October 2014

Subsurface Views

GPR Innovations: Hardware and Software

GPR for Infrastructure Assessment

The Latest Hardware & Software

Public and private infrastructure is in dire need of maintenance and repair – we constantly hear media reports about collapsing bridges, water main breaks and the failure of busy roads due to subsurface sinkholes. An example was reported in this newsletter a few years ago when an airplane collapsed into the tarmac due to sinkhole development under the airport taxiway, causing extensive damage to the plane (see Subsurface Views, January 2012, on our website).

The state of U.S. public infrastructure was given a cumulative grade point average of D+ (poor) by the American Society of Civil Engineers (ASCE) in its 2013 report which is defined as "in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of significant concern with strong risk of failure." Similar reports have been produced in Canada and in Europe.

Owners of public infrastructure, such as DOTs (Departments of Transportation), Airport and Port Authorities as well as private assets owners of multi-level parking garages, shopping malls, toll roads are being challenged to maintain structures used by the public.

At the same time, money for infrastructure projects is limited, particularly for publicly owned structure, and insufficient for the level of maintenance required. The result is that funds are often applied to the most critical projects, and systematic maintenance that might maintain and extend a structure's operational life is given little attention.

To effectively allocate funds, there needs to be more systematic evaluation of structural integrity to develop meaningful indicators of current safety level and projected asset life expectancy. Tools such as PMS (Pavement Management Systems), BIM (Building Information Modeling) and Asset Management databases with appropriate means of introducing non--destructive testing data are the way of the future.

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GPR for Infrastructure

Asset owners using these systems can sensibly prioritize projects to ensure structure reliability and mitigate public safety concerns. Acquiring and regularly updating data about the structures is critical to enable intelligent decision-making using these tools.

The Transportation Research Board (TRB) in the USA has published several studies that tested various NDE technologies for road and bridge inspections. For many of these applications Ground Penetrating Radar (GPR) received the highest ranking for non-destructive evaluation technology .

Sensors & Software provides a range of GPR systems and configurations for infrastructure assessment. For more than a decade the proven RoadMap system has provided highway speed, ground-coupled GPR surveys. Conquest and Noggin SmartCart deployment platforms have provided smaller scale solutions. To address the need for quick deployment and large area coverage, the lightweight and readily shipped SmartChariot platform has been introduced (see side panel) .

To complement the SmartChariot and the other acquisition platforms, the EKKO_Project PC-based software has been enhanced with two new analysis modules which enable concrete bridge deck and pavement structure assessment and reporting. This new reporting software allows operators to follow an established methodology to easily interpret the data and generate reports in PDF format or export to other database systems. These hardware and software tools provide a total solution to assess common critical infrastructure.

The bridge deck condition report delivers images of the bridge deck based on ASTM 6087 (Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar). The report also contains statistics on the reinforcement depth and spacing. This powerful analysis can be used for bridge decks, parking decks, and even walls and floors of concrete buildings.

The pavement structure report generates cross-sections of interpreted layers in roads and runways. The report also contains statistics on the minimum, maximum and average thickness of each subsurface layer.

Data can be easily imported into Geographical Information Systems (GIS), Pavement Management Systems (PMS) and Building Information Modeling (BIM). These systems allow data from various sources to be integrated together to provide a high-level analysis of the asset so critical decisions can be made and priorities determined.

The accompanying case studies outline two of the most popular uses of GPR for infrastructure: creating reports for bridge deck condition assessment and pavement structure assessment. ■

The SmartChariot system illustrates the opportunities going forward:

- *A range of high resolution GPR sensors (250, 500 and 1000 MHz bandwidth units)*
- *Use on any vehicle with a hitch; no dedicated survey vehicle required*
- *Integrated odometer for data collection at equal intervals along the survey line (user-definable but defaults based on GPR sensor)*
- *Integrated GPS with offset and latency corrections for accurate data positioning*
- *The system is small and light enough to easily ship to distant job sites*
- *Ground-coupled GPR provides greatest penetration and highest resolution data*
- *The GPR sensor can also be deployed using other platforms like the SmartCart*

SmartChariot with Noggin 1000

Bridge Deck Condition

Case Study Survey

GPR data were acquired on the 3 east-bound lanes of a 90 meter long bridge using a Noggin 1000 GPR in a SmartChariot vehicle-towed configuration. Three lines were collected in each lane: in the Left Wheel Path (LWP), Right Wheel Path (RWP) and the Center (CTR). This provided 9 lines with a total of approximately 810 meters of GPR data on the bridge.

The odometer triggered data acquisition every 3 centimeters (about 1.25 inch) for a total of about 27,000 unique sample points on the bridge deck. GPS is a standard system component enabling all data to be accurately geo-referenced. For example, the position of the survey lines is displayed in Google Earth - see image on page 3.

Data acquisition took less than an hour – in fact more time was spent driving to the next exit and turning the tow vehicle around to collect another pass of the data then was spent actually acquiring the bridge data.

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A cross-section of a portion of one line is shown in Figure 1. The data show that the rebar spacing on the bridge deck is 25 centimeters (approximately 10 inches).

Using the EKKO_Project interpretation module, the hyperbolic responses from the rebar were picked – the new Smart Point feature was used to pick the best position of each rebar (Figure 1, red dots).

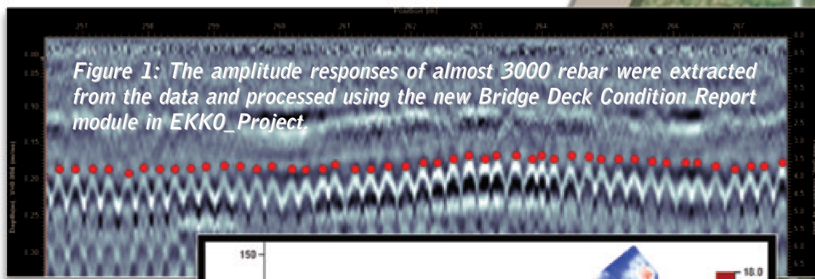

Figure 1: The amplitude responses of almost 3000 rebar were extracted from the data and processed using the new Bridge Deck Condition Report module in EKKO_Project.

The degree of salt-induced corrosion of reinforcing is a major concern with concrete decks and similar structures in northern climates where de-icing salt is used. Since the presence of saline water and corrosion bi-products causes strong attenuation of GPR signals, GPR attenuation has become an accepted indicator for rapid, non-invasive evaluation of concrete structures. The EKKO_Project software now includes the ability to process the rebar amplitude values and create signal attenuation map images. Two types of Response Amplitude displays are available; raw amplitude yields GPR signal strength in millivolts (mV) while a normalized display presents the data in decibels (dB). The latter map is often referred to as a Deterioration Index map (Figure 2). The 'dB' map uses an enhanced version of the processing outlined in ASTM standard 6087 for GPR data on asphalt-covered bridge decks.

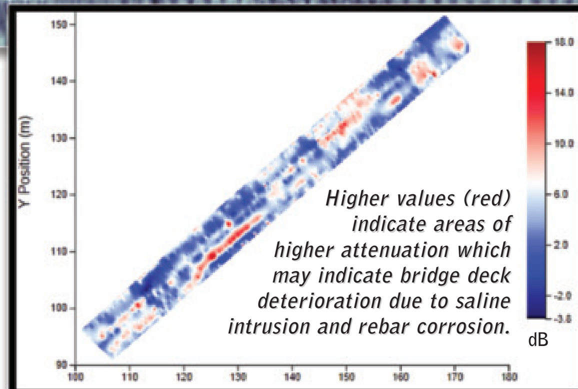

Figure 2 Rebar Response Amplitude map.

The EKKO_Project map image provides the option to change the Color Palette and amplitude range. This makes it possible to plot data from multiple bridges in the exact same format for comparison purposes.

The Sensors & Software method for processing the rebar amplitudes to produce a final amplitude map differs slightly from the ASTM 6087 standard. The standard uses the highest amplitude response of all the rebar as the reference amplitude. We feel that this methodology is not robust enough and opens the door for poor final result because, if there happens to be an anomalous high amplitude response picked, this will detrimentally skew the data. Instead, the Bridge Deck Condition processing uses the median amplitude of the top 10% strongest rebar responses.

Statistical Summary:

	GPR Amplitude (dB)	Reinforcement Depth (m)	Reinforcement Spacing (m)
Minimum	-5.007	0.120	0.149
Maximum	39.845	0.204	2.010
Average	5.795	0.164	0.254

Figure 3 Example of tabulated summary of analyzed data.

The rebar data also provide useful statistics including the minimum, maximum and average amplitude, rebar depth and rebar spacing (Figure 3). This information is especially important to civil engineers.

The EKKO_Project Bridge Deck Condition Report module outputs the map image in a report format with several fields for the GPR operator to fill in including the survey location, number of lanes and the GPR system used (Figure 4). The report can then be printed directly or to a PDF document.

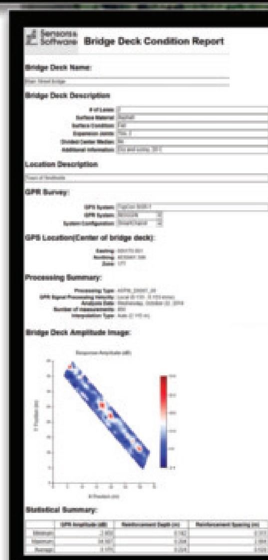

Figure 4 Example of an automated report created from EKKO_Project as a pdf document that is easy to share.

Despite its name, the Bridge Deck Report is not restricted to bridge decks; any concrete structure with reinforcing such as concrete highways, bridge piers, multi-level parking garages, warehouse floors etc. can be surveyed with GPR and processed in this way to assess their condition. Further, GPR data can be collected with variety of GPR system configurations such as the hand-pushed SmartCart, the hand-towed SmartTow or a hand deployed system like Conquest can be used.

The combination of high resolution, high quality GPR data combined with a standardized workflow and advanced but easy to use software mean professional results can be obtained the same day and at an affordable cost. ■

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Pavement Structure

Case Study Survey

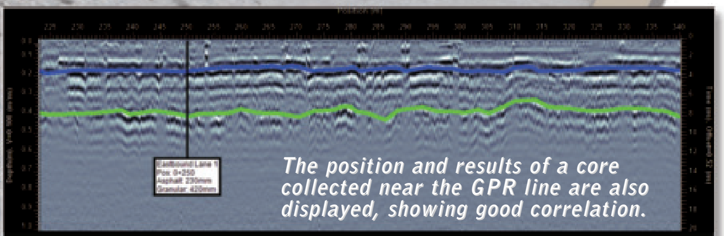

Figure A: Cross-section of road data showing the bottom of asphalt reflection in blue and the bottom of granular in green.

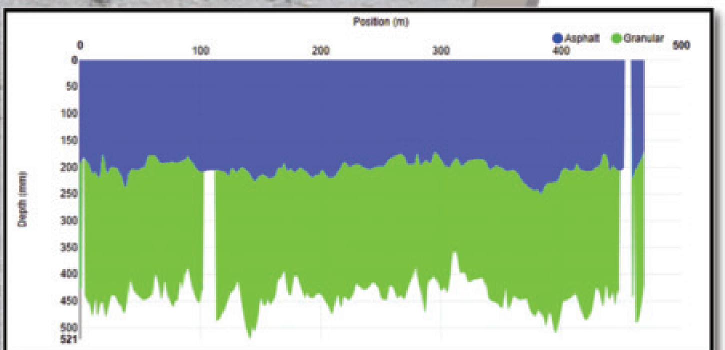

Figure B: Pavement structure chart displaying the thicknesses of the asphalt and granular layers over a 470 meter length of road. Blank areas indicate areas where confident picks could not be made.

Line Name: Ordinary Rd - Eastbound Lane 2

Layer	Thickness (mm)		
	Minimum	Maximum	Average
Asphalt	170	250	202
Granular	169	309	240

Figure C: Example of tabulated summary of analyzed data.

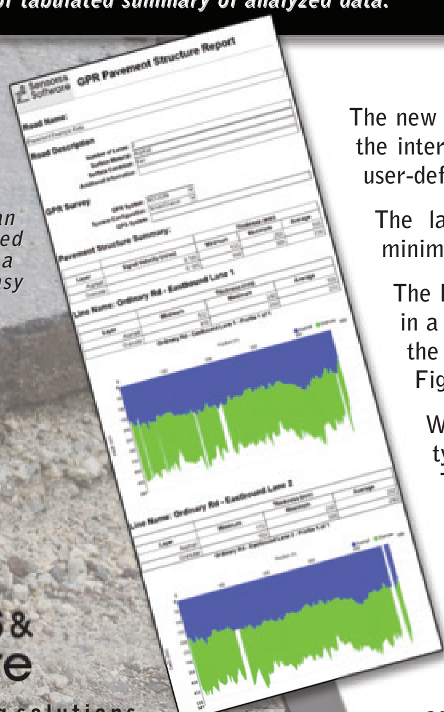

Figure D: Example of an automated report created from EKKO_Project as a pdf document that is easy to share.

Pavement evaluations usually involve expensive, labor-intensive, and destructive coring of the road structure to obtain estimates of the asphalt and granular thicknesses. Typically, cores are collected at set intervals to cover the length of the road with the spacing usually much greater than the scale of structure variations.

A GPR survey conducted before coring provides a solid basis for determining how many cores are really necessary and where they should be placed. For example, if the GPR survey shows that asphalt and granular boundaries show very little spatial variation, only one core may be required to validate the GPR interpretation. If the GPR survey reveals large variations in the subsurface, cores can be placed at positions of thick, thin or anomalous layering to understand the subsurface in detail.

In this case study, 2 parallel lines of GPR data were acquired on a 500 meter section of road using a Noggin 1000 on a vehicle-towed SmartChariot configuration. The odometer triggered data acquisition at 5 centimeter (2 inch) intervals for a total of about 20,000 unique sample points on the road. Data were acquired in about 15 minutes.

100 meters of the pass along the road are shown in cross-section in Figure A. The data indicate two main sub-horizontal boundaries inferred to be the bottom of asphalt/top of granular interface and the bottom of granular/sub-base material interface. These interpretations were confirmed by a core acquired near the position 250m on the GPR line (the coring location was not on the GPR line which explains the slight differences between the GPR and core layer thicknesses).

Using the EKKO_Project interpretation module, the asphalt and granular bottoms were picked using the 'polyline' interpretation tool. Figure A depicts the asphalt bottom as blue and the granular bottom as green.

The new EKKO_Project Pavement Structure Report module was used to translate the interpreted boundaries into a depth section and provide sampled output at a user-defined interval; the resulting section plot is shown in Figure B.

The layered structure reporting tool also provides output statistics including the minimum, maximum and average layer thicknesses such as shown in Figure C.

The Pavement Structure Report module outputs the pavement thickness charts in a report format with several fields for the GPR operator to fill in including the road name, number of lanes and the GPR system used (depicted in Figure D). The report can then be printed directly or to a PDF document.

While the EKKO_Project Pavement Structure Report is designed for typical road survey analysis, the "pavement structure" can take many forms. This analysis and reporting tool can also be applied to any layered structures such as rail beds, runways, water depth and bathymetry, snow and ice thickness, and layered geology.

GPR data can be collected with a variety of deployment configurations such as the vehicle-towed SmartChariot, the hand-pushed SmartCart and the hand-towed SmartTow.

Any combination of easy-to-deploy GPR data acquisition system and advanced but easy-to-use EKKO_Project software enables users to quickly process the data results into meaningful subsurface information. The inspection of roads has just become a lot easier and more affordable! ■

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