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5-1702-01-1

1. Report No. FHWA/TX-05/5-1702-01-1		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle IMPLEMENTING GROUND PENETRATING RADAR TECHNOLOGY WITHIN TXDOT				5. Report Date March 2005	
				6. Performing Organization Code	
7. Author(s) Tom Scullion				8. Performing Organization Report No. Report 5-1702-01-1	
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. Project 5-1702-01	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P. O. Box 5080 Austin, Texas 78763-5080				13. Type of Report and Period Covered Implementation Report: September 2003 – August 2004	
				14. Sponsoring Agency Code	
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Project Title: Training and Equipment for GPR Implementation URL: http://tti.tamu.edu/documents/5-1702-01-1.pdf					
16. Abstract The Texas Department of Transportation (TxDOT) continues to take a lead role in the implementation of Ground Penetration Radar (GPR) technology. With the ultimate goal of statewide implementation, Mr. Carl Bertrand of TxDOT's Construction Division initiated a project with Texas Transportation Institute (TTI) to purchase the necessary hardware to complete TxDOT's GPR fleet and also to document the key steps in both data collection and data processing. With these objectives in mind, implementation project 5-1702 entitled "Training and Equipment for GPR Implementation" was initiated in the fall of 2000. In this project two complete GPR systems were purchased and implemented with TxDOT. Two training CDs were also developed. The first CD covers all of the steps required to collect GPR data in the field. It documents both the hardware assembly and use of TxDOT's data acquisition program RADAR 2K. The second CD covers the steps required to process the GPR signals to provide information of use to pavement engineers. The analysis CD contains several video clips and animations to explain the technology and it provides copies of the analysis programs COLORMAP and RADSEG and raw data from four projects in Texas for the user to process. The user can compare his or her analysis results with those stored on the CD.					
17. Key Words GPR, COLORMAP, CD			18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov		
19. Security Classif.(of this report) Unclassified		20. Security Classif.(of this page) Unclassified		21. No. of Pages 16	22. Price

**IMPLEMENTING GROUND PENETRATING RADAR TECHNOLOGY
WITHIN TXDOT**

by

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Report 5-1702-01-1
Project 5-1702-01
Project Title: Training and Equipment for GPR Implementation

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

March 2005

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The engineer in charge was Tom Scullion, P.E., #62683.

ACKNOWLEDGMENTS

The training CDs were developed by Mark Coppock and Richard Cole of Texas Transportation Institute's (TTI's) Communications Division. The direction of the project director Carl Bertrand and his staff is greatly appreciated. Yiqing Chen and Wenting Liu of TTI wrote the code for both COLORMAP and Radar2K. The comments of many TxDOT ground penetrating radar (GPR) users including Joe Leidy, P.E., Andrew Wimsatt, P.E., and Darlene Goehl, P.E., were very beneficial in the development of the final software packages.

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BACKGROUND

Research project 0-1702 was completed by the Texas Transportation Institute (TTI) in the fall of 1999 (Scullion and Chen, 1999a). In that project TTI continued its development and implementation of ground penetrating radar (GPR) technology for highway applications. New versions of the GPR data acquisition program (Radar2K) and data analysis system (COLORMAP) were developed. New antenna configurations were designed and field tested and specifications were developed for the purchase of new systems. A series of GPR training schools was also conducted around the state to introduce district personnel to GPR technology and how to use the results in pavement evaluations.

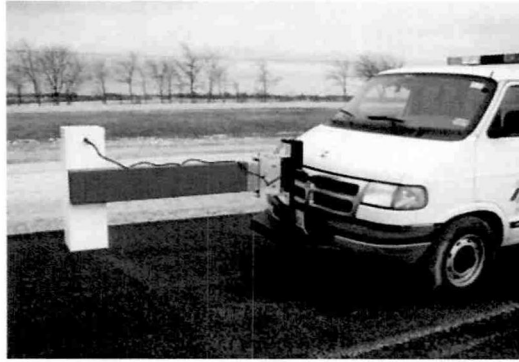
During this period the use of GPR technology became commonplace in Texas Department of Transportation (TxDOT) forensic studies. In addition to the recognized applications of measuring layer thicknesses, identifying section breaks and locating areas of subsurface moisture damage, several new applications were validated. GPR became recognized as an excellent tool for identifying poorly constructed longitudinal joints and for detecting areas of segregation in newly placed asphalt surfaces.

With the widespread use of GPR within TxDOT and with the ultimate goal of statewide implementation, Mr. Carl Bertrand of TxDOT's Construction Division initiated an interagency agreement with TTI to purchase the necessary hardware to complete TxDOT's GPR fleet and also to document the key steps in both data collection and data processing. With these objectives in mind, implementation project 5-1702 entitled "Training and Equipment for GPR Implementation" was initiated in the fall of 2000.

EQUIPMENT PURCHASES

The first task in project 5-1702 was to purchase two complete GPR systems for TxDOT. Performance specifications were developed and an evaluation was made of the performance of all of the available commercial systems. In the summer of 2001 a contract was initiated with Wavebounce, Inc., of Houston, Texas, to manufacture the GPR systems for TxDOT. This unit met the seven performance criteria identified by TTI as critical to provide the quality GPR signals required for accurate predictions (Scullion, 1995). These specifications include a signal-to-noise ratio, short- and long-term stability requirements and other criteria.

One of these new systems mounted on a TxDOT vehicle is shown in Figure 1. In addition to the 1 GHz antenna, the vehicle also contains an integrated video system for capturing simultaneous surface images, a GPS system, and all of the necessary data acquisition hardware.



**Figure 1. TxDOT's GPR Vehicle with the Wavebounce
1 GHz Air Coupled Antenna.**

DEVELOPMENT OF TRAINING MATERIALS

The next step was to develop the necessary training materials for TxDOT personnel who will be involved in both data acquisition and data processing. For this part of the contract TTI's Communications division developed two interactive training CDs. Mr. Mark Coppock of TTI Communications played a lead role in this development. The first CD covers all aspects of collecting GPR data in the field, the second CD deals with processing the GPR data with the COLORMAP analysis system. The introductory screen to the data collection CD is shown in Figure 2.



Figure 2. Introductory Screen to GPR Data Collection CD.

The intent of the first CD is to provide TxDOT’s field personnel with all of the skills required to operate one of TxDOT’s GPR vehicles. The CD is menu driven and the menu items are shown on the right side of Figure 2. In the hardware assembly part of the CD, all aspects of system set up are covered in detailed photographs or short video clips. For example, instructions for mounting the GPR boom and antenna are shown in Figure 3.

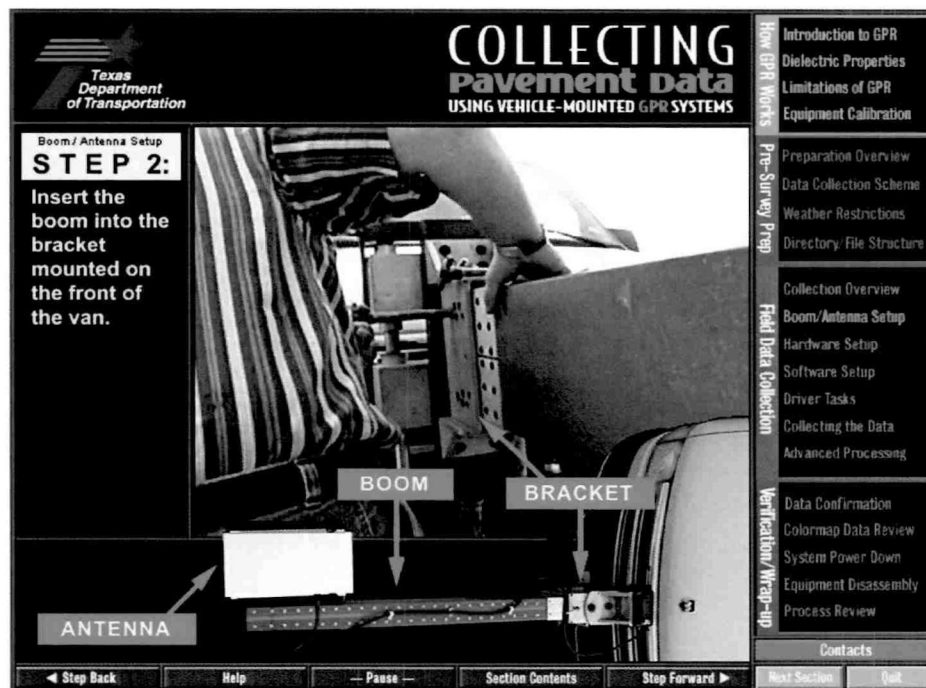


Figure 3. Instructions for Mounting Antenna to Test Vehicle.

The CD also includes installation guidelines and a user's manual for the data acquisition software Radar2K.

A second CD was developed to introduce TxDOT personnel to the data processing and interpretation of GPR signals. The introductory screen for this interactive CD is shown in Figure 4. Included in this CD are:

- an overview of how GPR works, animated descriptions of how GPR signals are generated from subsurface layer reflections, and how variations in these signals are related to key engineering properties of layer thickness, density, and moisture content;
- a detailed step-by-step description of TxDOT's main GPR data processing system COLORMAP;
- a set of four problems where the student is supplied with a raw GPR data set from an actual TxDOT project and given instructions on the steps required to process the data with COLORMAP—this is followed by supplied answers to each problem;
- an introduction to advanced GPR analysis techniques where the GPR signals can be converted into asphalt layer air void contents and base layer moisture contents—in each case material-specific regression equations are developed by taking station GPR readings at three to four locations and removing cores from these locations for lab testing.

All of the software is included on the CD with directions on how to download and install it.

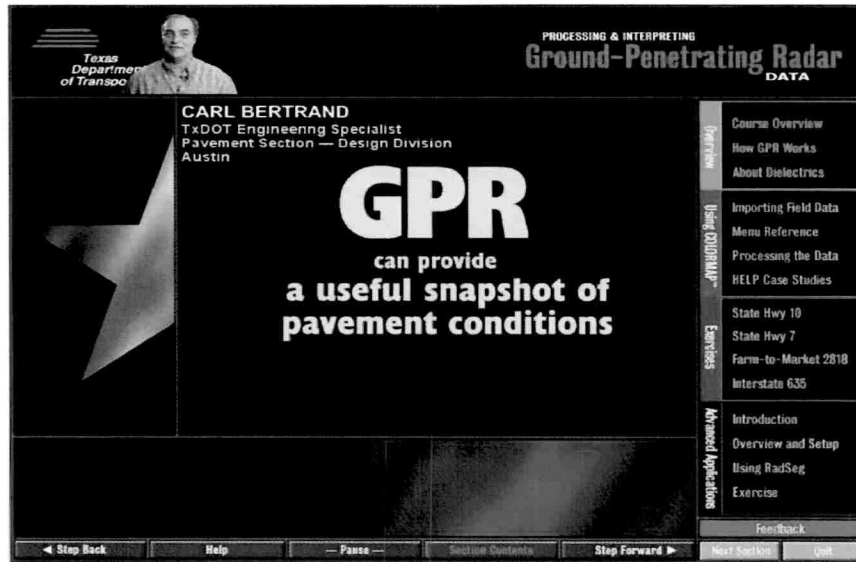


Figure 4. Introductory Screen to GPR Data Processing Software.

This CD contains many animations and video clips to explain GPR technology to pavement engineers. For example, the basics of GPR signal interpretation are shown in Figure 5, where the significance of the amplitudes and time delays between amplitudes is explained. The CD training is self-paced, and the user can step forward and backward through the lessons using the keys at the bottom of the screen.

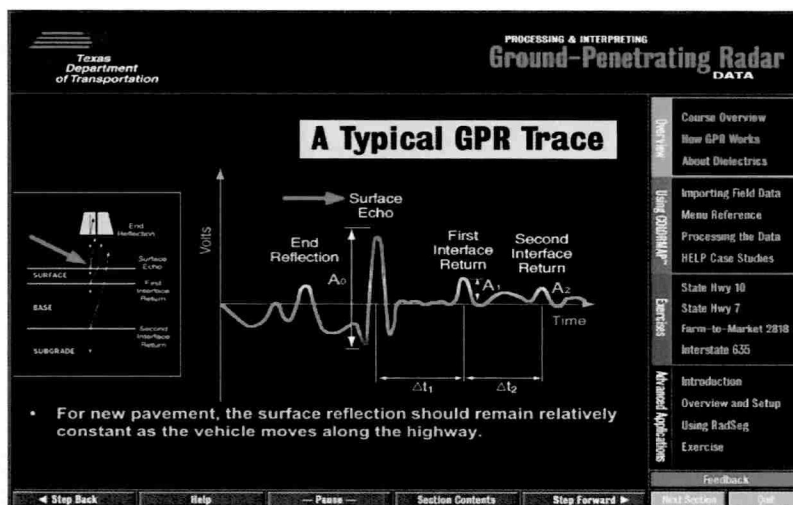


Figure 5. Basics of GPR Signal Interpretation.

The final section of the analysis CD covers the use of GPR for quality assurance testing of new hot-mix surfacing. In a typical GPR quality assurance survey of a new hot-mix overlay, GPR data are collected at one-foot intervals. Using well established equations the amplitude of reflection of the GPR wave from the surface layer is converted into a top layer dielectric value. To convert the measured dielectrics into layer density and air void content the RADSEG program is supplied on the CD. This program uses the techniques and laboratory calibration procedures developed in earlier TTI studies (Scullion and Chen 1999b). To perform the analysis the operator collects static GPR data in the field and takes calibration cores from these locations. These cores are returned to the laboratory where densities and air void contents are determined. RADSEG requests that the user input the lab core densities and air voids together with the field dielectric values. A minimum of three locations is needed for any project. Regression analysis software is included in the RADSEG program and the calibration factors are automatically generated and used to convert the GPR properties into engineering properties. Figure 6 shows the calculated air void profile for a new hot-mix surface layer.

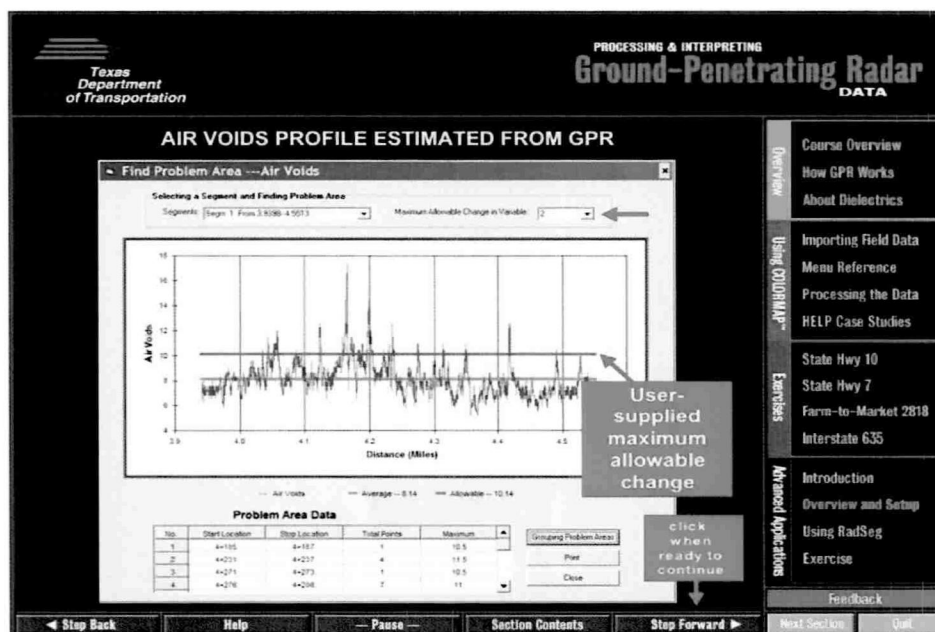


Figure 6. Calculated Air Void for New Hot-Mix Surface Layer.

CONCLUSIONS AND RECOMMENDATIONS

The Texas Department of Transportation continues to take a lead role in the implementation of GPR technology. GPR has been in routine use within TxDOT since the mid 1990s. Combining GPR information with structural strength testing from the falling weight deflectometer is routinely performed to diagnose subsurface conditions, identify the cause of pavement problems and to plan rehabilitation activities.

The CDs developed in this project have been delivered to TxDOT. They are now used as part of TxDOT's technician and engineer training programs. The CDs with their frequent use of videos and animation are an excellent resource for both initial training of new personnel and as refresher courses for the infrequent GPR user.

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