

Appendix A
Ground Penetrating Radar Field Exploration and Testing
Report No. 28-00441

A.1 FIELD EXPLORATION

The pavement structural conditions at the site were evaluated nondestructively using Ground Penetrating Radar (GPR). The description of the equipment precedes the GPR Data and Analysis Results in this appendix.

A.2 EQUIPMENT DESCRIPTION

A.2.1 GSSI GPR Test System

The GPR test system owned by AET is a GSSI Roadscan System that consists of a bumper-mounted, 2 GHz air-coupled antenna and a SIR-20 control and data acquisition processor, featuring dual channels. The GPR processor, including a SIR-20 data acquisition system, wheel-mounted DMI (Distance Measuring Instrument), and a tough book with the SIR-20 Field Program constitutes the newest, most sophisticated GSSI Test System, which fulfills or exceeds all requirements to meet ASTM-4748, ASTM D-6087 Standards. Figure C1 provides a view of this equipment.



Figure A1. GSSI 2 GHz air-coupled GPR Test System

The GPR antenna emits a high frequency electromagnetic wave into the material under investigation. The reflected energy caused by changes in the electromagnetic properties within the material is detected by a receiver antenna and recorded for subsequent analysis. The 2 GHz air-coupled GPR is capable of collecting radar waveforms at more than 100 signals per second, allows for data to be collected at driving speeds along the longitudinal dimension of the pavements or bridge decks with the antennas fixed at the rear or in front of the vehicle.

The antenna used for Roadscan is the Horn antenna Model 4105 (2 GHz). The 2 GHz antenna is the current antenna of choice for road survey because it combines excellent resolution with reasonable depth penetration (18-24 inches in pavement materials). The data collection is performed at normal driving speeds (45-55 mph), requiring no lane closures nor causing traffic congestion. At this speed the 2 GHz antenna is capable of collecting data at 1-foot interval (1 scan/foot).

The data were collected at a rate of about 1 vertical scans per foot. Each vertical scan consisted of 512 samples and the record length in time of each scan was 12 nanoseconds. Filters used during acquisition were 300 MHz high pass and 5,000 MHz low pass.

In a GPR test, the antenna is moved continuously across the test surface and the control unit collects data at a specified distance increment. In this way, the data collection rate is independent of the scan rate. Alternatively, scanning can be performed at a constant rate of time, regardless of the scan distance. Single point scans can be performed as well. Data is reviewed on-screen and in the field to identify reflections and ensure proper data collection parameters.

Field testing is performed in accordance with the standard ASTM procedures as described in ASTM D 4695-96, "Standard Guide for General Pavement Deflection Measurements".

A.2.2 System Calibrations

Horn antenna processing is used to get the velocity of the radar energy in the material by comparing the reflection strengths (amplitudes) from a pavement layer interface with a perfect reflector (a metal plate). The calibration scan is obtained with the horn antenna placed over a metal plate at the same elevation as a scan obtained over pavement.

The boring logs include descriptions of apparent geology. The geologic depositional origin of each soil layer is interpreted primarily by observation of the soil samples, which can be limited. Observations of the surrounding topography, vegetation, and development can sometimes aid this judgment.

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The same setting for data collection is used for metal plate calibration. Fifteen seconds are need for jumping up and down on the vehicle's bumper to collect the full range of motion for the vehicle's shocks. The filename of raw calibration file is recorded.

Survey wheel is calibrated by laying out a long distance (> 50 feet) with tape measure.

A.2.3 Linear Distance and Spatial Reference System

Distance measuring instrument (DMI) is a trailer mounted two phase encoder system. When DMI is connected to the SIR-20 it provides for automatic display and recording distance information in both English and metric units with a 1 foot (0.3 meters) resolution and four percent accuracy when calibrated using provided procedure in the Field Program.

Spatial reference system is a Trimble ProXH Global Positioning System (GPS) that consists of fully integrated receiver, antenna and battery unit with Trimble's new H-Star™ technology to provide subfoot (30 cm) post processed accuracy. The External Patch antenna is added to the ProXH receiver for the position of the loading plate. The External Patch antenna can be conveniently elevated with the optional baseball cap to prevent any signal blockage.

A.2.4 Camera Monitoring System

A battery operated independent DC-1908E multi-functional digital camera with a SD card is used for easy positioning of the loading plate or of the pavement surface condition at the testing locations.

A.3 SAMPLING METHODS

At the project level, the testing interval is set at 12 scans per foot in the Outside Wheel Path (OWP) = $2.5 \text{ ft} \pm 0.25 \text{ ft}$ (0.76 m \pm 0.08 m) for nominal 12 ft (3.7 m) wide lanes at a survey speed of approximately 10 mph. Where a divided roadbed exists, surveys will be taken in both directions if the project will include improvements in both directions. If there is more than one lane in one direction the surveys will be taken in the outer driving lane (truck lane) versus the passing lane of the highway. GPR tests are performed at a constant lateral offset down the test section. When GPR tests are performed on bridge decks, multiple survey lines are followed transversely at 2-foot spacing between survey lines.

At the network level, GPR tests on one scan per foot are set to be able to collect data on pavements at driving speeds, without statistically compromising the quality of the data collected. If GPR tests are for the in situ characterization of material GPR data will be collected at two scan per foot at slower driving speeds.

A.4 QUALITY CONTROL (QC) AND QUALITY ASSURANCE (QA)

Beside the daily metal plate calibration the DMI is also calibrated monthly by driving the vehicle over a known distance to calculate the distance scale factor. The GPR will be monitored in real time in the data collection vehicle to minimize data errors. The GPR units will be identified with a unique number and that number will accompany all data reported from that unit as required in the QC/QA plan.

Scheduled preventive maintenance ensures proper equipment operation and helps identify potential problems that can be corrected to avoid poor quality or missing data that results if the equipment malfunctions while on site. The routine and major maintenance procedures established by the LTPP are adopted and any maintenance has been done at the end of the day after the testing is complete and become part of the routine performed at the end of each test/travel day and on days when no other work is scheduled.

To insure quality data, the GPR assessments only took place on dry pavement surfaces, and data was collected in each wheel path.

A.5 DATA ANALYSIS METHODS

A.5.1 Data Editing

Field acquisition is seldom so routine that no errors, omissions or data redundancy occur. Data editing encompasses issues such as data re-organization, data file merging, data header or background information updates, repositioning and inclusion of elevation information with the data.

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A.5.2 Basic Processing

Basic data processing addresses some of the fundamental manipulations applied to data to make a more acceptable product for initial interpretation and data evaluation. In most instances this type of processing is already applied in real-time to generate the real-time display. The advantage of post survey processing is that the basic processing can be done more systematically and non-causal operators to remove or enhance certain features can be applied.

The Reflection Picking procedure is used to eliminate unwanted noise, detects significant reflections, and records the corresponding time and depth. It uses antenna calibration file data to calculate the radar signal velocity within the pavement.

A.5.3 Advance Processing

Advanced data processing addresses the types of processing which require a certain amount of operator bias to be applied and which will result in data which are significantly different from the raw information which were input to the processing.

A.5.4 Data Interpretation

The EZ Tracker Layer Interpretation procedure uses the output from the first step to map structural layers and calculate the corresponding velocities and depths.

A.6 TEST LIMITATIONS

A.6.1 Test Methods

The data derived through the testing program have been used to develop our opinions about the pavement conditions at your site. However, because no testing program can reveal totally what is in the subsurface, conditions between test locations and at other times, may differ from conditions described in this report. The testing we conducted identified pavement conditions only at those points where we measured pavement thicknesses and observed pavement surface conditions. Depending on the sampling methods and sampling frequency, every location may not be tested, and some anomalies which are present in the pavement may not be noted on the testing results. If conditions encountered during construction differ from those indicated by our testing, it may be necessary to alter our conclusions and recommendations, or to modify construction procedures, and the cost of construction may be affected.

A.6.2 Test Standards

Pavement testing is done in general conformance with the described procedures. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

A.7 SUPPORTING TEST METHODS

A.7.1 Falling Weight Deflectometer (FWD)

If the pavement layer moduli and subgrade soil strength are desired the deflection data are collected using a Dynatest 8000 FWD Test System that consists of a Dynatest 8002 trailer and a third generation control and data acquisition unit developed in 2003, called the Dynatest Compact15, featuring fifteen (15) deflection channels. The new generation FWD, including a Compact15 System and a standard PC with the FwdWin field Program constitutes the newest, most sophisticated Dynatest FWD Test System, which fulfills or exceeds all requirements to meet ASTM-4694, ASTM D-4695 Standards. The system provides continuous data at pre-set spacing.

A.7.2 Soil Boring/Coring Field Exploration

If both pavement thicknesses and subgrade soil types and conditions are desired the shallow coring/boring and sampling is used. The limited number of coring/boring is necessary to verify the GPR layer thickness data.

A.7.3 Pavement Surface Condition Survey

The type and severity of pavement distress influence the deflection response for a pavement. Therefore, GPR operators record any distress located from about 1 ft (0.3 m) in front of vehicle to about 30 ft (9 m) ahead. This information is recorded in the FWD file using the comment line in the field program immediately following the test.