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REPORT TITLE:

COMPARISON OF FAA P-601 ASPHALT MIXTURE AND LOGAN AIRPORT ASPHALT MIXTURE

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BACKGROUND

A research study was conducted to compare the asphalt mixture properties of a FAA P-601 asphalt mixture and a typical surface course asphalt mixture placed at Logan Airport in Boston, Massachusetts. The FAA P-601 asphalt mixture is an asphalt mixture designed to be highly impermeable and resistant to jet fuel spillage. Information generated in the study can help pavement designers understand the potential benefit of utilizing a P-601 asphalt mixture on highly trafficked runway and taxiway areas.

LABORATORY TESTING

The laboratory testing program consisted of a variety of asphalt mixture test methods to evaluate the respective stiffness, rutting potential and cracking potential after short-term and long-term aging. The laboratory program consisted of:

a. Condition to 2 hours at Compaction Temperature
   i. Dynamic Modulus (3 specimens)
   ii. SCB Flexibility Index (4 specimens)
   iii. Overlay Tester (5 specimens)
   iv. Flexural Beam Fatigue (minimum of 3 specimens)
   v. Flow Number (use tested Dynamic Modulus samples)

b. Long Term Condition via 24 Hours of Loose Mix Conditioning at 135C
   i. Dynamic Modulus (3 specimens)
   ii. SCB Flexibility Index (4 specimens)
   iii. Overlay Tester (5 specimens)
   iv. Flexural Beam Fatigue (minimum of 3 specimens)

Asphalt Mixture Performance Testing

For this study, test specimens were compacted to air void levels ranging between 6 and 7%, except for moisture damage susceptibility testing (AASHTO T283) where the samples were prepared to air voids ranging between 6.5 and 7.5%.

The asphalt mixtures were conditioned to represent both short-term and long-term field performance conditions. For short-term conditioning (STOA), the loose mix was conditioned for 2 hours at the respective compaction temperature of the asphalt binder. For the long-term conditioning (LTOA), the asphalt mixtures were conditioned loose for 24 hours at 135^{o}C. As noted earlier, the asphalt mixtures were evaluated for their respective performance after both STOA and LTOA conditioned, depending on the test method utilized. Permanent deformation testing and wet Hamburg Wheel Tracking was conducted on test specimens that were only STOA conditioned. Meanwhile, mixture stiffness and fatigue cracking potential were evaluated at both STOA and LTOA conditioned test specimens.

Dynamic Modulus (AASHTO TP79)

Dynamic modulus and phase angle data were measured and collected in uniaxial compression using the Asphalt Mixture Performance Tester (AMPT) following the method outlined in AASHTO TP79, *Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)* (Figure 1). The data was collected at three temperatures; 4, 20, and 45°C using loading frequencies of 25, 10, 5, 1, 0.5, 0.1, and 0.01 Hz. Test specimens were evaluated under both STOA and LTOA conditions.

Figure 1 – Photo of the Asphalt Mixture Performance Tester (AMPT)

The collected modulus values of the varying temperatures and loading frequencies were used to develop Dynamic Modulus master stiffness curves and temperature shift factors using numerical optimization of Equations 1 and 2. The reference temperature used for the generation of the master curves and the shift factors was 20°C.

$$\log\left|E^*\right| = \delta + \frac{(Max - \delta)}{1 + e^{\beta + \gamma\left\{\log \omega + \frac{\Delta E_a}{19.14714}\left[\left(\frac{1}{T}\right) - \left(\frac{1}{T_r}\right)\right]\right\}}} \qquad (1)$$

where:

$|E^*|$ = dynamic modulus, psi
ω_r = reduced frequency, Hz
Max = limiting maximum modulus, psi
δ, β, and γ = fitting parameters

$$\log\left[a(T)\right] = \frac{\Delta E_a}{19.14714}\left(\frac{1}{T} - \frac{1}{T_r}\right) \qquad (2)$$

where:

$a(T)$ = shift factor at temperature T

T_r = reference temperature, °K

T = test temperature, °K

ΔE_a = activation energy (treated as a fitting parameter)

Well performing asphalt mixtures should result in high modulus at high temperatures to help resist rutting while achieving low modulus at intermediate/lower temperatures to help resist fatigue and thermal cracking.

The dynamic modulus master stiffness curves for the Short-Term Oven Aged (STOA) and Long-Term Oven Aged (LTOA) samples are shown in Figures 2 and 3. In Figure 2, it is quite noticeable that the P601 asphalt mixture has lower modulus values at the intermediate and lower temperatures (i.e. – middle and right side of the figure), while achieving higher modulus at the higher temperatures (i.e. – left side of the figure). In Figure 3, after the asphalt mixtures have been conditioned to simulate greater than 10 years of field aging, the dynamic modulus master stiffness curves show now that the Logan Airport asphalt mixture has higher modulus at all test temperatures and loading frequencies.

A review of how the asphalt mixtures are "aging" is shown in Figure 4. Figure 4 shows the dynamic modulus Aging Ratio, which is the ratio between the dynamic modulus measured after LTOA conditioning and dynamic modulus measured after STOA conditioning. Values greater than 1.0 indicate age hardening of the asphalt mixture, while values less than 1.0 indicate softening of the asphalt mixture. The figure shows that both asphalt mixtures have slight age hardening at lower temperatures (right side of the figure). However, at the intermediate and high temperature ranges (middle to left side of figure) show that the Logan Airport mix ages much more significantly than the P601 asphalt mixture. This age hardening is the reason for the higher modulus value at high temperatures previously noted in Figure 3.

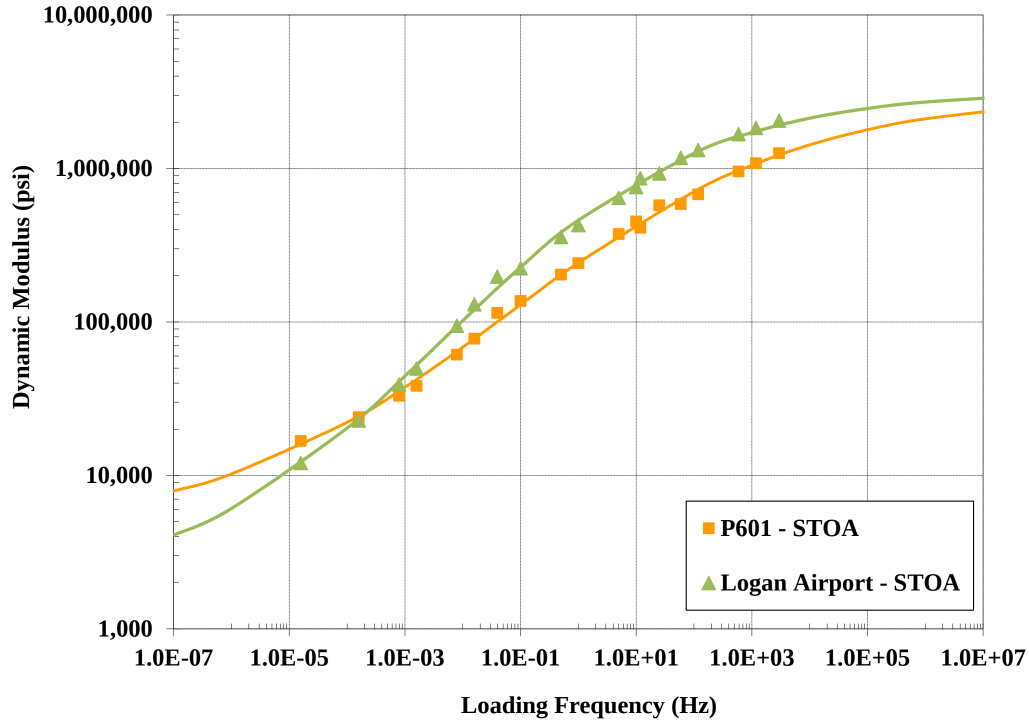

Figure 2 – Dynamic Modulus Master Stiffness Curve for Short-Term Oven Aged Asphalt Mixtures

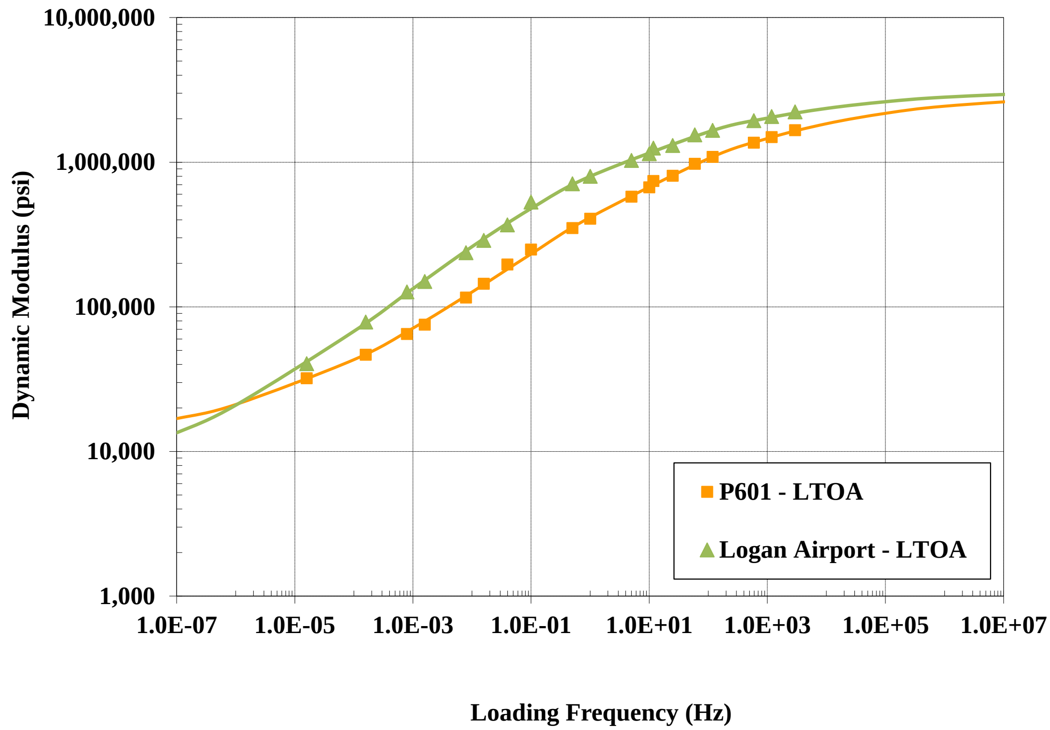

Figure 3 - Dynamic Modulus Master Stiffness Curve for Short-Term Oven Aged Asphalt Mixtures

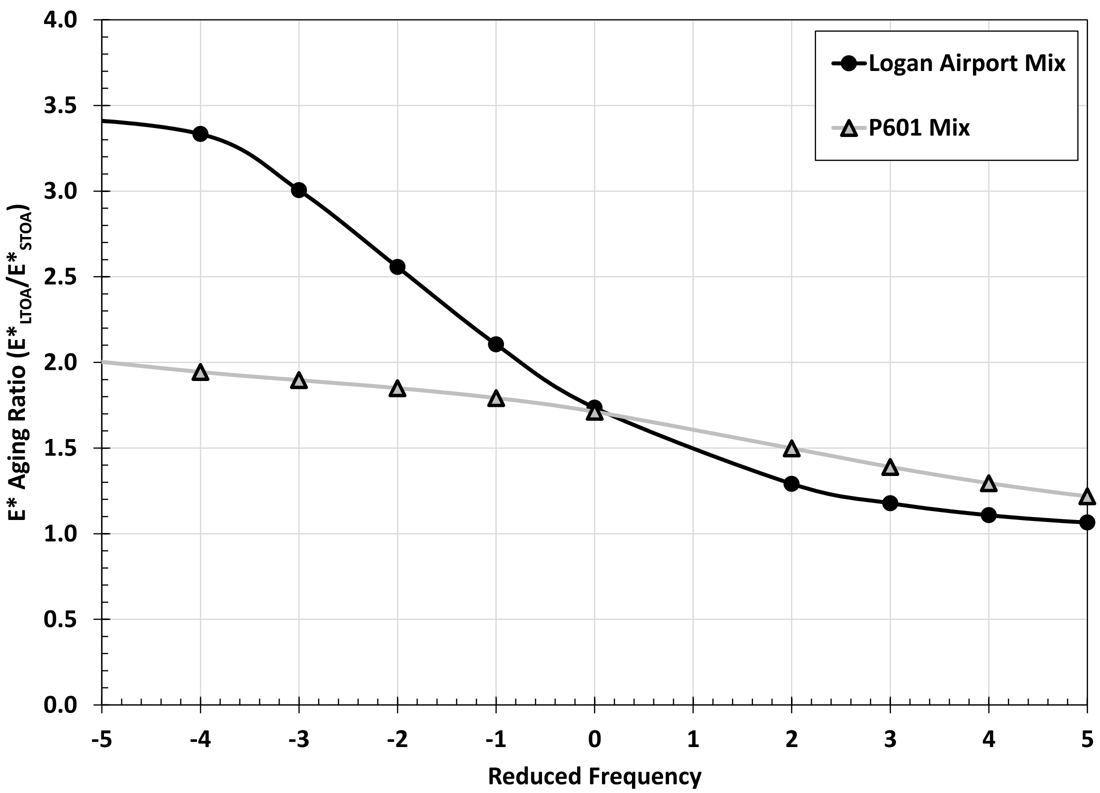

Figure 4 – Dynamic Modulus Aging Ratio

Rutting Evaluation

Repeated Load permanent deformation testing was measured and collected in uniaxial compression using the Asphalt Mixture Performance Tester (AMPT) following the method outlined in AASHTO TP79*, Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT).* The unconfined repeated load tests were conducted with a deviatoric stress of 600 kPa and a test temperature of 54^{o}C, which corresponds to New Jersey's average 50% reliability high pavement temperature at a depth of 20 mm according the LTPPBind 3.1 software. These testing parameters (temperature and applied stress) conform to the recommendations currently proposed in NCHRP Project 9-33, *A Mix Design Manual for Hot Mix Asphalt*. Testing was conducted until a permanent vertical strain of 5% or 10,000 cycles was obtained.

The permanent deformation results are shown in Figure 5. The results show that the P601 asphalt mixture is far superior in rutting resistance than the Logan Airport asphalt mixture. Table 1 provides Recommended Minimum Flow Number Values as a function of design traffic level based on the work in NCHRP Project 9-33. Although airport traffic varies from highway traffic, the table still provides a means of comparison. The recommended values were used to compare the performance of the asphalt mixtures. The test results of the Logan Airport mix

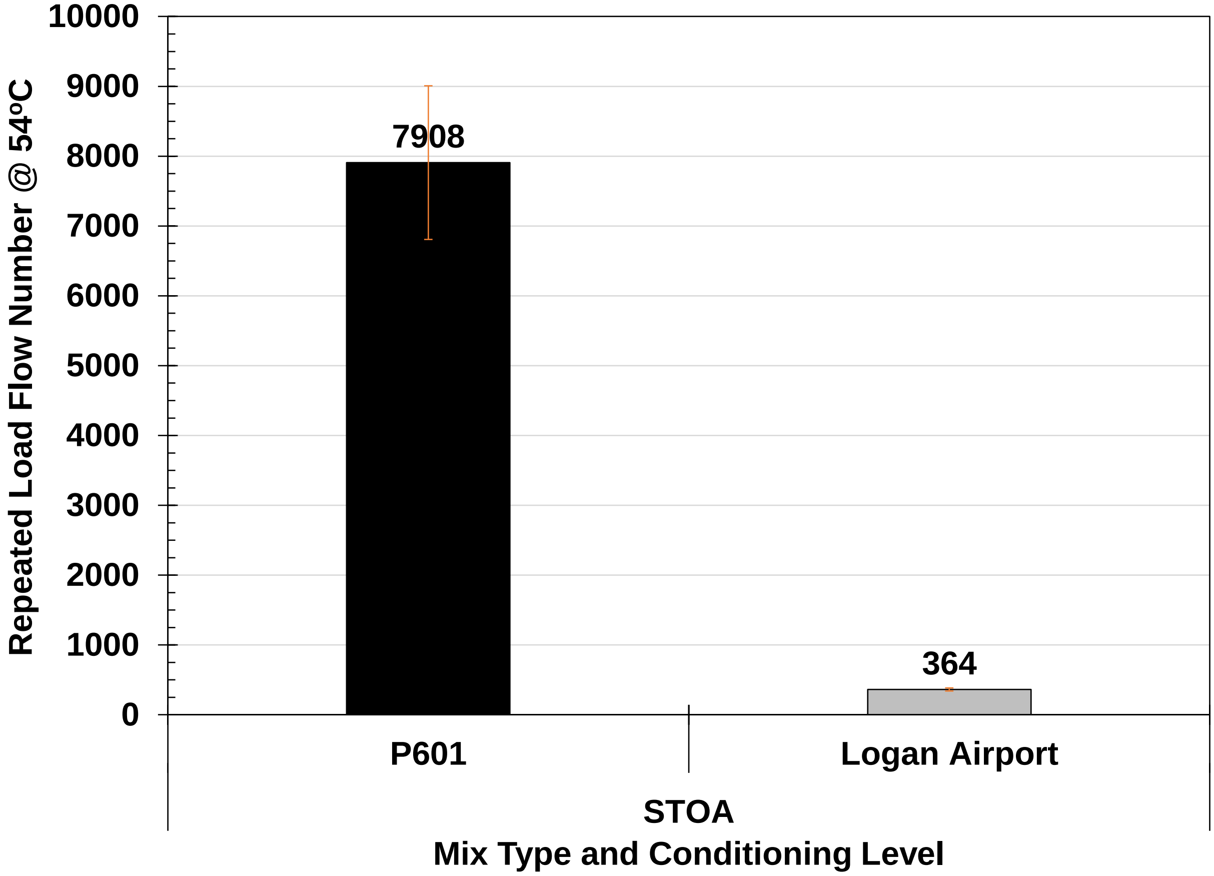

Figure 5 – AMPT Repeated Load Flow Number Results

Table 1 - Minimum Flow Number Requirements (adapted from NCHRP Project 9-33)

Traffic Level *Million ESALs*	**Minimum Flow Number** *Cycles*	**General Rut Resistance**
< 3	---	Poor to Fair
3 to < 10	53	Good
10 to < 30	190	Very Good
≥ 30	740	Excellent

would be sufficient to resist highway traffic of 10 to 30 million ESAL's, while the P601 asphalt mixture would be sufficient to resist highway traffic greater than 30 million ESAL's.

Fatigue Cracking Evaluation

The fatigue cracking properties of the mixtures were evaluated using two test procedures; 1) the Overlay Tester (NJDOT B-10), 2) Semi-Circular Bend (SCB) Flexibility Index (AASHTO TP124), and 3) Flexural Beam Fatigue (AASHTO T321). Fatigue cracking tests were conducted on both short-term conditioned and long-term conditioned asphalt mixtures.

<u>Overlay Tester (NJDOT B-10)</u>

The Overlay Tester, described by Zhou and Scullion (2007), has shown to provide an excellent correlation to field cracking for both composite pavements (Zhou and Scullion, 2007; Bennert et al., 2009) as well as flexible pavements (Zhou et al., 2007). Figure 11 shows a picture of the Overlay Tester used in this study. Sample preparation and test parameters used in this study followed that of NJDOT B-10, *Overlay Test for Determining Crack Resistance of HMA*. These included:

- 25^oC (77^oF) test temperature;
- Opening width of 0.025 inches;
- Cycle time of 10 seconds (5 seconds loading, 5 seconds unloading); and
- Specimen failure defined as 93% reduction in Initial Load.

Test specimens were evaluated under both short-term and long-term aged conditions.

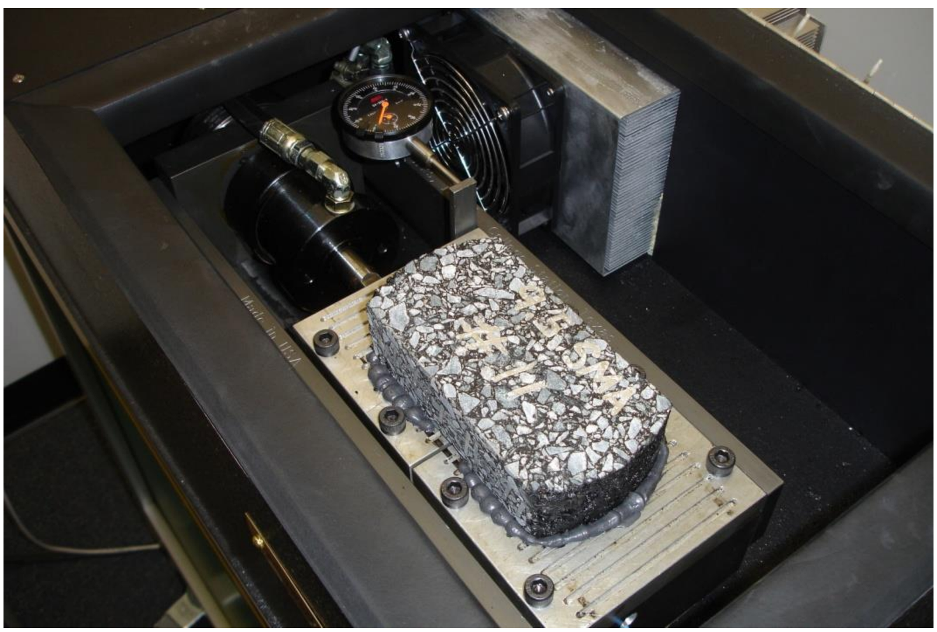

Figure 6 – Picture of the Overlay Tester (Chamber Door Open)

The test results for the Overlay Tester are shown in Figure 7. The test results show that the P601 asphalt mixture was far superior in resisting fatigue cracking resistance at both the Short-term and Long-term aged conditions.

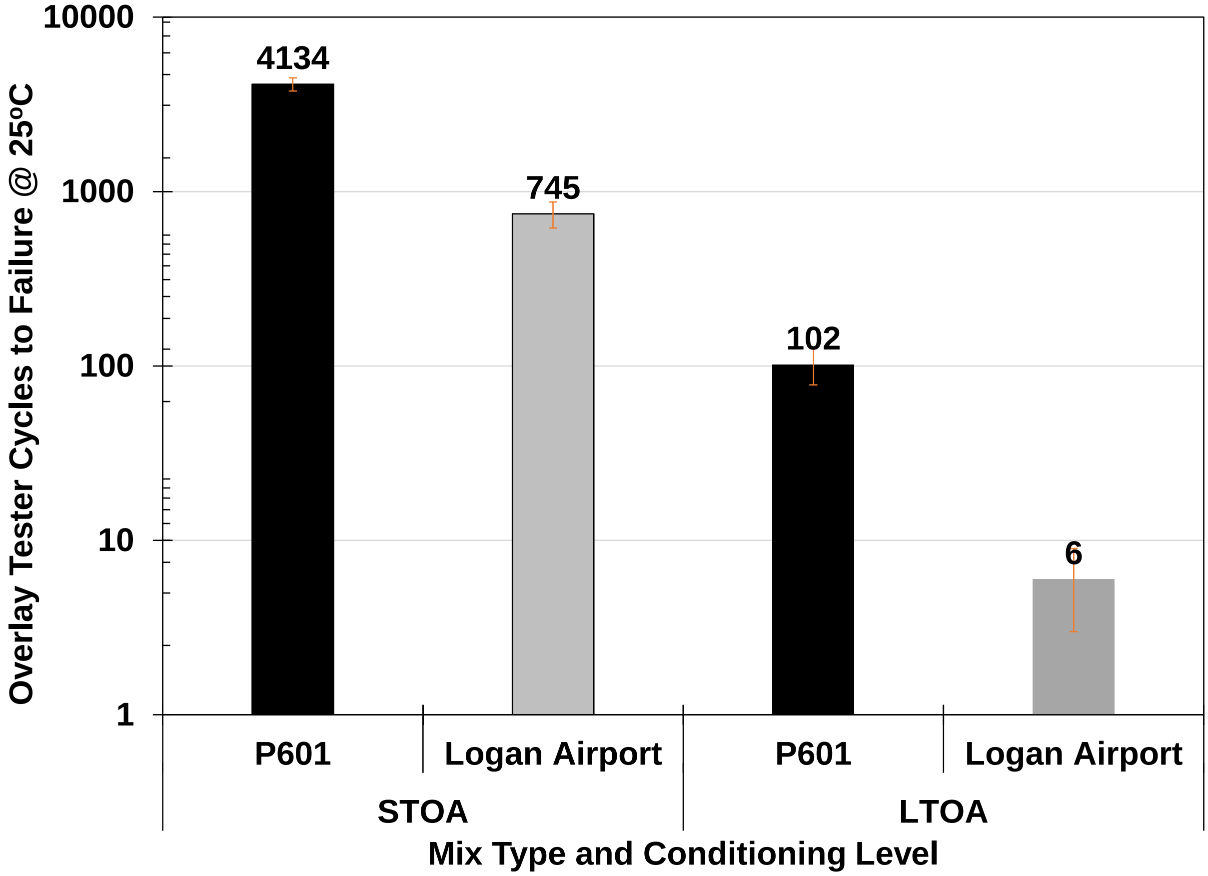

Figure 7 – Overlay Tester Test Results for P601 and Logan Airport Asphalt Mixtures

<u>Semi-Circular Bend (SCB) Flexibility Index (aka I-FIT)</u>

The Illinois SCB Flexibility Index (FI) is conducted using a specimen thickness of 50 mm cut from the middle of a gyratory sample. Strength and displacement are recorded during a 50 mm/min deformation rate. Each SCB-FI sample also has 15.0 mm notch depth to initiate the location of the crack. The FI is equal to the fracture energy divided by the slope of the post peak load-displacement curve at the inflection point, as shown in Figure 8. In general, as the SCB Flexibility Index (FI) value increases, the asphalt mixture's fatigue cracking resistance increases.

The SCB Flexibility Index fatigue cracking test results are shown in Figure 9. Similar to the Overlay Tester, the P601 asphalt mixture shows a better resistance to fatigue cracking at both short-term and long-term aged conditions.

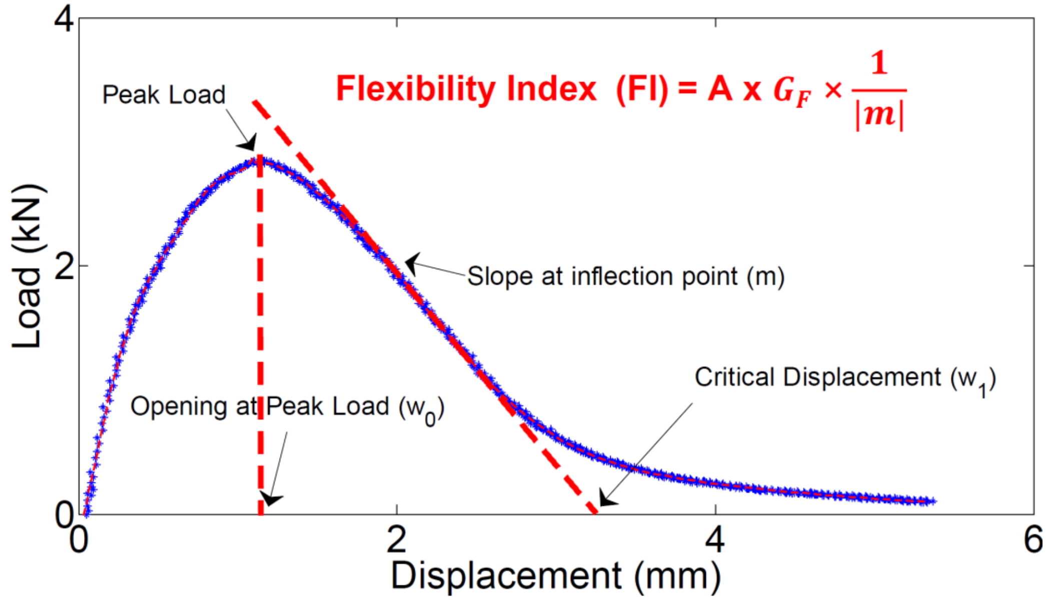

Figure 8 – Illinois SCB Flexibility Index (FI)

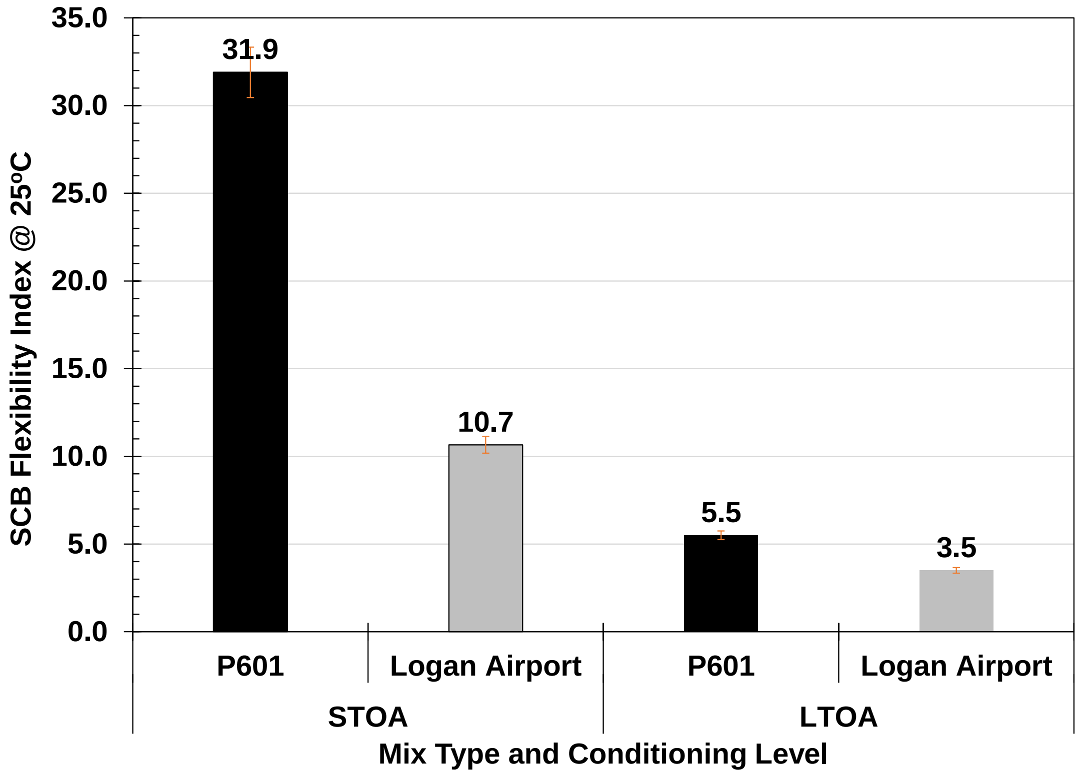

Figure 9 – SCB Flexibility Index Fatigue Cracking Results for P601 and Logan Airport Asphalt Mixtures

Flexural Beam Fatigue (AASHTO T321)

Fatigue testing was conducted using the Flexural Beam Fatigue test procedure outlined in AASHTO T321, *Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending*. The applied tensile strain levels used for the fatigue evaluation ranged between ; 300 to 1200 micro-strains, depending on the asphalt mixture evaluated. Samples were tested at short-term and long-term aged conditions as mentioned earlier.

Samples used for the Flexural Beam Fatigue test were compacted using a vibratory compactor designed to compact brick samples of 400 mm in length, 150 mm in width, and 100 mm in height. After the compaction and aging was complete, the samples were trimmed to within the recommended dimensions and tolerances specified under AASHTO T321. The test conditions utilized were those recommended by AASHTO T321 and were as follows:

- Test temperature = 15^{o}C;
- Sinusoidal waveform;
- Strain-controlled mode of loading and loading frequency of 10 Hz.

The flexural beam fatigue results are shown in Figure 10. At each respective condition, STOA and LTOA, once again the P601 asphalt mixture has a greater resistance to fatigue resistance than the Logan Airport asphalt mixture.

SUMMARY

A testing program was conducted to evaluate the stiffness, rutting and fatigue cracking performance of two different asphalt mixtures utilized on airfield pavements; 1) FAA P601 asphalt mixture and 2) Logan Airport mixture recently utilized on an airfield pavement section on Logan Airport, Boston, MA. The testing program showed that:

- The P601 asphalt mixture achieved better stiffness properties than the Logan Airport asphalt mixture. At the short-term aged condition, the P601 achieved higher modulus at high temperatures, while achieved lower modulus at intermediate/low temperatures. After the asphalt mixtures were aged to simulate approximately 10 years of service life, the P601 asphalt mixture resulted in lower age hardening than the Logan Airport asphalt mixture.
- The permanent deformation properties were evaluated using the AMPT Repeated Load Flow Number test. The P601 asphalt mixture was found to be far superior in rutting resistance than the Logan Airport asphalt mixture.
- The fatigue cracking performance was characterized using three various test methods; 1) Overlay Tester, 2) SCB Flexibility Index, and 3) Flexural Beam Fatigue. A unanimous conclusion was found where the fatigue cracking resistance of the P601 asphalt mixture resulted in better fatigue resistance in all three test methods when compared to the Logan Airport asphalt mixture. This was found at both the STOA and LTOA aged conditions.

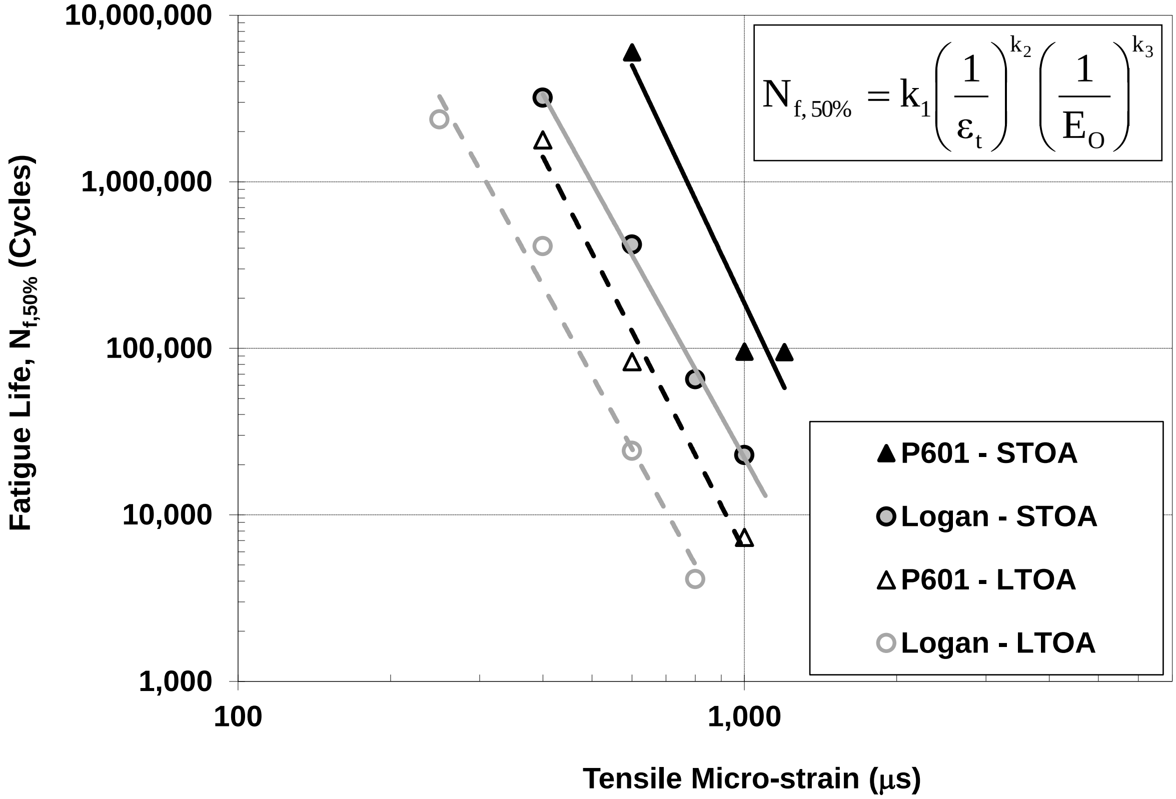

Figure 10 – Flexural Fatigue Results for P601 and Logan Airport Asphalt Mixtures