APA rutting as the I-4 HD mix.

The comparison of APA rut depths for samples compacted to 4% air voids show similar rutting resistance properties at the lower air void level (3.25mm for the I-4 HD and 3.33mm for the ¼" Mix). It should be noted that a performance criteria has not been established for samples compacted to 4% air voids. However, the large discrepancy of APA rut depths when the samples were compacted at 4 and 7% air voids may mean that the rutting performance of I-4 HD is highly sensitive to quality of the field compaction level.

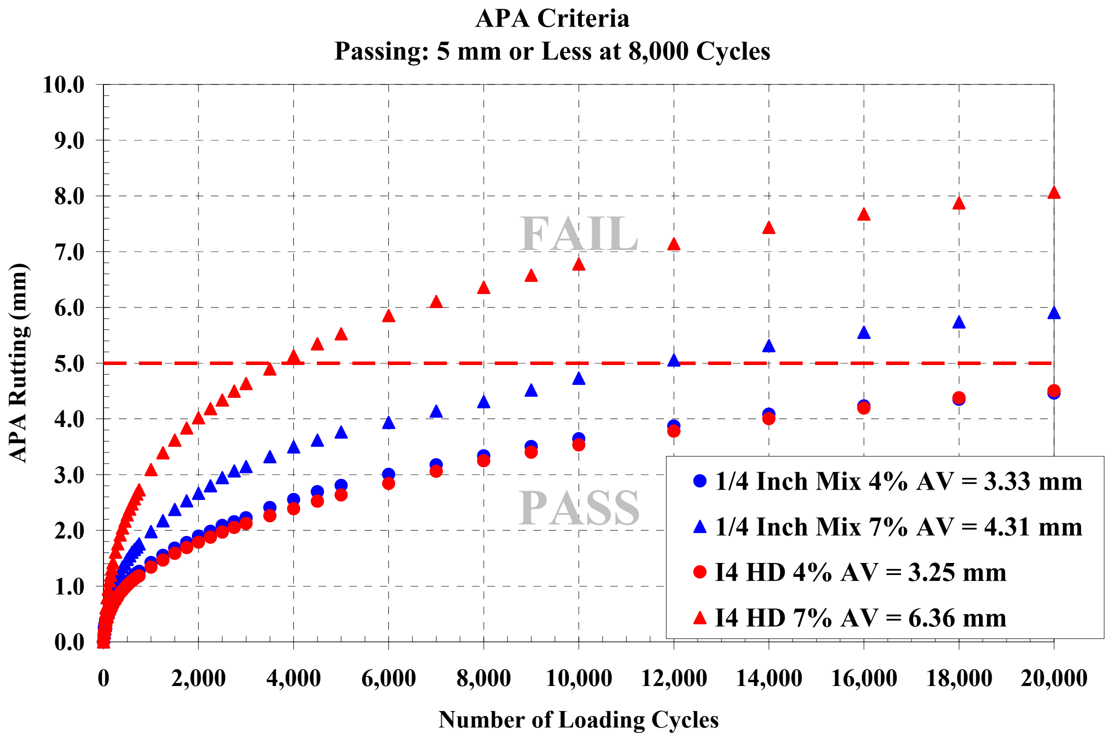

Figure 5 – APA Rutting Results for I-4 HD and ¼" Mix

I-5 HD vs A.E. Stone ¼" Mix

The APA rutting comparison between the I-5 HD and the A.E. Stone ¼" Mix is shown in Figure 6. The results show that for the mixes compacted to 7% air voids, the I-5 HD has an APA rut depth of 6.38mm, while the ¼" Mix has an APA rut depth of 4.31mm. Based on the criteria discussed earlier, the I-5 HD may be susceptible to rutting while the ¼" Mix should be able to withstand rutting in the field. Again, it should be emphasized that the ¼" Mix obtained only 2/3 the APA rutting as the I-5 HD mix.

The I-5 HD 4% air void samples showed a similar trend to the I-4 HD samples discussed earlier.

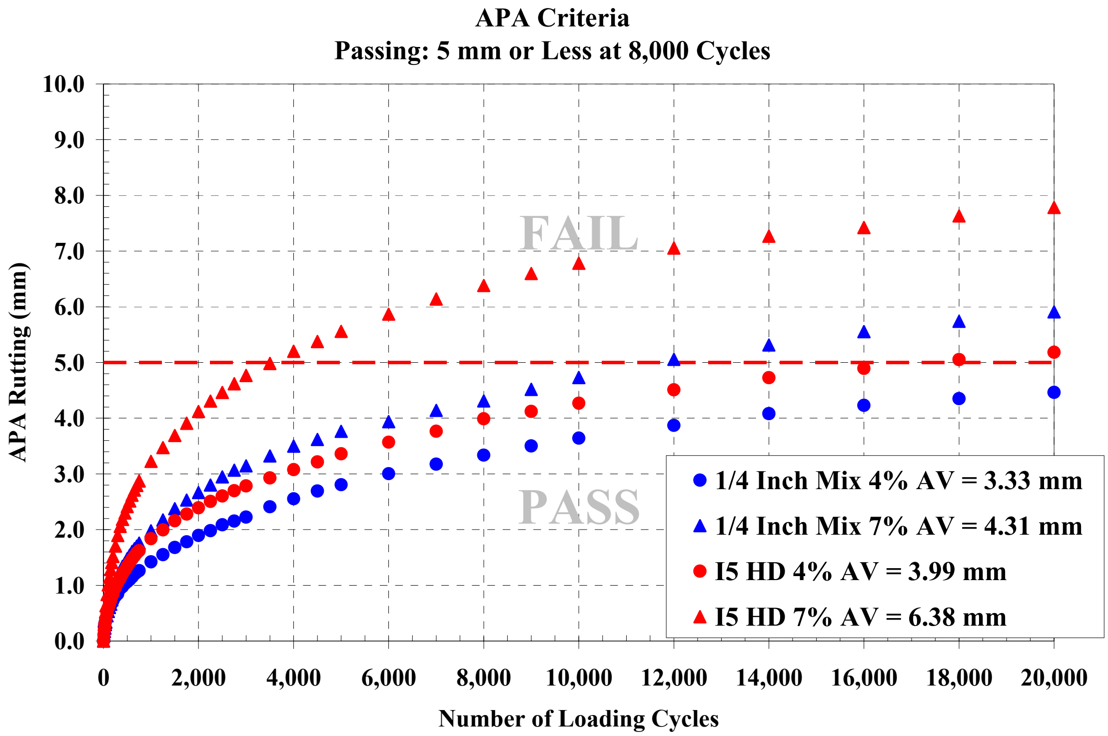

Figure 6 – APA Rutting Results for I-5 HD and ¼" Mix

Flexural Fatigue Device (FFD)

The test results for FFD are shown in Figures 7 and 8. In both figures, the A.E. Stone ¼" Mix is compared to either the I-4 HD or the I-5 HD.

I-4 HD vs A.E. Stone ¼" Mix

The flexural fatigue properties of the I-4 HD and the ¼" Mix are shown in Figure 7. The test results clearly show that the ¼" Mix has a flexural fatigue life more than 15 times greater than the I-4 HD mix. Although a criteria has yet to be developed for the testing protocol used in this study, the test results clearly show the ¼" Mix's superior fatigue resistance over the I-4 HD mix.

I-5 HD vs A.E. Stone ¼" Mix

The flexural fatigue properties of the I-5 HD and the ¼" Mix are shown in Figure 8. The test results clearly show that the ¼" Mix has a flexural fatigue life more than 30 times greater than the I-5 HD mix. Although a criteria has yet to be developed for the testing protocol used in this study, the test results clearly show the ¼" Mix's superior fatigue resistance over the I-5 HD mix.

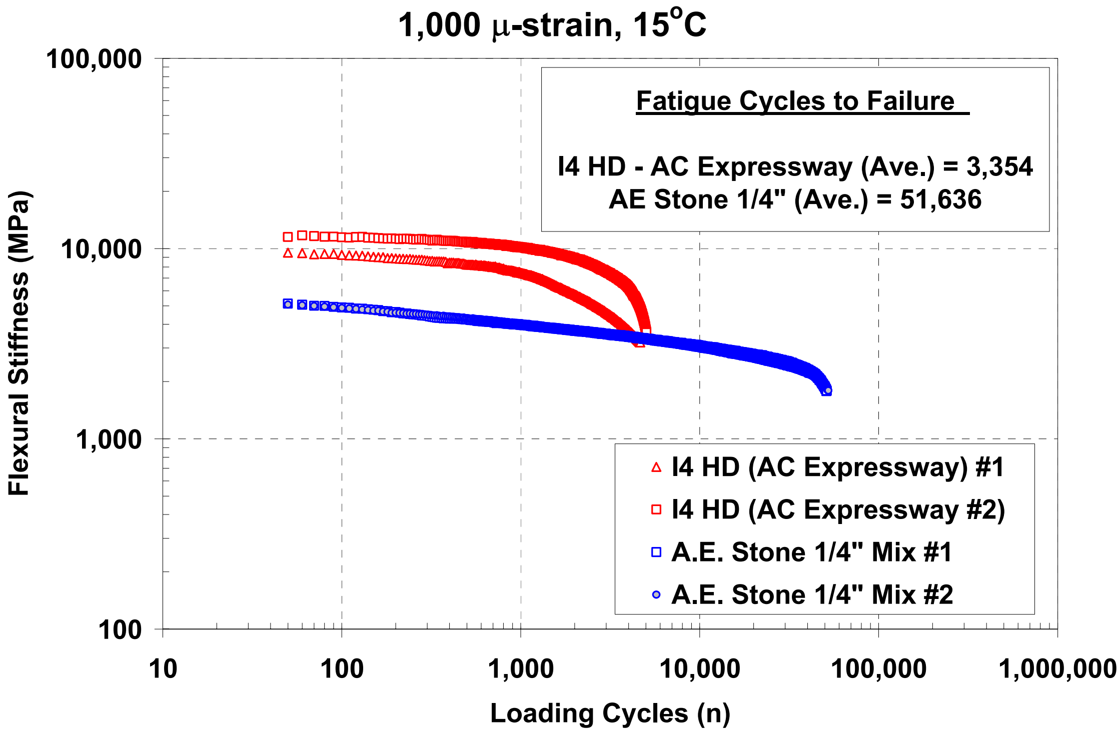

Figure 7 – Flexural Fatigue Properties of I-4 HD vs ¼" Mix

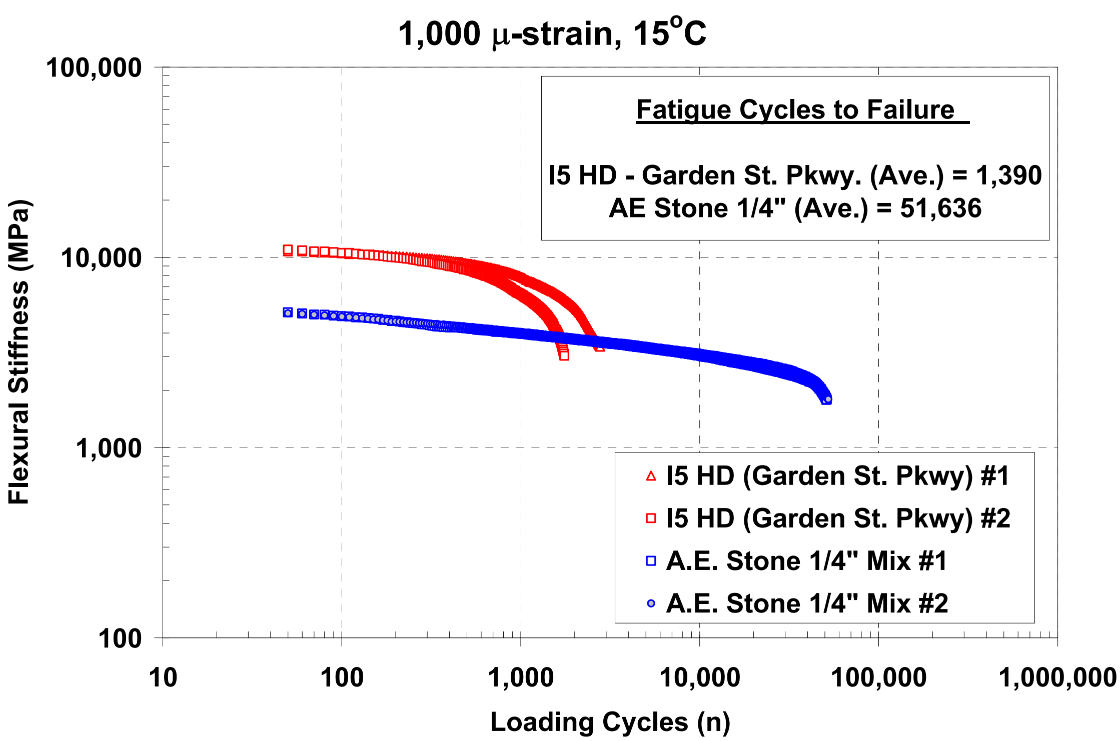

Figure 8 – Flexural Fatigue Properties of I-5 HD vs ¼" Mix

SUMMARY/CONCLUSIONS

An I-4 HD and I-5 HD plant produced mixes were compared to A.E. Stone's ¼" Mix under rutting and fatigue performance tests. Based on the testing and materials evaluated in this study, the following conclusions can be drawn:

- Based on the Asphalt Pavement Analyzer rutting criteria, which has been accepted and used by a number of researchers and state agencies, both the I-4 HD and I-5 HD may be prone to rutting in the field. This is based on the APA rut depth criteria of 5mm (< 5mm = good resistance to rutting: > 5mm = poor resistance to rutting). The I-4 HD mix obtained 6.36mm of APA rutting while the I-5HD mix obtained 6.38mm of APA rutting. Meanwhile, the A.E. Stone ¼" Mix showed to have a good resistance to field rutting based on its performance in the APA (4.31mm of rutting). The APA test results also showed that the A.E. Stone ¼" Mix had better rutting resistance properties than both the I-4 HD and the I-5 HD.
- Based on the Flexural Beam Fatigue Device (FFD), the ¼" Mix was far superior in its resistance to fatigue failure. The ¼" Mix had a fatigue over 15 times greater than I-4 HD mix and over 30 times greater than the I-5 HD mix.

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