Use of GPR for Subsurface Pavement Investigations of 23 Airports in South Carolina

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ABSTRACT: Ground Penetrating Radar (GPR) has been used as a subsurface investigation tool in updating the pavement management and maintenance system (PMMS) for the South Carolina Aeronautics Commission (SCAC). An essential aspect of this system is tracking the deterioration of the pavement surface condition over time, and determining the load carrying capacity for each pavement surface. The evaluation reported in this paper addressed this need on 23 airfields by combining historical records research, visual site inspections, and physical testing. Testing included FWD measurements, GPR scanning, and coring. The specific objective of the GPR testing was to determine pavement layer structure information and to identify deeper subsurface features including voids or foreign objects, such as, abandoned fuel tanks, tree stumps, etc. in embankments. GPR was used to scan all major pavement elements, including runways, taxiways, and aprons. The GPR system combined a 1 GHz horn antenna to characterize pavement layer structure, and a 400 MHz antenna to identify utilities, voids, foreign objects, and areas of high moisture to a depth of 7 feet. The equipment was set up to travel at speeds of 15-20 mph, and was equipped with a differential GPS unit to provide a detailed track of the survey paths. The efficiency of this setup permitted the survey of 2 airports per day on average. The data was analyzed to identify thickness of the bound and unbound pavement layers. This data was presented in tabular and graphical form, and was used with the FWD data for back-calculation of layer moduli. The deeper subsurface features were identified and mapped using geo-referenced data files. The paper describes the equipment and methodology, the type of data generated, the methods of data analysis, and representative results.

KEY WORDS: Ground penetrating radar (GPR), pavement thickness, falling weight deflectometer (FWD), airfield pavement, pavement classification number (PCN)

1 INTRODUCTION

The South Carolina Aeronautics Commission (SCAC) recently completed a project to evaluate the condition and capacity of pavements at 23 airfields in South Carolina. The project, carried out by Applied Research Associates (ARA) with support from Infrasense, sought to evaluate both the weight bearing strength and the Pavement Classification Number (PCN) on all runways, taxiways, aprons, and ramps for each of the airfields investigated. aircraft.

Pavement classification numbers (PCN) are used in conjunction with aircraft classification numbers (ACN) to identify the strength of airport pavement facilities. This information is critical for airport operations with regards to determining the types of aircrafts that can land and prescribing taxiing patterns at different airports. Overloading of airport pavements can significantly reduce their life and performance and leads to relatively costly rehabilitation maintenance efforts.

The PCN is expressed as a five character code which incorporates load capacity, pavement type, substructure strength, maximum tire pressure capacity, and method of evaluation. The technical evaluation used in this work involves the use of falling weight deflectometer (FWD) in combination with a number of cores/ borings to determine both the pavement structure strength and layer thicknesses and properties. However, more recently, GPR has been utilized to supplement coring, to mitigate disruption to normal airport operations and provide more comprehensive pavement structure information.

The PCN on these 23 airports was evaluated using FWD data at 200 foot test point intervals combined with ground penetrating radar (GPR) pavement thickness data collected continuously on each airfield element. Cores were taken at selected locations for verification of the GPR data and for characterization of pavement material types.

The GPR testing was also used to determine pavement layer structure information for FWD back-calculation and to identify deeper subsurface features including voids or foreign objects, such as, abandoned fuel tanks, tree stumps, etc. in embankments.

All major pavement elements, including runways, taxiways, and aprons were continuously scanned with GPR. The GPR system combined a 1 GHz horn antenna to characterize pavement layer structure, and a 400 MHz antenna to identify utilities, voids, foreign objects, and areas of high moisture to a depth of 7 feet. The equipment was set up to travel at speeds of 15-20 mph, and was equipped with a differential GPS unit to provide a detailed track of the survey paths. The efficiency of this setup permitted the survey of 2 airports per day on average. The data was analyzed to identify thickness of the bound and unbound pavement layers. This data was presented in tabular and graphical form, and was used with the FWD data for back-calculation of layer moduli. The deeper subsurface features were identified and mapped using geo-referenced data files. This paper describes the rational for utilizing GPR, the data collection procedures, the methods of data analysis, and representative results.

2 GPR COMBINED WITH FWD

The FWD is a non-destructive testing device that is used for determining pavement structure load carrying capacity. A key element in the successful analysis of FWD data is the knowledge of the pavement layer thicknesses. With most FWD evaluations, pavement layer thickness is estimated based on construction plans and occasional cores. However, pavement thickness can vary significantly from these assumed values, and small errors in the assumed asphalt thickness can result in large errors in back-calculated moduli of the asphalt and base layers (Briggs et. al., 1991).

Ground penetrating radar provides a means for obtaining accurate layer thickness data at FWD tests locations. The initial application of this technique to pavements (Maser and Scullion, 1992a) established the ability and accuracy of measuring the thickness of bound AC and unbound aggregate base layers, and for distinguishing the thickness of individual AC layers within the pavement structure (Maser and Scullion, 1992b). The use of GPR to measure pavement thickness has since become a subject of ongoing study and evaluations, and GPR has become a "mainstream" technology for pavement thickness evaluation.

Studies have shown that the level of accuracy in the GPR thickness measurement depends on the type of pavement structure and on the degree of calibration and verification used. These thickness studies generally compare GPR thickness values to pavement core thickness values, and the differences have generally ranged from 2 – 10% (Maser, 1999; Wenzlick, et. al. 1999, Al Qadi et. al, 2005). The variation is typically lowest for newer pavement, and highest for old pavement. Studies have demonstrated the use of selected cores to for both calibration and for ensuring the direct identification of layer types. Studies that have used cores in this fashion generally show closer agreement with overall core data (Maser, 2003; Al Qadi et. al., 2005).

3 DATA COLLECTION

A field data collection program was designed to acquire the data needed to support the objectives of this project while minimizing disruption to normal airport operations. This program included GPR data collection, FWD data collection, and coring. The projected called for data collection at 23 airports, each of which was surveyed with GPR and FWD to obtain complete coverage of each pavement facility (runways, taxiways, and aprons). Coring was carried out at select locations within each facility to confirm and calibrate layer thicknesses determined using GPR and also to enable material interpretation of base layers.

The GPR equipment used on this project consisted of a vehicle-mounted GSSI SIR-20 radar control and data acquisition unit, an electronic distance-measuring device (DMI) attached to the vehicle wheel, a Trimble AG 114 GPS unit with Omnistar differential correction, a 400 MHz ground coupled antenna and a 1GHz horn antenna. The purpose of the two antenna approach was to achieve a combination of adequate depth of penetration and high resolution for accurately determining the pavement and base course layer thicknesses, identifying areas of high moisture content and detecting any subsurface utilities or embedded objects (i.e. fuel tanks, tree stumps). The equipment is set up so that survey speeds can be carried out at 15-20 mph. The GPR survey of the runways and taxiways consisted of a series of either 2 or 4 parallel passes (offset from the CL) covering the length of each facility. The apron areas were surveyed with a series of parallel passes spaced at consistent 25 or 50 foot intervals (depending on the specifications) to obtain complete coverage. Real-time GPS guidance was used to maintain parallel survey lines of equal spacing.

During the survey, markers were placed in the GPR data at reference locations (i.e. boundary and hold lines) to supplement the GPS coordinates to ensure accurate spatial positioning and synchronization to FWD test locations. The GPR equipment setup is shown in Figure 1.

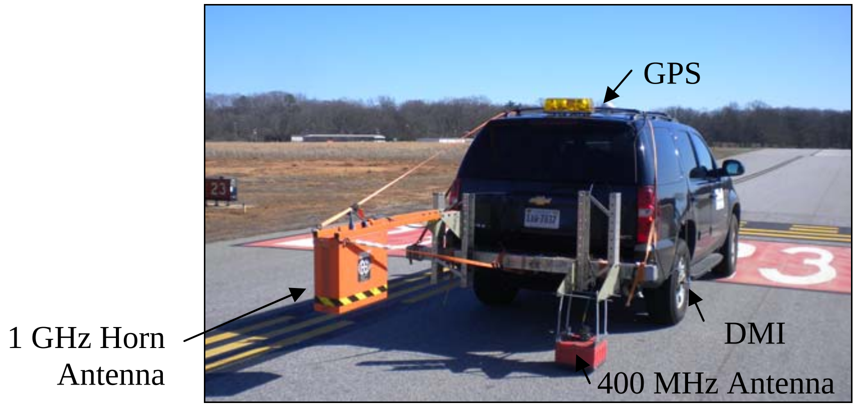

Figure 1: GPR Equipment Setup

4 DATA ANALYSIS AND RESULTS

GPR data was analyzed to calculate pavement and base layer thicknesses, identify areas of high moisture and detect embedded utilities and objects. Using Infrasense's proprietary software, the GPR data file is observed visually on the screen in B-scan display, and the analyst "picks" the relevant pavement and base layers as they are observed. Coring data was then used for calibrating and confirming the GPR thickness results.

The processed GPR data was reported in tabular spreadsheet form as shown in Table 1. Runway and taxiway facilities were also presented graphically as depth scatter plots (see Figure 2). The plot is Figure 2 shows close agreement with core data, and therefore no calibration was required. Additionally, the pavement thickness was also plotted as area contour maps for all apron facilities (see Figure 3). Note that wide variation in pavement structure encountered in this apron.

An additional analysis was carried out to identify anomalous activity (down to 7 feet beneath the surface) indicative of high moisture content, voids and embedded utilities or objects. Utilities were identified as sharp hyperbolas that appear consistently across a number of adjacent passes. Areas of high moisture content were distinguished as having relatively high amplitude reflections and also appearing consistently across multiple adjacent passes. Voids (likely tree stumps and other anomalous native elements) were recognized as areas of irregular, sharp reflections. These prescribed events were picked and processed to produce a Google Earth .KML files (see Figure 4).

Table 1: Sample Tabular Spreadsheet of GPR Results

Latitude	Longitude	Distance From W End of RW9-27 (ft.)	Total Asphalt Thickness (in.)	Total PCC Thickness (in.)
34.18531866	-79.73385129	0	8.57	5.92
34.18531675	-79.73383946	5	8.49	6.50
34.18531578	-79.73382742	10	8.41	6.36
34.18531563	-79.73381548	15	7.85	6.22
34.185316	-79.73380467	20	7.59	6.08
34.18531733	-79.73378811	25	8.36	7.04
34.18532066	-79.73376185	30	8.45	6.70

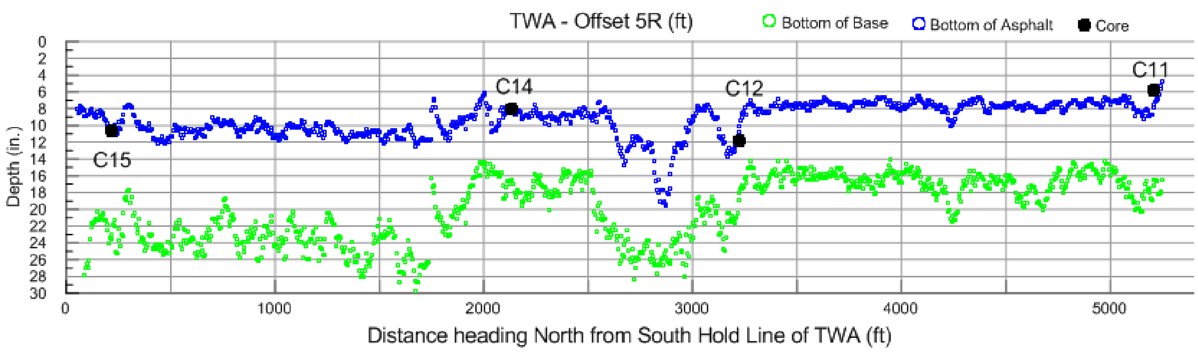

Figure 2: Sample Depth Scatter Plot

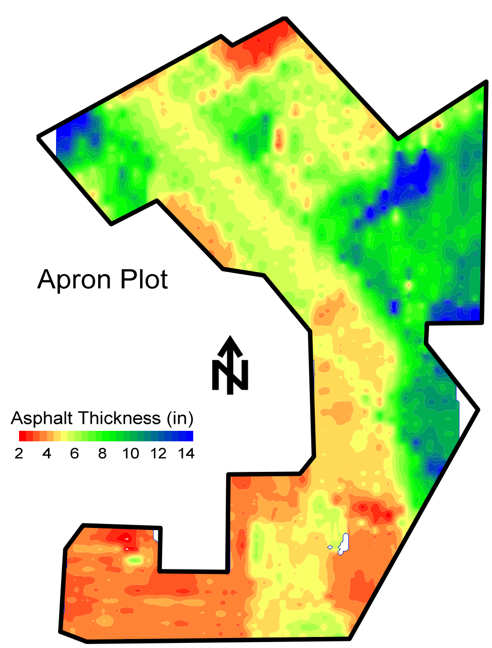

Figure 3: Sample of Apron Pavement Thickness Contour Map

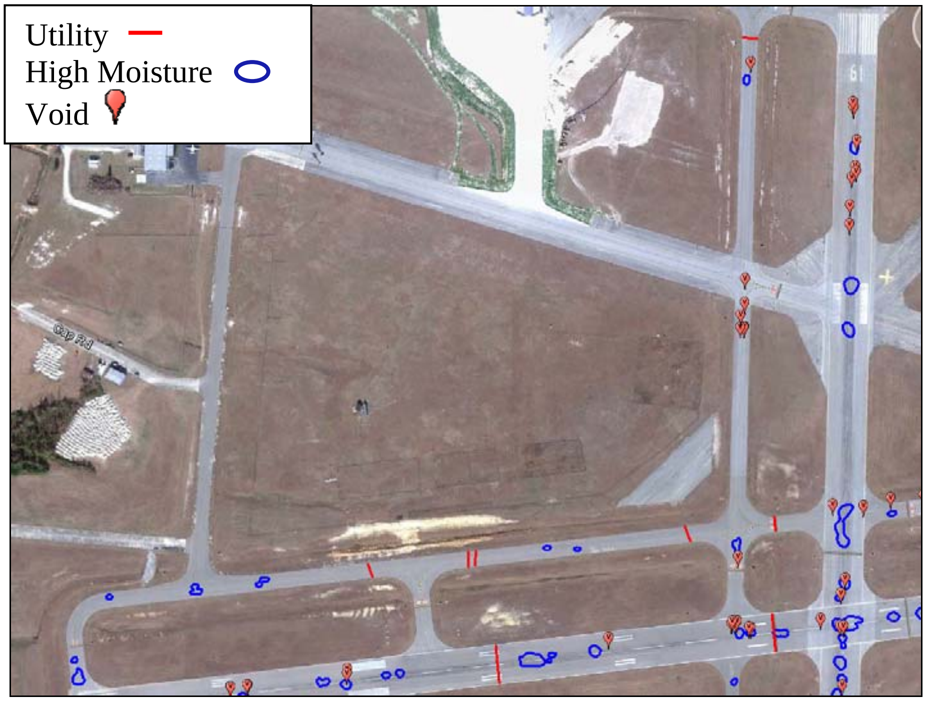

Figure 4: Sample Google Earth KML Showing Utilities, Areas of High Moisture Content and Voids

5 DISCUSSION AND CONCLUSION

The work presented in this paper documents the use and benefit of GPR in combination with FWD for evaluating the load carrying capacity of airport pavements. Specifically, the GPR survey was able to provide accurate bound and unbound pavement layer thickness information with full coverage for each airport facility (runways, taxiways, aprons). The GPR data was also able to reveal large variations in pavement structure that may not have been evident using random cores. Additionally, the rapid nature of the survey both minimizes disruption to normal airport operations and allows for high productivity (2 airports surveyed per day on average). Finally, the GPR survey was able to reveal subsurface utilities and other features which would not have been otherwise evident.

GPR provided a comprehensive subsurface view over a larger pavement area than the point-specific coring and FWD testing. Whereas the coring operation revealed the base layer material, GPR results were used to measure the thickness of the base layer which the PCN methodology is highly sensitive to. Nearly half of the 23 airports evaluated in South Carolina were quickly constructed during WWII with base materials that often contained substandard components that have deteriorated over the years. The GPR data was able to quantify these conditions and provide SCAC a subsurface view of the source of many distress issues that will need to be accounted for in future rehabilitation plans.

6 ACKNOWLEDGEMENT

The authors would like to acknowledge the South Carolina Aeronautics Commission (SCAC) for providing the opportunity to conduct this work, and particularly Mr. Jamey Kempson, SCAC project manager who worked closely with the project team.

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