N D E

GROUND PENETRATING RADAR [GPR]

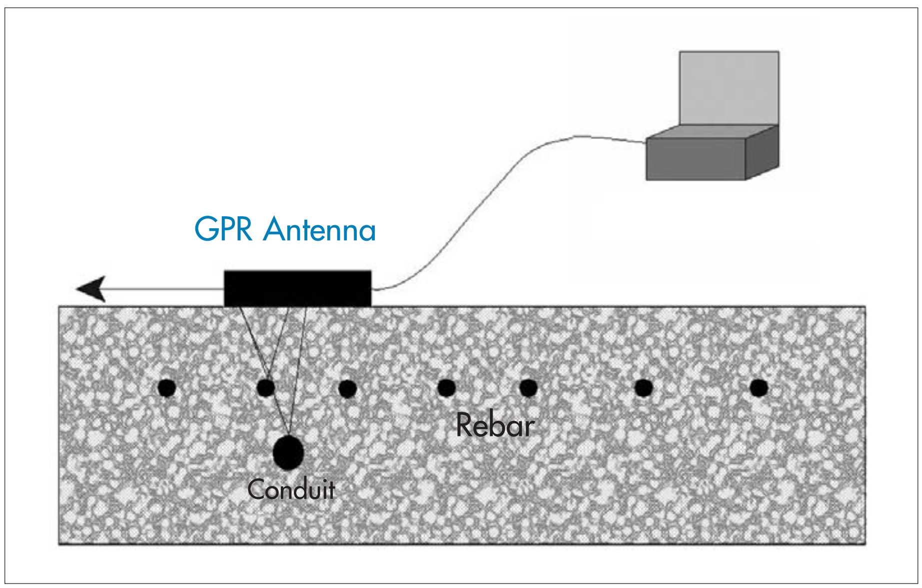





APPLICATION

The Ground Penetrating Radar (GPR) method is primarily applied to locate and measure the depth of steel reinforcement, post-tensioning and prestress tendons or ducts, and embedded metallic or plastic conduits in concrete slabs, walls, or structural members. The GPR method is also applied to define areas of corrosion in reinforced bridge decks or other elements, determine thicknesses of members with little or no reinforcement, measure pavement thickness and properties, and locate subgrade voids below concrete slabs or behind retaining walls. GPR scans can be performed on concrete elements, standard framed or masonry walls, concrete and asphalt pavements, and soil. GPR is used for many geophysical applications as well.

The GPR method is a wave propagation technique that transmits and receives electromagnetic waves (EM or radio waves). The technology is usually used in zero-offset reflection surveys but can be used in direct transmission. Many antennas are available ranging in center frequency from 25 to 1500 MHz. For **NDE** applications, the selection of antenna is dependent on the desired feature resolution and depth of penetration and the typical range is 400 to 1500 MHz.



Also known as: Surface/Ground Probing Radar, Surface/Subsurface Penetrating Radar (SPR).

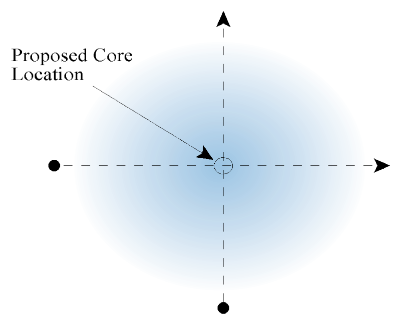
STANDARDS

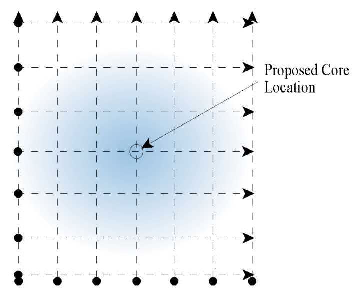
Standards for the GPR method include AASHTO TP-36 and ASTM D6087 for evaluating asphalt-covered concrete bridge decks, ASTM D6432 for general geophysical and NDE applications of GPR, ACI 228.2R for NDE applications in concrete structures, and AASHTO PP 40, ASTM D4748, FHWA-HIF-00-015, NCHRP Synthesis No. 255, SHRP C-101 and SHRP Catalogue No. 4008 for pavement evaluations.

- **See end of document for full references.**

FIELD INVESTIGATION

GPR data are collected in either a 2-D (distance and time) or 3-D (x, y, and time) fashion, depending on the application. The scan patterns for clearing a proposed corehole in a concrete slab for 2-D and 3-D investigations are shown in the figures below.





For feature mapping over large areas with little known information, 3-D scanning is typically utilized. A 3-D investigation compiles multiple parallel and perpendicular 2-D lines into a panel or panels. 2-D scanning is often reserved for single point locates or for situations in which a good portion of the field conditions are known.

ACCESS

Only one surface needs to be accessible for the antenna placement. There are no personnel evacuation requirements with GPR as there are with X-ray (radiography). Scanning along the surface of the test members allows identification of reflection from buried objects along the scan line. The scan path test surface needs to be free of obstacles and debris and clean. A borehole GPR antenna requires typically a 2-4 inch diameter PVC access tube.

COLLECTION OF DATA

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.

DATA REDUCTION

PROCESSING TECHNIQUES

For a 2-D investigation, features and their locations are identified on-screen and marked in the field. For a 3-D investigation, data are downloaded either on-site or in our offices to processing clients. The data processing steps may include a variety of geophysical algorithms (initially developed in the field of seismology); the steps performed depend on the data characteristics and project goals. For embedded conduit location, 3-D GPR data are typically migrated and interpolated from scan to scan to produce plan view depth slices, analogous to X-ray images.

INTERPRETATION OF DATA

GPR tests rely on reflection of electromagnetic waves. The results from a GPR test can be viewed on the screen in terms of a plot of time or depth versus scanning distance (2-D investigation). The two-way travel time is used to calculate the reflector depth assuming that the velocity of the penetrated material(s) is reasonably estimated or known from correlations with destructive coring at selected locations ofthe site. This velocity depends on the material relative dielectric constant. GPR depth calibrations on concrete are often performed from element thickness correlation with Impact Echo (IE) data. For a 3-D dataset, buried features are identified by viewing plan or perspective views of individual depth slices or a cube/block of data.

EFFECTIVENESS

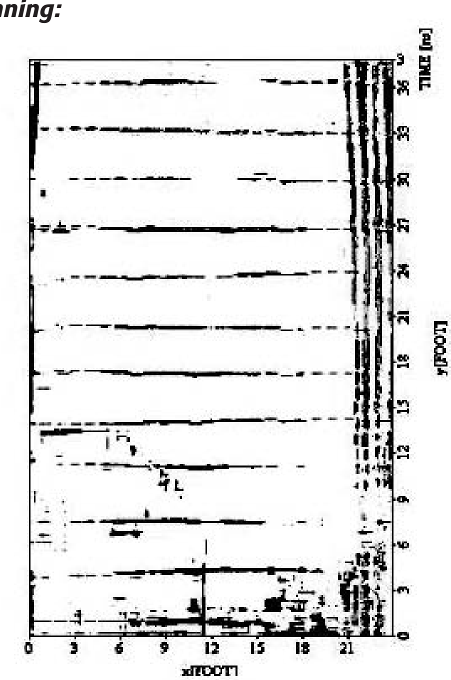
The effectiveness of GPR scanning and interpretation is highly dependent on the existing field conditions. Heavily reinforced members may shield radar signals from deeper material or features. Deep, small diameter features are more difficult to detect than shallow, large diameter features. Moisture content and clayey materials limit signal penetration. Ambient EM noise may distort data. For depth determination, velocity estimation must be performed from a location of known thickness. Typical accuracies for linear feature centerline locations are ± 0.25 to ±1.0 inches or less.

EXAMPLE RESULTS

Example results for various applications of both 2-D and 3-D scanning:

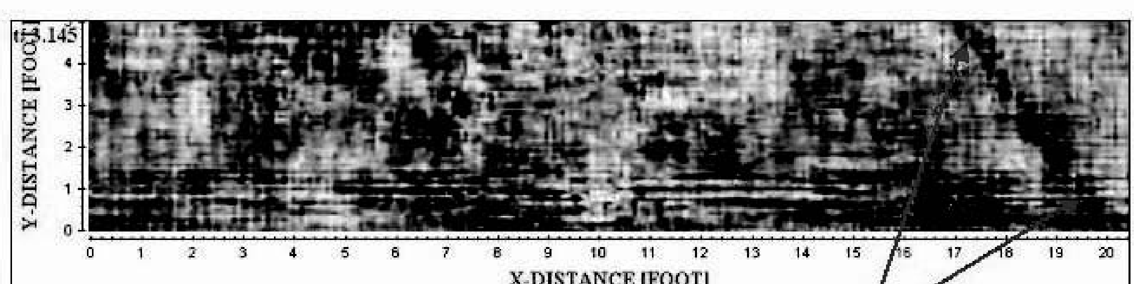
STRUCTURAL - PT TENDONS

The results of 3-D scanning to identify post-tensioning (PT) tendons in a 12 inch thick elevated concrete floor slab are presented in the figure to the right. The x-trending tendons were spaced at nominally 3 ft. A group of four y-trending tendons pass over a column at x = 22-23 ft. The tendons were successfully located and allow for safe coring of approximately 25 holes for a restaurant kitchen remodel.



STRUCTURAL - BURIED CONDUIT

A pair of 1.75 inch diameter conduits below a 4-6 inch thick concrete floor slab were found with 3-D GPR scanning at a hospital remodel. The slab varied in thickness from 4-6 inches and contained a mat of welded wire fabric reinforcement with 6 inch spacing. The 6 inch deep conduits housed critical 480 volt power supply lines to the hospital building. The scanning was performed to locate any embedded or buried features to allow for safe slab cutting of trenches for plumbing installation.

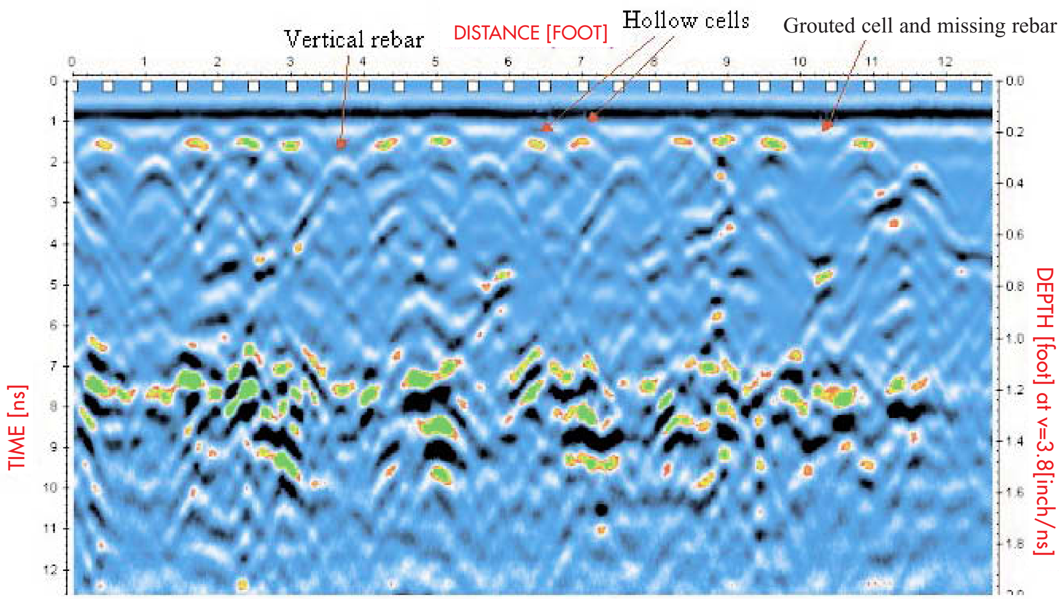


Paired 1.75 inch diameter plastic electrical conduits, 6 inches deep below slab.

EXAMPLE RESULTS *cont.*

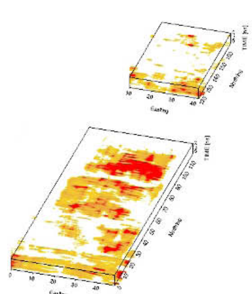
STRUCTURAL - CMU WALL

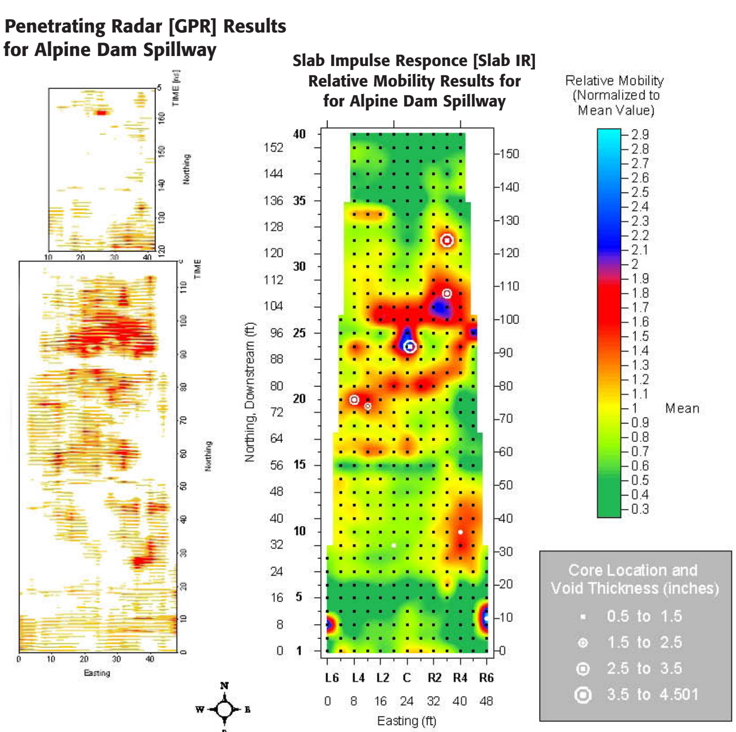
A 2-D GPR scan was performed along a new concrete-masonry unit (CMU) perimeter security wall for a country club. The scanning was performed confirm the presence or absence of vertical rebar and to distinguish between grouted and hollow cells. The results were confirmed with destructive chipping and a repair plan was designed for the wall.



STRUCTURAL - SUBGRADE VOIDS

GPR was combined with the [Slab Impulse Response (Slab IR) method] to locate sub-grade voids below an alpine dam spillway (see references for full text).

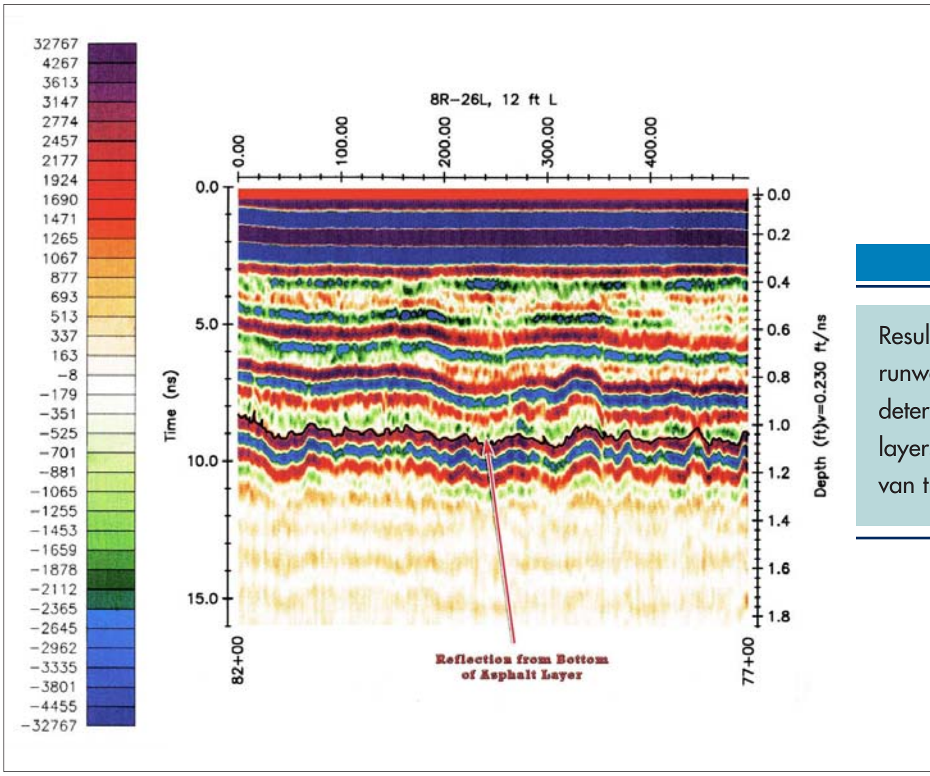




CONCRETE PAVEMENT

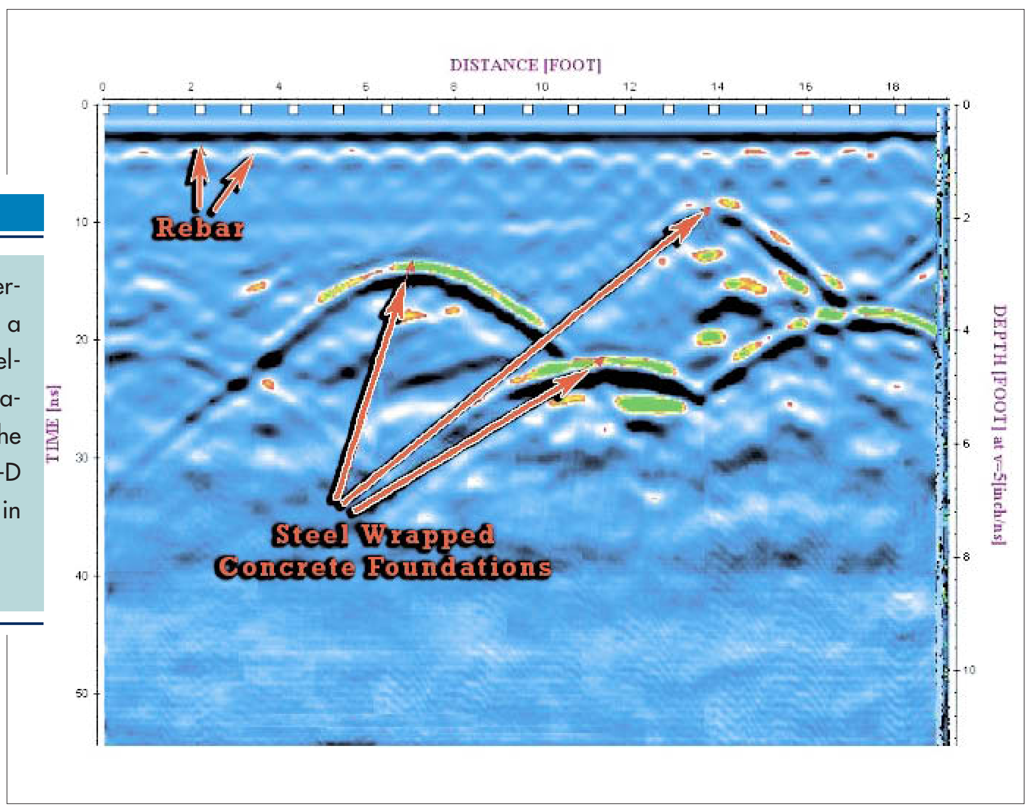
A 3-D GPR investigation was performed on an outdoor concrete parking lot after isolated cracking had occurred upon heavy vehicle/machinery loading. The slab thickness for each scan was semi-automatically identified and exported from the GPR processing software. The tabulated data were then contoured. The slab design thickness was 6 inches and the full western 40 feet was designed to be 8 inches. The critically thin threshold was designated as 4 inches.

FIELD INVESTIGATION



ASPHALT RUNWAY

Results from GPR tests performed on runways and taxiways of an airport to determine the thickness of the asphalt layers. The antenna was mounted to a van trailer hitch for fast data collection.



FOUNDATIONS

GPR scanning was performed at the base of a wall to locate steel-wrapped concrete foundations (caissons) behind the wall. The results of 2-D scanning are presented in the figure to the right.