DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

8 FEB 2008

FROM: AFCESA/CEOA
139 Barnes Drive, Suite 1
Tyndall AFB FL 32403-5319

SUBJECT: **Engineering Technical Letter (ETL) 08-1 (Change 1): Evaluation Criteria for Aged Asphalt Concrete (AC) Surfaces**

1. Purpose. This ETL provides guidance and methods for evaluating aged (i.e., three years or older) asphalt concrete (AC) surfaces in the field.

This ETL supersedes ETL 07-11, *Evaluation Criteria for Aged Asphalt Concrete (AC) Surfaces*, dated 25 September 2007.

2. Application. All Department of Defense (DOD) organizations responsible for airfield maintenance and evaluating airfield pavements.

2.1. Authority: Air Force policy directive (AFPD) 32-10, *Air Force Installations and Facilities.*

2.2. Coordination: Major command (MAJCOM) pavement engineers.

2.3. Effective Date: Immediately.

2.4. Intended Users:
- Air Force Prime BEEF and RED HORSE units.
- U.S. Army Corps of Engineers (USACE).
- Navy and Marine Corps.
- Organizations performing DOD airfield pavement evaluations and/or others responsible for airfield maintenance.

3. Referenced Publications:

3.1. Air Force:
- AFPD 32-10, *Air Force Installations and Facilities*, available at http://www.e-publishing.af.mil/

3.2. Army
- Bell, Haley P. and Reed B. Freeman. (2007). “Evaluation Criteria for Aged Asphalt Concrete Surfaces.” ERDC/GSL TR-07-18. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

http://libweb.wes.army.mil/uhtbin/cgisirsi/20071206203827/SIRSI/0/518/0/GSL-TR-07-18.pdf/Content/1?new_gateway_db=HYPERION

- Bell, Haley P. (2006). "Operating the Portable Seismic Pavement Analyzer," ERDC/GSL SR-06-9, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://libweb.wes.army.mil/uhtbin/cgisirsi/Thu+Aug++9+11:22:41+CDT+2007/SIRSI/0/518/0/GSL-SR-06-9.pdf/Content/1?new_gateway_db=HYPERION
- Bell, Haley P., Dr. Reed B. Freeman, and Dr. E. Ray Brown. (2007). "Evaluation Criteria for Aged Asphalt Concrete Surfaces – Phase II (Draft)."

3.3. Unified Facilities Criteria (UFC):

- UFC 3-260-03, *Airfield Pavement Evaluation*, available at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

3.4. American Society for Testing and Materials (ASTM):

- *Annual Book of ASTM Standards*, available at http://www.astm.org
- ASTM D 6931-07, *Standard Test Method for Indirect Tensile (IDT) Strength of Bituminous Mixtures*, available at http://www.astm.org

4. Acronyms and Terms:

AC	– asphalt concrete
AFC	– aged field correction factor
AFCESA	– Air Force Civil Engineer Support Agency
ASTM	– American Society for Testing and Materials
C	– Celsius
DOD	– Department of Defense
ETL	– engineering technical letter
F	– Fahrenheit
Hz	– hertz
ITS	– indirect tensile strength
IDT	– indirect tensile
ksi	– 1,000 pounds per square inch
lb	– pound
Prime BEEF	– Prime Base Engineer Emergency Force
psi	– pounds per square inch
PSPA	– portable seismic pavement analyzer
RED HORSE	– Rapid Engineers Deployable - Heavy Operations Repair Squadron
USACE	– United States Army Corps of Engineers
USAF	– United States Air Force

5. Preface. It is often necessary for military operations to use existing airfields or roads that consist of aged or brittle AC surfaces. The Air Force's ability to select suitable operating surfaces in the theater of operations is limited by the standard practices of airfield pavement evaluations, which have failed to identify problems caused by the use of aged AC pavements. Military missions may be severely impacted without the ability to predict the performance of aged AC pavements. Field and laboratory tests of aged and unaged AC conducted by the U.S. Army Engineer Research and Development Center concluded that the current DOD criterion for AC fatigue life has difficulty predicting fatigue failure for aged AC surfaces (Bell and Freeman, 2007). The testing protocol presented herein is new criteria for pavement performance predictions at or close to 77 °F (25 °C) and an adjustment to the current DOD criterion at any other pavement temperature. The new criteria and the adjusted criterion are necessary for DOD organizations to improve fatigue life predictions of aged AC pavements (Bell, et al., 2007).

6. Relevant Standard Test Method:

- *Annual Book of ASTM Standards*
- ASTM D 6931-07, *Standard Test Method for Indirect Tensile (IDT) Strength of Bituminous Mixtures*

7. Aged AC Performance Prediction Methods.

7.1. Description of Tests.

7.1.1. Portable Seismic Pavement Analyzer (PSPA) Tests. The PSPA is a nondestructive testing device that rapidly measures Young's modulus via ultrasonic surface waves. The PSPA is used to estimate the in situ seismic modulus of near surface pavement layers and determine relative strength parameters for use in pavement evaluations. The device is operated with a laptop computer connected to an electronics box by a cable that transmits power to the receivers and the source. The source impacts the pavement surface, generating surface waves that are detected by the receivers. The measured signals are returned to the data acquisition board in the computer. The velocity at which the surface waves propagate is determined and the modulus is computed. PSPA tests can be completed within a few seconds and should be conducted at least three times in the same location so an average modulus can be determined. At least ten PSPA measurements should be obtained for each airfield feature (Bell, 2006).

The modulus of AC pavements is dependent upon temperature; therefore, a design modulus must be used to standardize the PSPA results for purposes of predicting pavement performance. The AC design modulus is used to adjust the modulus measured by the PSPA at the field temperature, to a temperature of 77 °F (25 °C) and a design frequency of 15 hertz (Hz) using Equation 1.

$$E_{77^\circ F} = \frac{E_{PSPA}}{\left[(-0.0109*((T-32)*\frac{5}{9})+1.2627)*(3.2)\right]} \tag{1}$$

$E_{77°F}$ = AC design modulus, ksi
E_{PSPA} = modulus measured from the PSPA, ksi
T = AC pavement temperature, °F

The AC design modulus is incorporated with the test results during the data analysis phase. $E_{77°F}$ is the adjusted AC modulus value to use for recording or analyzing data (Bell, 2006).

7.1.2. Indirect Tensile Strength (ITS) Tests. ITS tests determine the tensile strength or stress of a cored sample. The tests are performed by loading a cylindrical specimen on a machine where a compressive load at a controlled deformation rate of 2 inches (50 millimeters) per minute is applied. The peak load at failure is recorded and used to calculate the ITS peak stress of the cored specimen. The ITS test procedure is presented in ASTM D 6931-07. Equation 2 is used to calculate the ITS peak stress of a sample.

$$S = \frac{2*P}{\pi * t * D} \tag{2}$$

S = ITS peak stress, psi
P = maximum load, lb
t = specimen height before test, inches
D = specimen diameter, inches

7.2. Testing Protocol. If predicting pavement performance (passes to failure), pavement evaluations should include either PSPA tests to determine the AC design modulus (at 15 Hz and 77 °F [25 °C]) or ITS tests on 4-inch (100-millimeter) -diameter cores to determine the peak stress.

7.2.1. PSPA Modulus. If the PSPA is included in a pavement evaluation, to indicate AC integrity in terms of elastic modulus, use Equation 3 to predict the fatigue life of aged field AC at or around 77 °F (25 °C). The PSPA can be used on an AC surface at any pavement temperature; however, the field-measured modulus must be adjusted to the AC design modulus using Equation 1 as shown in paragraph 7.1.1. The corrected modulus at 77 °F (25 °C) should then be used with Equation 3 to predict the fatigue life of the pavement. The estimated tensile strain at the bottom of the AC layer should be found by layered elastic analysis (i.e., WinJULEA) using the AC modulus (E), or estimates can be found in Tables 1 and 2.

$$Log_{10}(\varepsilon_{ra}) = 7.94 - \left[\frac{LN\left(S_A x10^6\right)}{2.61}\right]^2 + \frac{E}{438{,}000\text{ psi}} \quad (3)$$

ε_{ra} = allowable strain repetitions for aged field AC
S_A = tensile strain of AC, inch/inch
E = AC design modulus, psi

7.2.2. ITS Test. If ITS tests are used in a pavement evaluation, to indicate AC integrity in terms of peak ITS stress, use Equation 4 to predict the fatigue life of aged field AC at 77 °F (25 °C). The ITS tests are performed in a laboratory at room temperature (around 77 °F [25 °C]). An estimate for AC modulus is needed to calculate the AC tensile strain by layered elastic analysis. Methods of estimating AC modulus are presented in UFC 3-260-03, *Airfield Pavement Evaluation*.

$$Log_{10}(\varepsilon_{ra}) = 8.36 - \left[\frac{LN\left(S_A x10^6\right)}{2.62}\right]^2 + \frac{ITS\ Peak\ Stress,\ psi}{264\text{ psi}} \quad (4)$$

Note: The tests described in paragraphs 7.2.1 and 7.2.2 estimate passes to failure only when the pavement temperature is at or close to 77 °F (25 °C). Paragraph 7.2.3 describes how to determine passes to failure at any pavement temperature (other than 77 °F [25 °C]). One of the tests described in paragraphs 7.2.1 and 7.2.2 must be completed, in addition to the procedure described in paragraph 7.2.3, if the pavement performance at any temperature other than 77 °F (25 °C) is desired.

7.2.3. Adjusting Original DOD Fatigue Criterion. To predict repetitions to failure for aged field AC at any temperature other than 77 °F (25 °C), an aged field AC fatigue correction factor (AFC) must be calculated and applied, as follows in Equation 5. Each Log$_{10}$(ε_r) is calculated with the same assumption for strain.

$$AFC = \frac{Log_{10}(\varepsilon_{ra})\, at\, 77°F\ using\ aged,\ field\ asphalt\ criteria}{Log_{10}(\varepsilon_r)\, at\, 77°F\ using\ the\ original\ DOD\ criterion} \quad (5)$$

Log$_{10}$(ε_{ra}) at 77 °F (25 °C) using aged field asphalt criteria is found using Equation 3 (paragraph section 7.2.1) or Equation 4 (paragraph 7.2.2). Log$_{10}$(ε_r) at 77 °F (25 °C) using the original DOD criterion can be found with Equation 6 below. E is the modulus of a pavement at or around 77 °F (25 °C), and ε_r is the allowable strain repetitions for the AC.

$$Log_{10}(\varepsilon_r) = 2.68 - 5.0 * Log(S_A) - 2.665 * Log(E) \quad (6)$$

Once the AFC is known, the adjustment factor is applied to the original DOD criterion for calculated repetitions to failure at any temperature (Equation 7 or 8). The term ε_{rc}

is the allowable strain repetition corrected for any pavement temperature and modulus.

$$Log_{10}(\varepsilon_{rc}) = Log_{10}(\varepsilon_r) \times AFC \tag{7}$$

or

$$\varepsilon_{rc} = (\varepsilon_r)^{AFC} \tag{8}$$

Note: If the strain at the bottom of the AC is unknown, then refer to Tables 1 and 2 below for an estimate. The tables give typical values of S_A for DOD aircraft according to AC pavement thickness, AC modulus, base thickness, and aircraft pass levels. Table 1 is for an AC modulus of approximately 350 ksi and Table 2 is for an AC modulus of approximately 700 ksi.

Note: The strain at the bottom of the AC can also be computed using a design analysis within WinJULEA, available under the Help/Utilities menu of the PCASE (Pavement-Transportation Computer Assisted Structural Engineering) software (www.pcase.com).

Table 1. Pavement Designs and Calculated AC Strains for a 350 ksi AC Modulus.

Aircraft	AC Thickness (in.)	Base Thickness (in.)	Base Modulus (ksi)	Subgrade Modulus (ksi)	Design Aircraft Passes	S_A (in./in.)
C-17	3	19	50	15	2,000	-2.95E-04
C-17	3	23	50	15	50,000	-2.94E-04
C-17	3	12	75	30	20,000	-1.74E-04
C-17	3	14.5	75	30	1,000,000	-1.70E-04
C-17	4	17	50	15	2,000	-3.98E-04
C-17	4	21.5	50	15	50,000	-3.90E-04
C-17	5	15.5	50	15	2,000	-4.36E-04
C-17	5	20	50	15	50,000	-4.22E-04
C-17	10.5	20	75	30	1,000,000	-2.43E-04
C-130	3	13.5	50	15	2,000	-1.83E-04
C-130	3	18.5	50	15	200,000	-1.73E-04
C-130	3	7.5	75	30	20,000	-1.21E-04
C-130	3	10	75	30	1,000,000	-1.03E-04
C-130	4	15.5	50	15	50,000	-2.66E-04
C-130	4	17	50	15	200,000	-2.62E-04
C-130	4	18.5	50	15	1,000,000	-2.59E-04
C-130	5	10	50	15	2,000	-3.41E-04
C-130	5	15	50	15	200,000	-3.05E-04
C-130	5	15.5	50	7.5	2,000	-3.09E-04
C-130	5	20	75	30	1,000,000	-1.93E-04
F-15	3	16.5	50	15	2,000	-8.92E-04
F-15	3	18	50	15	10,000	-8.79E-04
F-15	5	20	50	15	20,000	-7.73E-04
F-15	7.5	20	50	15	100,000	-5.58E-04
F-15	9	20	75	30	1,000,000	-3.66E-04

Analysis based on an AC Poisson’s ratio of 0.35, base Poisson’s ratio of 0.35, and subgrade Poisson’s ratio of 0.40.

Table 2. Pavement Designs and Calculated AC Strains for a 700 ksi AC Modulus.

Aircraft	AC Thickness (in.)	Base Thickness (in.)	Base Modulus (ksi)	Subgrade Modulus (ksi)	Design Aircraft Passes	S_A (in./in.)
C-17	3	18	50	15	2,000	-3.40E-04
C-17	3	22	50	15	50,000	-3.33E-04
C-17	3	11	75	30	20,000	-2.35E-04
C-17	3	12.5	75	30	200,000	-2.29E-04
C-17	4	16	50	15	2,000	-3.85E-04
C-17	4	19	50	15	20,000	-3.75E-04
C-17	4	9	75	30	20,000	-2.98E-04
C-17	5	13.5	50	15	2,000	-3.90E-04
C-17	5	16.5	50	15	20,000	-3.75E-04
C-17	12.5	20	75	30	1,000,000	-1.52E-04
C-130	3	13	50	15	2,000	-2.39E-04
C-130	3	19.5	50	15	1,000,000	-2.18E-04
C-130	3	6.5	75	30	20,000	-1.86E-04
C-130	3	9	75	30	1,000,000	-1.61E-04
C-130	4	8	50	15	2,000	-3.35E-04
C-130	4	14	50	15	50,000	-2.79E-04
C-130	4	15.5	50	15	200,000	-2.73E-04
C-130	4	6.5	75	30	500,000	-2.30E-04
C-130	5	7.5	50	15	2,000	-3.38E-04
C-130	5	13	50	15	200,000	-2.89E-04
C-130	5	13.5	50	7.5	2,000	-3.07E-04
C-130	5	20	75	30	1,000,000	-1.89E-04
F-15	3	15.5	50	15	2,000	-7.64E-04
F-15	5.5	20	50	15	20,000	-5.28E-04
F-15	7.5	20	50	15	100,000	-3.86E-04
F-15	9.5	20	75	30	1,000,000	-2.41E-04
Analysis based on an AC Poisson's ratio of 0.35, base Poisson's ratio of 0.35, and subgrade Poisson's ratio of 0.40.						

8. Point of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to the Pavements Engineer, HQ AFCESA/CEOA, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, DSN 523-6439, commercial (850) 283-6439, e-mail AFCESAReachbackCenter@tyndall.af.mil

JAMES D. FRISHKORN, Colonel, USAF
Director, Operations and Program Support

1 Atch
Distribution List

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Defense Commissary Agency (1)
Design and Construction Division
2250 Foulois St., Suite 2
Lackland AFB, TX 78236

AAFES (1)
ATTN: RE-C
PO Box 660202
Dallas, TX 75266-0202

SPECIAL INTEREST ORGANIZATIONS

Information Handling Services (1)
15 Inverness Way East
Englewood, CO 80150

Construction Criteria Base (1)
National Institute of Bldg Sciences
Washington, DC 20005