SEISMIC MEASUREMENT OF PORTLAND CEMENT CONCRETE SURFACES AS AN ALTERNATIVE TO CONCRETE CORING

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ABSTRACT

An assessment of the portable seismic pavement analyzer (PSPA) was conducted on three military airfields in order to determine the feasibility of rapidly obtaining the modulus and flexural strength of Portland cement concrete (PCC) pavements. The PSPA is a nondestructive testing device that measures the seismic modulus of concrete pavements using ultrasonic surface waves. The objective of this research was to evaluate the PSPA as an alternative to core sampling. This would potentially reduce the amount of time required for field testing and eliminate the need for laboratory testing of concrete cores. Currently, there are no methods other than laboratory testing to determine the flexural strength of PCC. Laboratory and field test results from the PSPA investigation were used to form a relationship between PSPA modulus and flexural strength. Additional laboratory testing was conducted to check the validity of the new relationship. Results of the research showed that with the use of the PSPA, strength parameters of PCC can be determined within a few seconds. The PSPA is a critical testing device needed by pavement evaluation teams in order to determine PCC strength properties and complete military pavement evaluations in a more effective manner.

1 BACKGROUND

Pavement evaluation teams remove as many as 100 to 150 cores samples for a typical airfield evaluation in order to determine the flexural strength and thickness of the concrete pavement. Airfield pavement evaluation teams have an immediate need for non-destructive testing equipment and analytical procedures for assessing the integrity of Portland cement concrete (PCC) pavements onsite, thereby eliminating the cost and time delays associated with obtaining concrete cores and awaiting laboratory test results. Seismic testing techniques have shown great promise, and recent equipment developments make this a potentially viable option.

Removal of concrete cores allows for visual inspection of the entire surface layer, accurate thickness measurements, and provides a cylindrical specimen for laboratory tensile splitting tests. However, obtaining concrete core samples is costly, destructive, time-consuming, and may not be representative of the entire pavement area. With non-destructive testing methods, there is minimal interference with airfield operations. The objective of this study was to evaluate the portable seismic pavement analyzer (PSPA) as non-destructive alternative to core sampling. This would potentially reduce the amount of time required for testing, eliminate the need for laboratory testing of concrete cores, and reduce costs.

1.1 PSPA Description

The PSPA was developed to aid in detecting pavement defects during curing and in early stages. The PSPA (Figure 1) is a simple, non-destructive device that rapidly measures Young's modulus via ultrasonic surface waves, completing tests within a few seconds. The purpose of the PSPA for this research was to estimate the in situ seismic modulus of concrete pavements and determine relevant strength parameters for use in pavement evaluations.

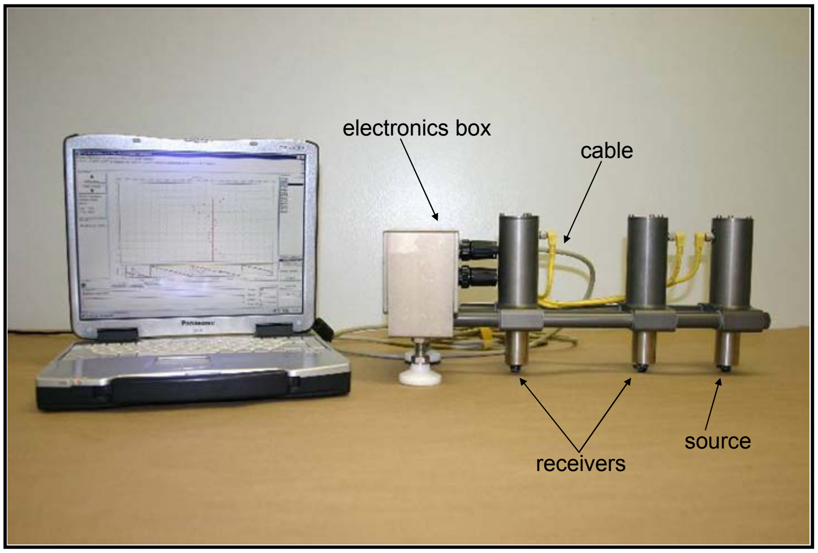

Figure 1 – PSPA components.

The PSPA is operated from a laptop computer, which is connected to an electronics box by a cable that transmits power to two receivers and a source. The source impacts the pavement surface, generating surface waves that are detected by the receivers. The measured signals are then returned to the data acquisition board in the computer. The velocity at which the surface waves propagate is determined, and the modulus is computed.

2 FIELD TESTING PROCEDURES

PSPA evaluations were conducted at Hurlburt Air Force Base (HAFB) in Fort Walton Beach, FL, and Barksdale Air Force Base (BAFB) in Shreveport, LA. PSPA tests were conducted on the core hole locations just prior to drilling core samples (Figure 2). After the concrete cores samples were obtained from the airfield, members of the airfield pavement evaluation team sawed the ends of the cores and performed tensile splitting tests on site. The tensile splitting strength, σ, was then used in Equation 1, shown below, to obtain the flexural strength for the concrete pavements [1]. This procedure is common when determining flexural strength of military airfield pavements. Flexural strength and tensile spitting strength are reported in units of psi.

$$\text{flexural strength} = \sigma * 1.02 + 210 \quad (1)$$

Figure 2 – PSPA testing at the core hole location.

3 RELATED PSPA STUDIES

3.1 In Situ Strength Measurements

A combined field testing and laboratory study was conducted in 1996 for the Pavement Technical Assistance Program to evaluate the capabilities of the PSPA and develop test procedures and relationships for the determination of PCC flexural strength for use in pavement structural evaluations. The laboratory testing included using two aggregate types (crushed limestone and siliceous river gravel) and multiple PCC strengths, while the field testing assessed the ruggedness and reliability of the PSPA, provided verification for the laboratory testing, and allowed for the direct correlation of in situ seismic measurements with laboratory measurements. A relationship between measured PSPA modulus and flexural strength was developed from this study [2].

3.2 Acceptance Criteria Based on Innovative Testing of Concrete Pavements

A PSPA laboratory study was conducted in 2005 for the Innovative Pavement Research Foundation as a collaborative effort involving the US Army Engineer Research and Development Center (ERDC), Vicksburg, MS, the University of Texas at El Paso, El Paso, TX, and the University of Illinois at Chicago, Chicago, IL, to implement seismic testing as an acceptance criteria for concrete airfield pavement construction. The procedure consisted of building small-scale slabs using three aggregate types (siliceous river gravel, granite, and limestone) with multiple mix design deviations and obtaining core samples and beams from the concrete slabs. The PSPA was tested on the slabs at time intervals of 1, 3, 7, 14, and 28 days before the beams and cores were removed. Flexural strength was determined from the beams, and compressive strength was determined from the core samples [3].

4 FLEXURAL STRENGTH RELATIONSHIP

The data from the PSPA laboratory studies conducted in 1996 and 2005 were combined in order to develop a relationship between the PSPA modulus and flexural strength for PCC pavements. The flexural strength values from these studies were obtained from beams that were prepared and tested in the laboratory. Figure 3 shows the correlation that was developed using four aggregate types. As shown on the plot, the R-squared value is 0.53, and the correlation is shown in Equation 2. E_{PSPA} is the measured PSPA modulus in units of ksi, and flexural strength is calculated in units of psi.

$$\text{flexural strength} = 0.12 * E_{PSPA} \qquad (2)$$

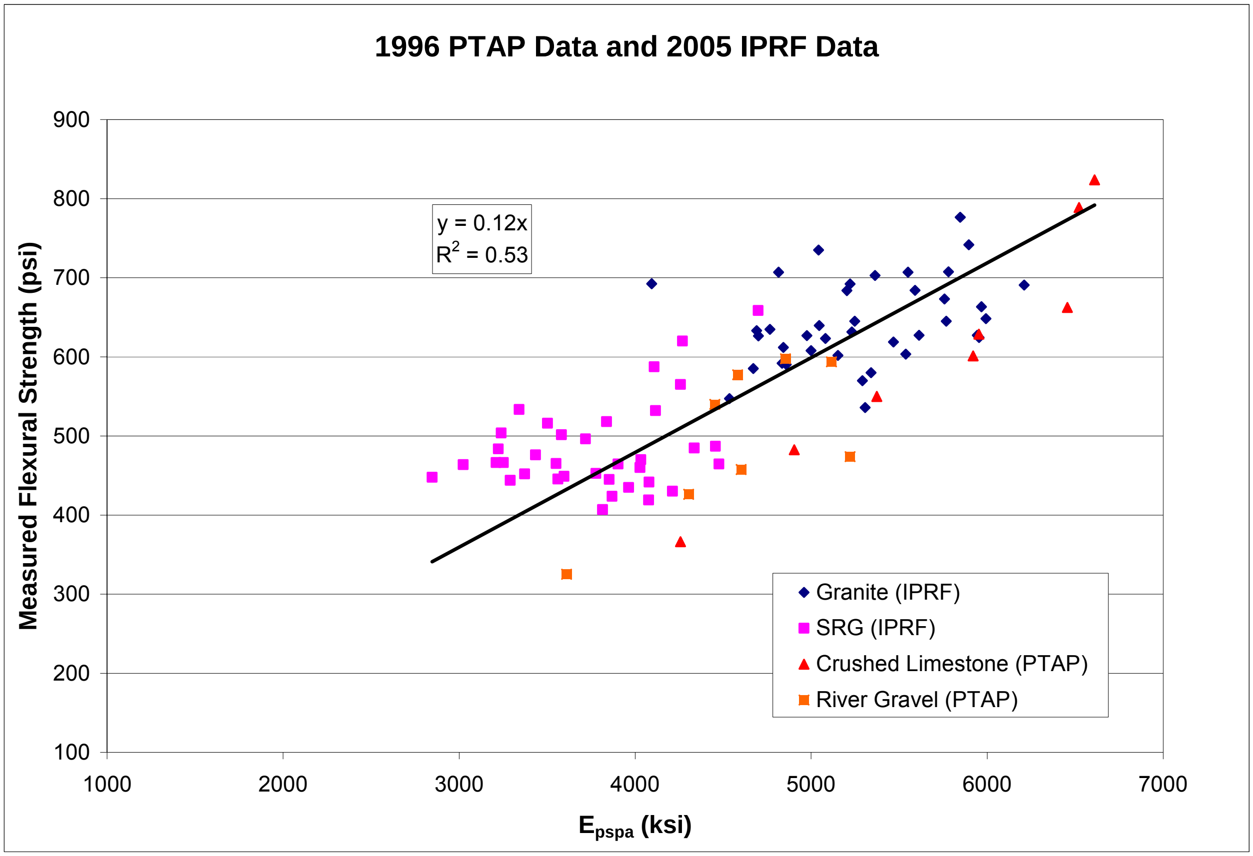

Figure 3 – Correlation between measured PSPA modulus and flexural strength.

5 ADDITIONAL TESTING

Additional PSPA testing was conducted on a PCC slab located under the Hangar 4 facility at the ERDC and from a removed PCC slab from BAFB. The purpose of this additional testing was to compare the flexural strength determined from the correlation of the PSPA modulus (Equation 2) with the flexural strength determined from the correlation of the tensile splitting strength (Equation 1) using the actual flexural strength determined from breaking the beams in the laboratory. The Hangar 4 slab consisted of 18 in. of PCC, and the BAFB slab consisted of 8 in. of PCC. The PSPA was tested at several locations on the slabs to determine an average modulus before the slabs were brought to the concrete laboratory for beam and core removal and testing. A total of eight beams (four from the top and four from the bottom) and three cores were removed from the Hangar 4 slab. Five beams and three cores were removed from the BAFB slab. The beams were broken using repeated flexural bending in order to determine the flexural strength of the concrete, and tensile splitting tests were conducted on the core samples. Flexural strength was estimated from the tensile splitting results using Equation 1, and from the PSPA modulus correlation (Equation 2).

6 RESULTS AND DISCUSSION

The recently developed correlation between measured PSPA modulus and flexural strength (Equation 2) was incorporated with the measured PSPA moduli from HAFB and BAFB to obtain flexural strength. Figure 4 shows the flexural strength data of HAFB computed from the tensile splitting tests (Equation 1) and PSPA correlation (Equation 2) at each core hole, and Figure 5 shows the same estimates of flexural strength from BAFB.

The plots show that the average flexural strength from the PSPA correlation (Equation 2) is consistently around 20% lower than the average flexural strength from the tensile splitting correlation (Equation 1).

The same trend was observed when comparing the flexural strengths of the two correlations from the Hangar 4 slab and the BAFB slab, as shown in Table 1. More importantly, the data shows that the average flexural strength obtained from the PSPA modulus correlation is closer to the actual average flexural strength determined from the beam tests in the laboratory than the flexural strength determined from the tensile splitting correlation.

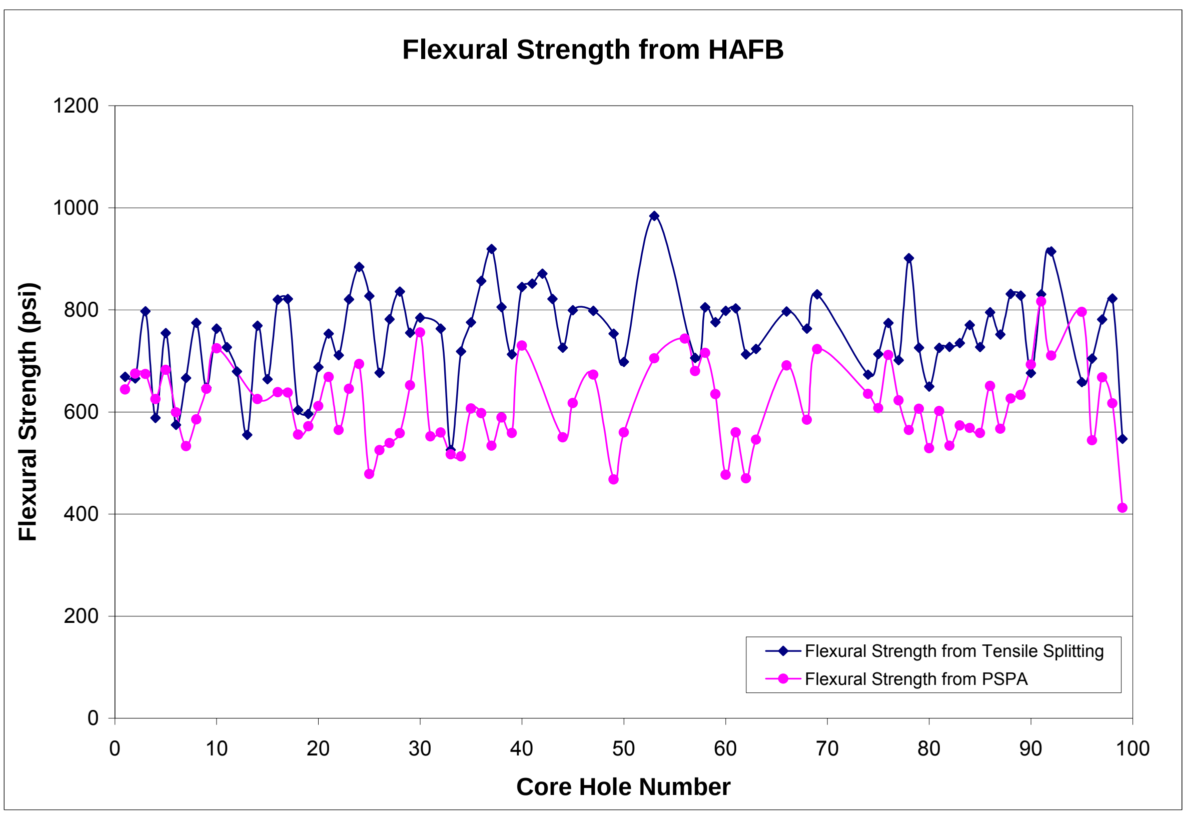

Figure 4 – Flexural strength values from PSPA and tensile splitting correlations at HAFB.

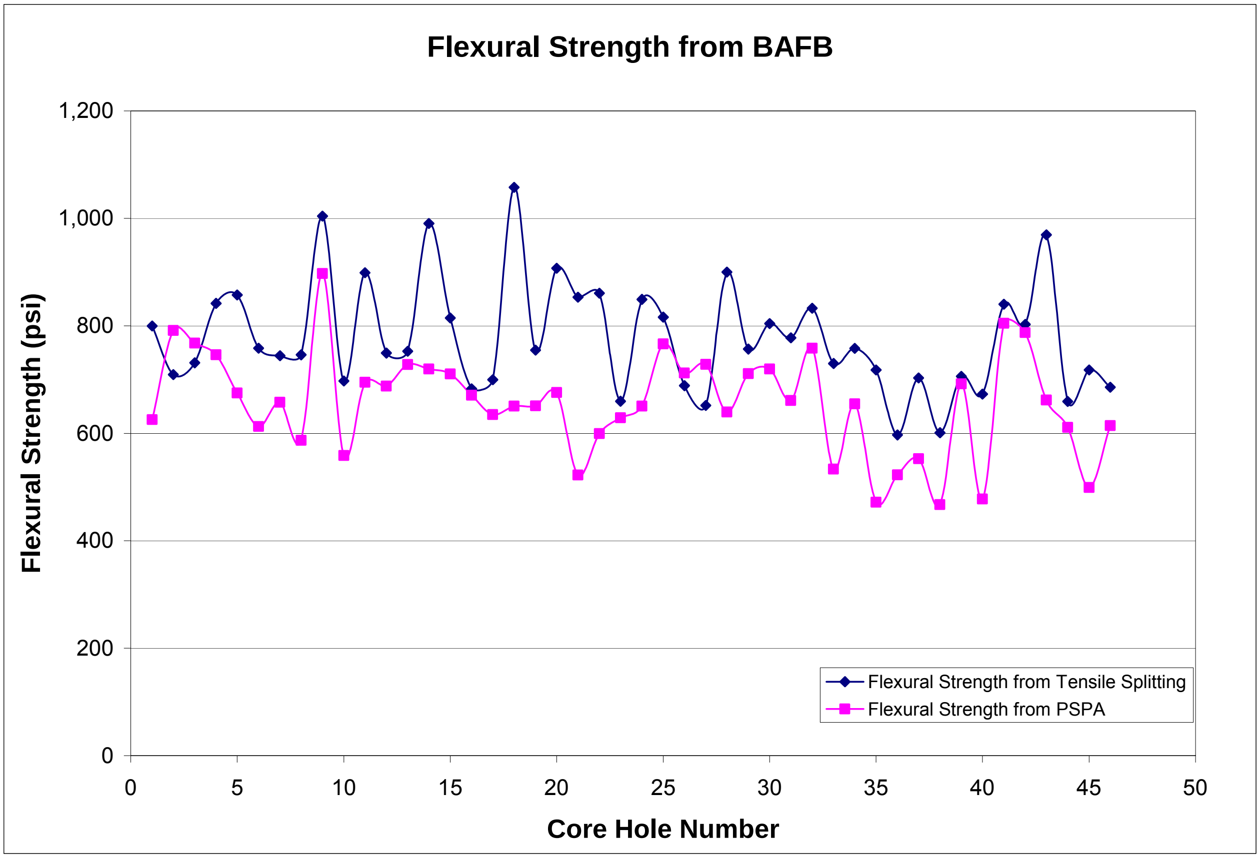

Figure 5 – Flexural strength values from PSPA and tensile splitting correlations at BAFB.

Table 1 – Flexural strength values from field and laboratory tests.

Test Site	Average Flexural Strength (psi)			Ratio (PSPA: TS)
	Beam Tests	PSPA	Tensile Splitting	
HAFB	------	612	751	0.81
BAFB	------	656	778	0.84
Hangar 4 Slab	547	653	788	0.83
BAFB Slab	814	726	936	0.78

7 SUMMARY

This study concluded that the PSPA provides a reliable measure of PSPA modulus. Furthermore, a correlation between the measured PSPA modulus and flexural strength was developed based on data from the 1996 Pavement Technical Assistance Program and 2005 Innovative Pavement Research Foundation studies. The average flexural strength obtained from the PSPA modulus correlation is closer to the actual average flexural strength determined from beam tests in the laboratory than the flexural strength obtained from tensile splitting tests. The flexural strength obtained from PSPA measurements is consistently about

20% less than comparable flexural strength obtained using tensile splitting tests. Airfield pavement evaluation teams put a large amount of labor and time into collecting concrete core samples. In the time that one core sample is collected, 20 PSPA tests can be completed. Precise pavement thickness is one important measurement the PSPA is lacking. Thickness estimates from the PSPA are not accurate enough for pavement evaluations; however, additional research could potentially yield the desired accuracy.

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