SUBSURFACE SENSING LAB
THE UNIVERSITY OF HOUSTON

Project Summary Report 0-4827-S
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Project 0-4827: Feasibility Study of Non-Contact, High Speed Elastic Property Measurement of Pavements
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PROJECT SUMMARY REPORT

# Feasibility Study of Non-Contact, High Speed Elastic Property Measurement of Pavements: Summary Report

Elastic properties of asphalt pavements are extensively used for pavement evaluation and maintenance scheduling. Presently, methods such as Falling Weight Deflectometer (FWD), Plate Load Tests and Rolling Dynamic Deflectometer (RDD) are used by the Texas Department of Transportation (TxDOT) for these measurements. These methods have a slow rate of data production because they are contact measurement systems. In this project, a laser system and a Ground Penetrating Radar (GPR) system were developed for the measurement of the elastic properties of asphalt pavement. Several experiments and field tests were conducted to find the correlation between the electrical properties and the elastic properties of asphalt pavements. Lab tests performed using the frequency-modulated continuous-wave (FMCW) GPR and the Pulse GPR indicated a close correlation between the dielectric constant of asphalt and its density. The Pulse GPR was then used to estimate pavement deflection for a 0.3-mile pavement section and the results were compared with the FWD results. The pavement deflections estimated using the GPR and those measured using the FWD were found to be within an acceptable range of error.

## *What We Did …*

This research is to study the following two aspects: 1) replacing geophone sensors with laser sensors; 2) the relationship between elastic and electrical properties of pavement materials, and finding methods to derive elastic property values of pavement materials by measuring their electrical properties. The research conducted in this project includes:

### (1) Laser Device for Deflection Measurement

The laser device developed for measurement of pavement deflection works on the triangulation principle. Figure 1 demonstrates the geometry of image formation. The laser beam intercepts the optical axis at point A and the reflected laser spot located at point A′ (on the position detector). Image B′ corresponds to point B. By the law of image focusing, the change of $h$ on the position detector is determined by

$$h = \frac{Hf \sin\alpha}{(H\sin\alpha - f)\sin\beta}$$

where $f$ is the focus length of the lens; $\alpha$ is the angle between the projected laser beam and reflected laser beam; $\beta$ is the angle of the reflected laser beam on the position detector; and H is the sensing range. On the other hand, once $h$ is measured, $H$ can be found.

### (2) Accelerometer

Because the pushcart or the FWD frame, referred to as laser frame on which the laser device is mounted, will vibrate after the falling weight impacts on the pavement, this frame vibration causes errors in the laser-measured deflections. To solve this problem, the accelerometers are employed to measure the vibration of the laser frame. The acceleration data was integrated twice to get the vibrations in mils. Finally, the pavement deflections measured using the laser were compensated by the laser frame vibration using the measured frame vibration. A setup of the laser and accelerometer with the FWD device is shown in Fig. 2.

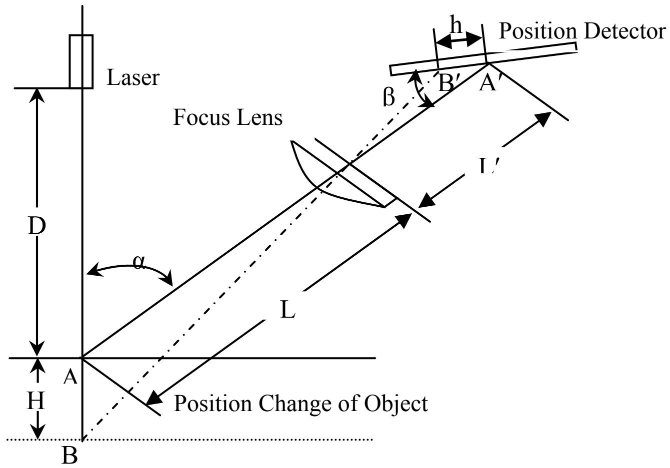


**Fig. 1 Triangulation principle**

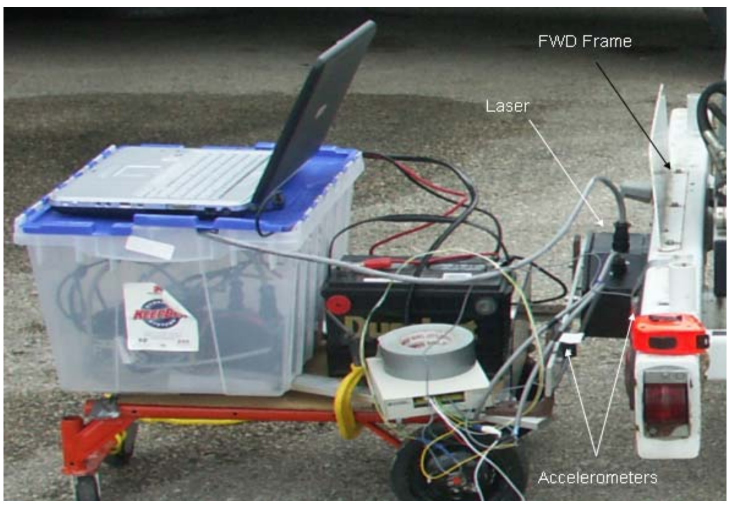


**Fig. 2 Laser device setup**

**Fig. 3 GPR device for elastic properties measurement**

### (3) GPR Device for Measuring Electrical Properties of Pavements

The elastic properties of pavement materials are theoretically correlated with their electrical properties. The measurement of elastic properties should be achieved indirectly by measuring the electrical properties of a pavement. To accurately measure the electrical properties of pavement, both time domain and frequency domain methods were investigated. The Pulse GPR is based on time domain measurement at a lower frequency band. It is used to measure elastic properties of deep pavement layers. The FMCW GPR is used to measure top pavement layers, especially thin asphalt layers, to increase the resolution. The developed GPR device is shown in Fig. 3.

### (4) Correlation Study between the Elastic and Electrical Properties of Pavement Materials

A step-by-step approach was used to corroborate the proposed methods for measurement of pavement deflections using GPR. Initial simple lab experiments were performed to confirm the relationship between the density of asphalt and its dielectric constant. These experiments were followed by field tests on test pads using the GPR and the FWD. The FWD and the GPR data were then processed and compared. The relationship between the two data sets was mapped and curve-fitted to give an empirical relationship between the deflection of pavements and the processed GPR data. As the final step, GPR data was collected from a section of pavement at intervals of 5 feet

**Table 1 Deflections measured by laser device and FWD**

| | Laser (mils) | FWD (mils) |
|---|---|---|
| **Drop 1** | 9.65 | 12.5 |
| **Drop 2** | 12.17 | 12.43 |
| **Drop 3** | 13.37 | 13.05 |
| **Drop 4** | 13.5 | 13.2 |
| **Drop 5** | 10.15 | 12.5 |

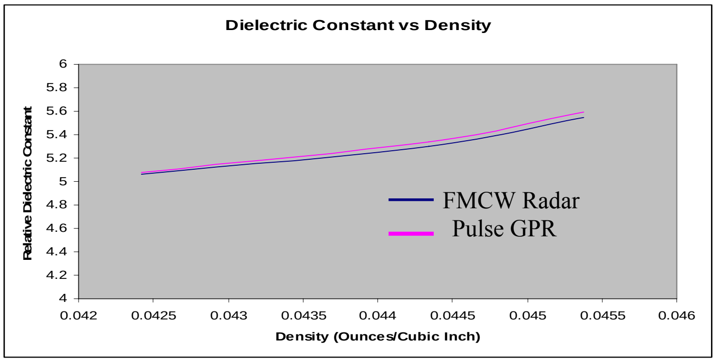


**Fig. 4 The relation between asphalt dielectric constant and its density**

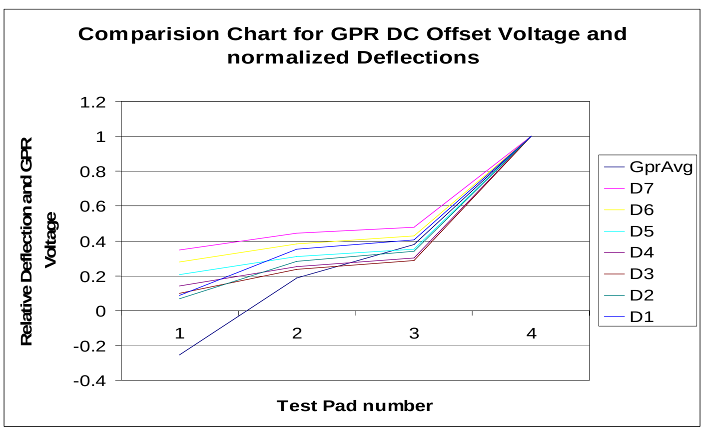


**Fig. 5 Comparison of GPR and FWD data**

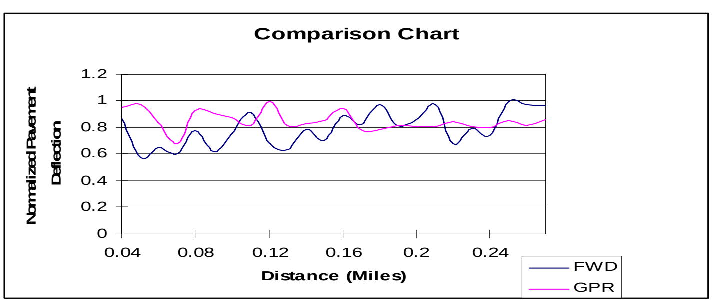


**Fig. 6 Correlation between GPR and FWD data**

and the calculated pavement deflection results were compared with the data collected by FWD.

## *What We Found…*

1.) The laser device and accelerometer device were tested in the field; the setup of the devices is illustrated in Fig. 2. After compensating the effect of the laser frame vibration from the recorded deflections, the pavement deflections using the laser device and FWD were compared. Table 1 shows the results obtained using the FWD and the laser device for deflections measured at 20 inches from the point of load impact. The laser device measured results are very close to the results measured by FWD geophone sensors. Laser sensors are verified to be capable of replacing current geophone sensors.

2.) The measured dielectric constants of asphalt by Pulse GPR and FMCW GPR were plotted against density as shown in Fig. 4. This graph clearly shows that the dielectric constant of asphalt is correlated with its density. The correlation is more of a monotonic correspondence.

3.) The tests conducted on TTI Test Pads, as shown in Fig. 5, demonstrate that the pavement deflections have a monotonic correspondence with the GPR data.

4.) As shown in Fig. 5, the profile of the deflections measured on TTI Annex using the GPR and the FWD indicates that the relative error between the measurements using FWD and GPR was within the acceptable range.

## *The Researchers Recommend…*

Construct a database of different kinds of pavement structures to improve measurement accuracy and speed.

Develop algorithms for obtaining better correlation.

## *For More Details...*

This research is documented in:

Report 0-4827-1, *Feasibility Study of Non-Contact, High Speed Elastic Property Measurement of Pavements-Theoretical and Experimental Results*

Report 0-4827-2, *Feasibility Study of Non-Contact, High Speed Elastic Property Measurement of Pavements*


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