



## APPLICATION OF DATA INTEGRATION TECHNIQUES TO NONDESTRUCTIVE TESTING OF PAVEMENTS

Nondestructive testing (NDT) techniques have made substantial progress in the last two decades. The Falling Weight Deflectometer (FWD) is extensively used in the day-to-day activities. The Ground Penetrating Radar (GPR), the seismic pavement analyzer, and the portable seismic pavement analyzer (PSPA) are also used (see Figure 1). Each of these technologies has its strengths and weaknesses. However, when combined, they can provide a wealth of information not available when one technology is used alone.

The ideal NDT device for the pavement evaluation would be one that integrates as many NDT tools as possible. A fully integrated system

would offer many potential opportunities.

The first step toward a fully integrated hardware tool is an integrated software tool. The objective of this project is to harvest the strength of current NDT analysis tools and combine them in ways to improve pavement design and evaluation.

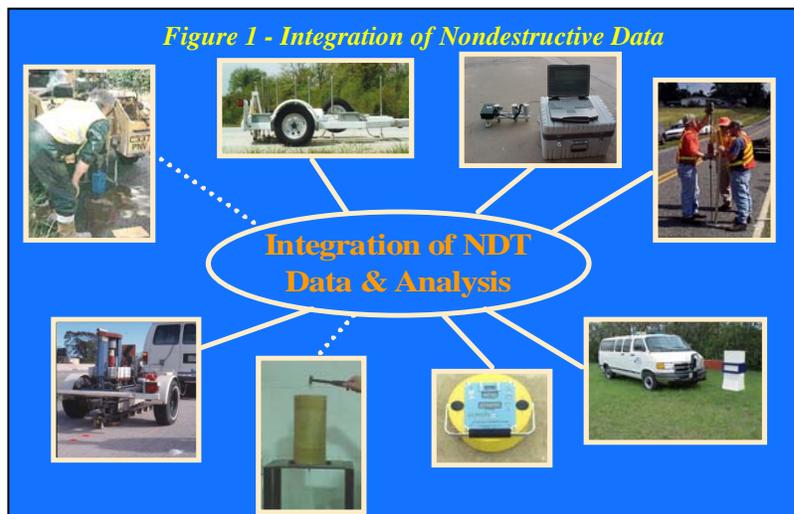
### What We Did ...

Under this project, the strengths and weaknesses of each NDT method were examined to develop a work plan for integrating information collected from each device in a rational

and practical manner to reliably determine the condition of pavements.

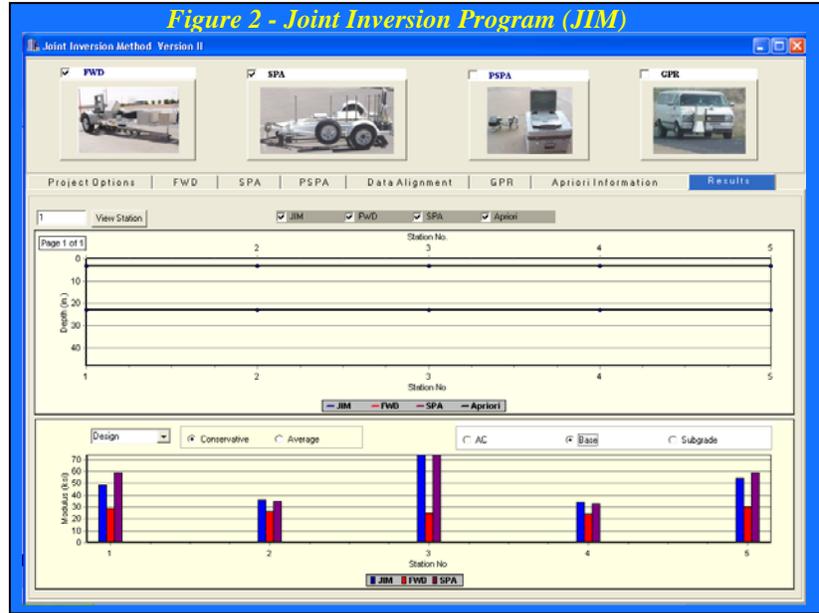
Various feasible alternatives of combining NDT analyses were investigated and appropriate algorithms were selected for feasible data integration. The idea was to merge the technologies and ultimately be capable of having one pavement analysis tool using the strength of existing NDT methods.

Two integration approaches were selected. The first approach was to combine the raw data from



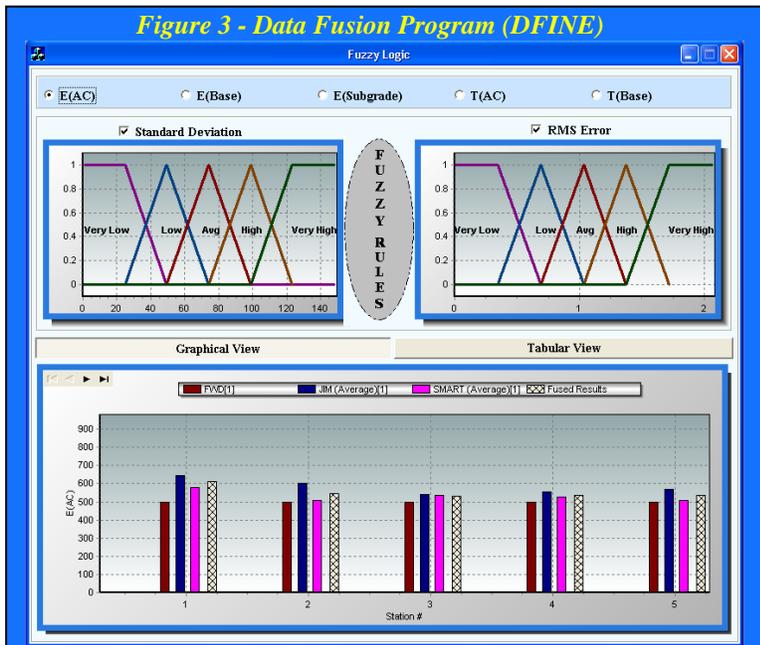
the various NDT devices in an advanced back-calculation program. The end product was a program called Joint Inversion Method (JIM). The results menu of JIM is highlighted in Figure 2. JIM incorporates the FWD deflections, seismic data from SPA and/or PSPA, and GPR thickness as well as any laboratory or core data that is available to back-calculate layer properties such as modulus and thickness. JIM includes a data-mining scheme to assist users in data alignment.

The second integration approach was to fuse the results from the existing NDT analyses. This process was a means to rationally reconcile the results from different methods to arrive at consistent results. Data



fusion is a process by which one source of data can be logically selected over another, or by which data from several available sources can be combined or “fused.” As each method for analyzing pavements has its own strengths and weaknesses, it is only reasonable to attempt to utilize all

methods to develop a better overall characterization of a pavement. As the parameters being measured are not “exact” and are subject to inherent errors, all information that has merit should be considered to some extent. This process is called data fusion. Three different fusion methods were incorporated into a program called Data Fusion for Intelligent Nondestructive Evaluation of flexible pavement (DFINE): a) Weighted Average, b) Statistical Weighted Average, and c) Fuzzy Logic. Figure 3 depicts the fuzzy logic menu in DFINE. The first two methods are a modification of the traditional averaging with weights incorporated based on the site statistics and the backcalculation errors



from different NDT analyses. The fuzzy logic method allows for the creation of rules that attempt to function in a manner that changes a subjective decision into a mathematical rule. These decisions, in turn, can be used to combine or filter data. In this case, the rules are used as a means to fuse results of the NDT analyses.

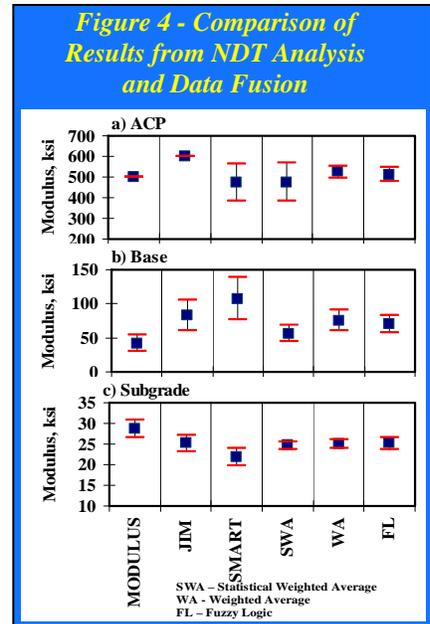
**What We Found ...**

Several sites across Texas were visited and data collected to demonstrate the feasibility and usefulness of the two integration programs, JIM and DFINE. Table 1 lists the sites visited and NDT devices used for data collection.

JIM backcalculation results showed the inherent strength of each data type, resulting in a more robust and stable algorithm. The seismic data had more impact on the results of the top layers, where the FWD data showed more sensitivity to the lower layers.

In the data fusion analysis, the inputs were the results from NDT tool currently available to TxDOT. Overall, the fused results represented a compromise between the results of the NDT analyses. Also, the fused results showed a lower variability compared to the individual analyses. This provides more confidence in the utilization of the results in pavement design and evaluation. Figure 4 provides a comparison of NDT analysis methods with data fusion results for pavement layer moduli.

The results from this project will not only assist TxDOT to better understand the strength and weakness of NDT analysis; they will also provide a tool that can aid in implementing design procedures based on the strength of all NDT results. In the design process, one tries to her/his best ability to experimentally simulate the design condition and then back-figure some material parameter that is relevant only to that



condition. This process has inherent non-uniqueness that can be minimized with input from more than one NDT device. The integration method, therefore, has a distinct advantage because it uses multiple sources to extract relevant pavement response to ensure that the properties specified are most representative of the pavement condition.

**The Researchers Recommend ...**

The initial implementation of the two programs in several projects has shown great potential. We recommend that TxDOT implement the new software as soon as possible, especially in those areas of the state where design based solely on the FWD data has raised some concern.

District	Site Location	NDT Devices
El Paso	TxDOT Parking Lot	FWD & SPA
Bryan	Rut Ride section	FWD, SPA, PSPA, and GPR
Laredo	Eagle Pass	FWD & SPA
Odessa	IH I-20 (Ward)	FWD & SPA
	IH I-20 (Ector)	FWD & SPA
Lubbock	US380	FWD & SPA
Amarillo	FM 1062	FWD, SPA, PSPA, and GPR
Austin	APT section	FWD, SPA & PSPA



***For More Details...***

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*The research is documented in the following reports:*

4393-1 *Feasibility of Integration of Non-Destructive Testing Data Analysis Techniques*

4393-2 *Implementation of Data Fusion Techniques in Nondestructive Testing of Pavements*

4393-3 *Case Studies on Application of Data Integration Techniques to Nondestructive Testing of Pavements*

**To obtain copies of a report:** Center for Transportation Infrastructure Systems  
(915) 747-6925, email [ctis@utep.edu](mailto:ctis@utep.edu).

**Disclaimer**

**This research was performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. The content of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement. The engineer in charge of the project was Soheil Nazarian, Ph.D., P.E. (Texas No. 69263).**

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