Advancements in GPR for a Sustainable Tomorrow

Shawn Lapain, BSc. E., EIT
Pavement Specialist
Applied Research Associates Inc.
5401 Eglinton Avenue West, Suite 105, Toronto, ON, Canada, M9C 5K6
Tel: 416-621-9555, fax: 416-621-4917, email: slapain@ara.com

ABSTRACT

Over the past several years, agencies have more widely accepted the use of Ground Penetrating Radar (GPR), as a supplementary tool for determining pavement thicknesses. While traditional pavement evaluation techniques are found to be time consuming, localized, and destructive, the use of GPR provides a non-destructive survey method with pavement thicknesses typically collected at intervals of 100 mm . Often these surveys can be completed with the survey vehicle travelling at the posted speed limit, with little disruption to the travelling public.

As the use of GPR surveys continues to gain acceptance within the transportation industry, our understanding of its abilities also continues to advance. Although this survey is an effective tool for determining pavement thicknesses, there are many other applications where this technology can improve current pavement evaluation practices.

The objective of this paper is to discuss the effectiveness in using GPR equipment as a pavement evaluation tool, and to present some innovative applications of the equipment. Some examples of these innovations include: the determining voids beneath concrete slabs; identifying subsurface pavement distress/repair areas; identifying frost tapers at culvert locations; and locating drainage outlets for pavement sub-drains. Continued advancement in the use of this technology will help develop a better understanding for the performance in our existing pavements, and help engineers design for a better tomorrow.

Key Words: Ground Penetrating Radar, Frost Tapers, Culverts

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INTRODUCTION

Ground penetrating radar (GPR) technologies have been around for quite some time. The usage of GPR as a non-destructive tool in road rehabilitation to supplement traditional pavement techniques has been gaining acceptance in the pavement industry as a tool to improve our understanding as to why roads deteriorate and to allow engineers to be able to better design roads to last longer.

Traditional applications of GPR technology have been to determine asphalt, concrete and granular thicknesses at assist in the rehabilitation design for roadways. GPR is able to determine variations in pavement thickness or anomalies in the existing pavement that traditional investigation techniques may possibly overlook.
As our understanding of GPR technology continues to grow, so does the innovative ways this technology is used. The purpose of this paper is to discuss the applications of ground penetrating radar and its use for innovative pavement investigation methods. This paper will also look at some newer applications of this existing technology.

ASPHALT PAVEMENTS

Variable Asphalt Thickness

While most pavements are constructed with reasonably uniform layer thicknesses, maintenance and rehabilitation over the years, results in milling or overlays that change this uniformity. A common problem with using traditional methods such as cores and boreholes to determine pavement thickness is that these variations cannot be accurately assessed by discrete, widely spaced sampling.

In the spring of 2003, a detailed pavement investigation was carried out on a section of Highway 401 in the Region of Peel from Credit River to the Highway 403/410 interchange in the Ontario Ministry of Transportation’s Central Region. In addition to conducting a detailed pavement investigation, a demonstration GPR survey was conducted on a 1km section of the site. The site was scanned using a Noggin 1000 MHz smart cart system as pictured below in figure 1.

Figure 1: Noggin 1000MHz Smart Cart System

The user of GPR during this investigation yielded many interesting results. The scans conducted after the pavement condition surveys, borehole/corehole investigation, and FWD testing indicated that it was indeed possible to correlate the GPR data with all of the other information collected. It also indicated that the data gathered from the GPR survey was accurate to a point and would allow an engineer to quantify the thicknesses variations accurately, thus closing the potential gaps left by a traditional borehole/corehole investigation.

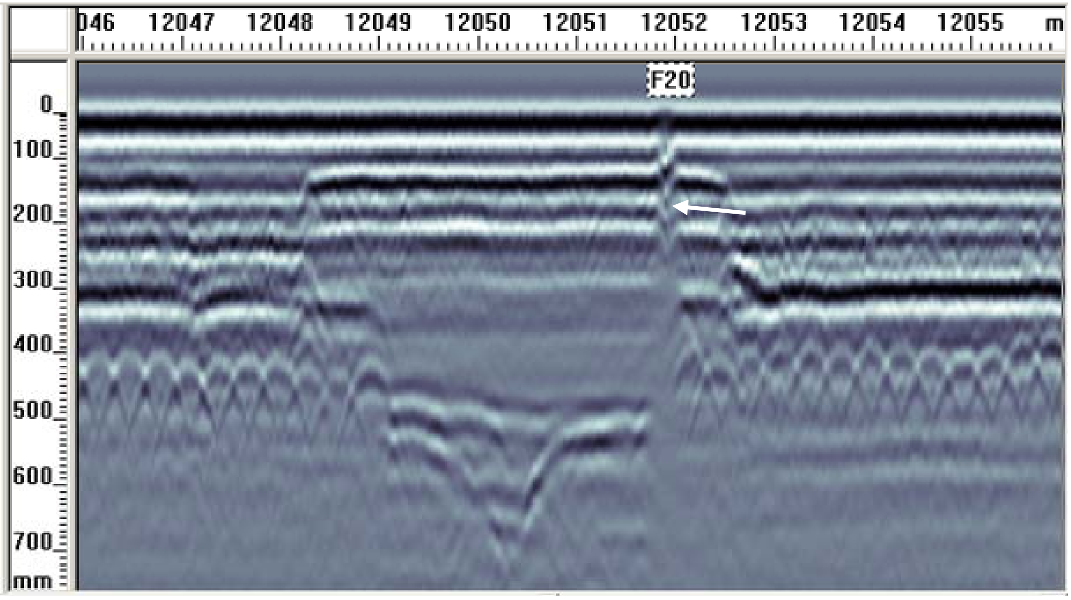

Figure 2: Variable Asphalt Thickness

Another useful application for GPR has has been in the investigation of pavement distress areas. In the summer of 2011, ARA completed a field investigation for the Ministry of Transportation (MTO) on Highway 11, south of Temagami Ontario. A GPR survey was conducted using the GPR trailer as seen below in figure 3.

Figure 3: SmartTrailer system with 3 GPR sensors

For this investigation, ARA identified 6 distress areas on the highway requiring remediation. The survey confirmed the pavement thickness that the corehole and borehole investigation provided in addition to indicating that there were areas in the investigation corridor that had thicker than average pavement that the corehole investigation did not pick up due to the drilling frequency.

CONCRETE PAVEMENTS

Currently, there are many different uses for GPR when it comes to investigation concrete pavements. Such uses are the traditional investigation of concrete pavement thicknesses, determining voids under concrete pavement joints, and examining tie and dowel bar alignment.

Determining Tie Bar and Dowel Bar Alignment

In the spring/summer of 2007, ARA was retained to provide quality assurance for a large expansion project on Highway 407. During this project, a comparison was done to gauge the accuracy of the tie bar and dowel bar placement within the concrete pavement structure using MIT Scan 2 and GPR equipment. Although GPR provided a more general understanding of the alignment of the tie bars and dowel bars present in terms of depth and orientation, it did provide a clearer picture as to the location of tie bars and tie bars and dowel bars at joint locations. In figure 4, the tie bars are noted by a hyberbolic curve. The location of the dowel bars in the concrete are indicated by the gap between the tie bars as shown below.

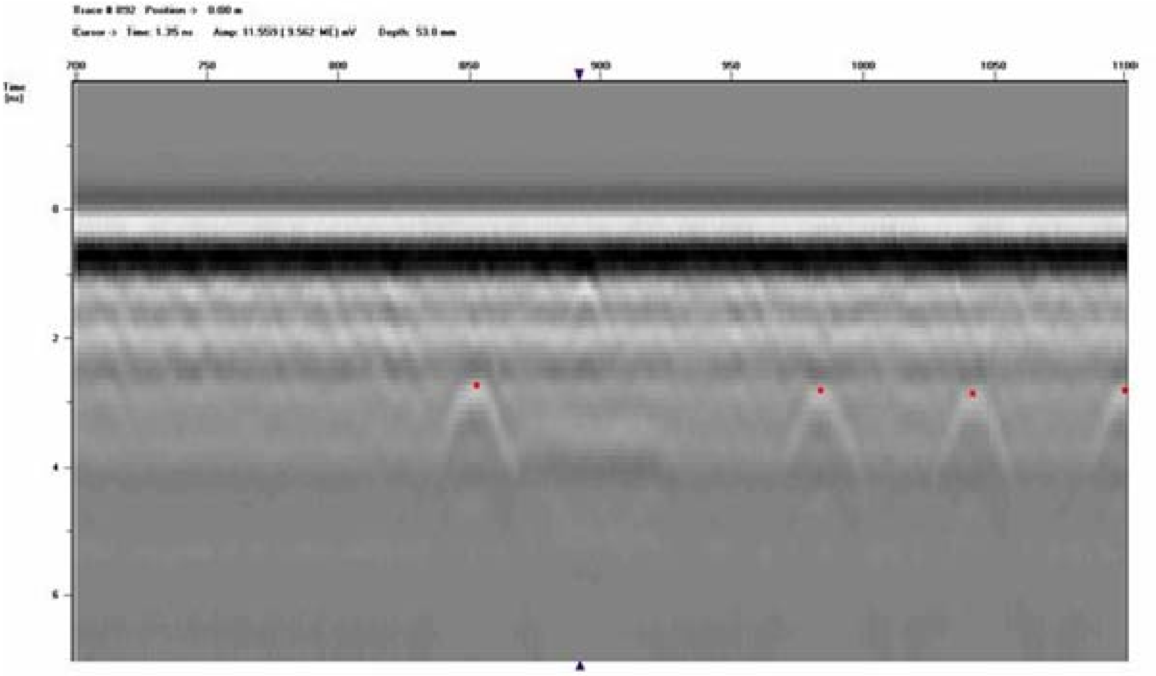

Figure 4: GPR Scan of Concrete Pavement

Cupolex

Cupolex is a 15 year old plastic injection technology that is becoming increasingly popular for the use of slabs on grade and structural slab concrete pavement construction. The overall goal is to provide a stable pavement structure but also provide significant cost savings by reducing the amount of concrete used for the construction of the slab/pavement. Currently, joint experimental research is being conducted by Dufferin Construction/Holcim Inc., Pontorollo Engineering, and Applied Research Associates to evaluate the effectiveness of Cupolex in concrete pavement construction. A photograph of a Cupolex slab before concreteing is shown in figure 5.

Figure 5: Typical Experimental Set Up of Cupolex System

In the fall of 2010, a research trial was conducted at a sand pit. After trafficking by over 150,000 heavy aggregates trucks, the 75 mm thick concrete section showed a few transverse cracks. Each crack location was surveyed in a 1200 x 1200 mm grid using a portable GPR system shown in figure 6.

Figure 6: GPR being used to scan a 1200 x 1200 mm grid

A total of five areas were selected for the survey. At three of the test locations, cracks were found to have formed at the rounded portions of the cupolex where concrete was at its thinnest. Two scans were performed, a shallow scan and then a deeper scan. The images below show how the GPR survey of the location was able to clearly show why the crack occurred, and the relationship to between the visible surface crack and the Cupolex unit placement. The grid-like structure appearing in figures 8 and 9 are the 100 x 100 mm steel mesh that was placed on top of the Cupolex before concrete placement.

Figure 7: Visible Surface Crack Marked Out in Pink Paint

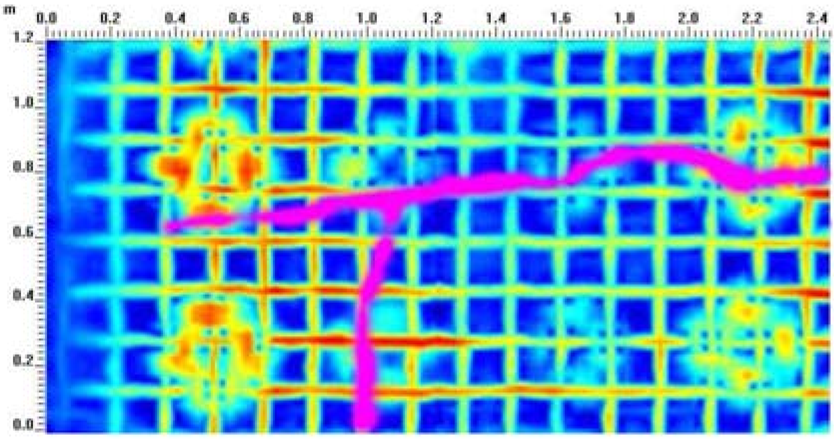

Figure 8: Depth Slice at 100 mm

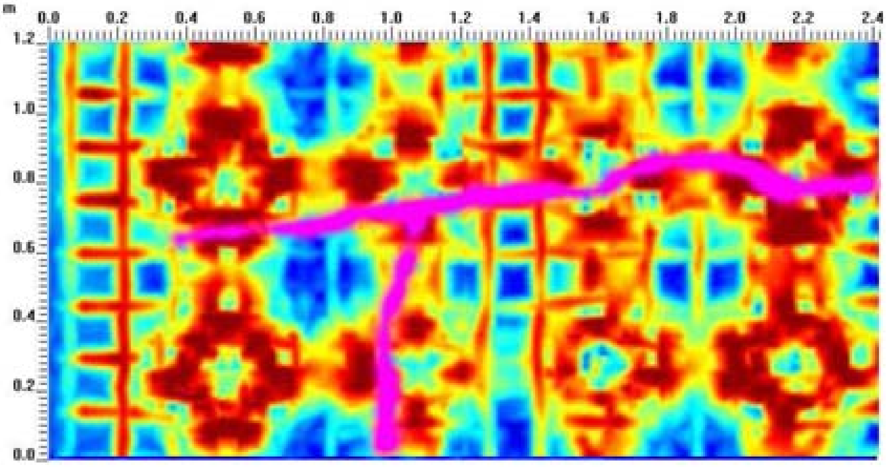

Figure 9: Depth Slice at 137 mm

APPLICATIONS TOWARDS GRANULAR MATERIALS

Location of Granular Base, Granular Subbase

Identifying granular materials is one of the traditional methods of using GPR. Current technology prevents GPR from being used to accurately distinguish the interface of the granular base from granular subbase.

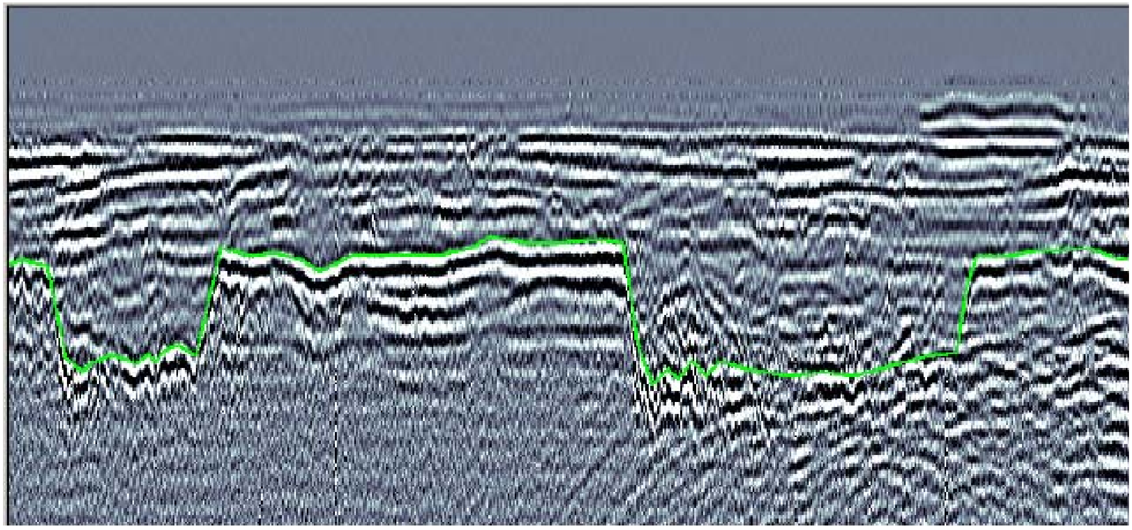

Figure 10: Granular Layer Indicated by Green Line

Location of Frost Tapers and Large Utilities

In a GPR survey conducted in September of 2007 on Highway 407, it was observed that the GPR scans were able to determine if a frost taper was present and also where the culvert was locations. As shown in figure 11, the survey indicated that it was indeed possible to the structures that were indicated by way of a hyberbolic curve. This will prove useful for utility construction as contractors no longer would have to waste valuable time and resources excavating for large utilities in the instance where repair or replacement of existing utilities would be deemed necessary. Using GPR in this manner would clearly provide a cost benefit to owners and contractors in that the utility needing repair could be found quicker. This technology could also prove useful as a utility locator tool for contractors during roadway construction, thus potentially avoiding costly accidents such as striking utilities and shutting projects down.

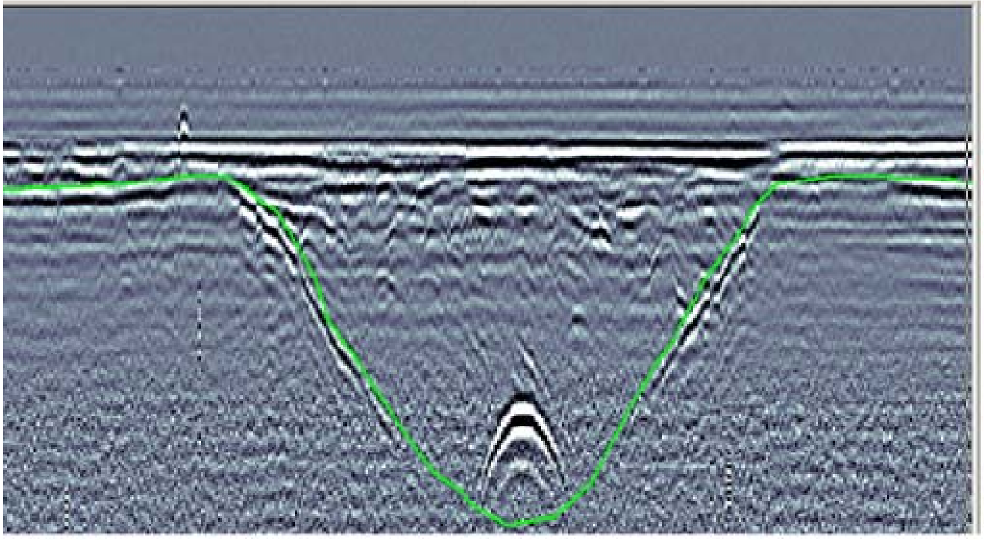

Figure 11: Frost Taper with Culvert Location

APPLICATIONS TOWARD BRIDGES

Reinforcing Bar Placement

Proper reinforcing bar placement during the construction of a bridge deck can sometimes mean the difference between a bridge deck lasting and premature failure. By using GPR to survey bridge locations like the scan in figure 12, the engineer can determine if the need for rehabilitation is due to deteriorated rebar or even improperly aligned tie bars and dowel bars.

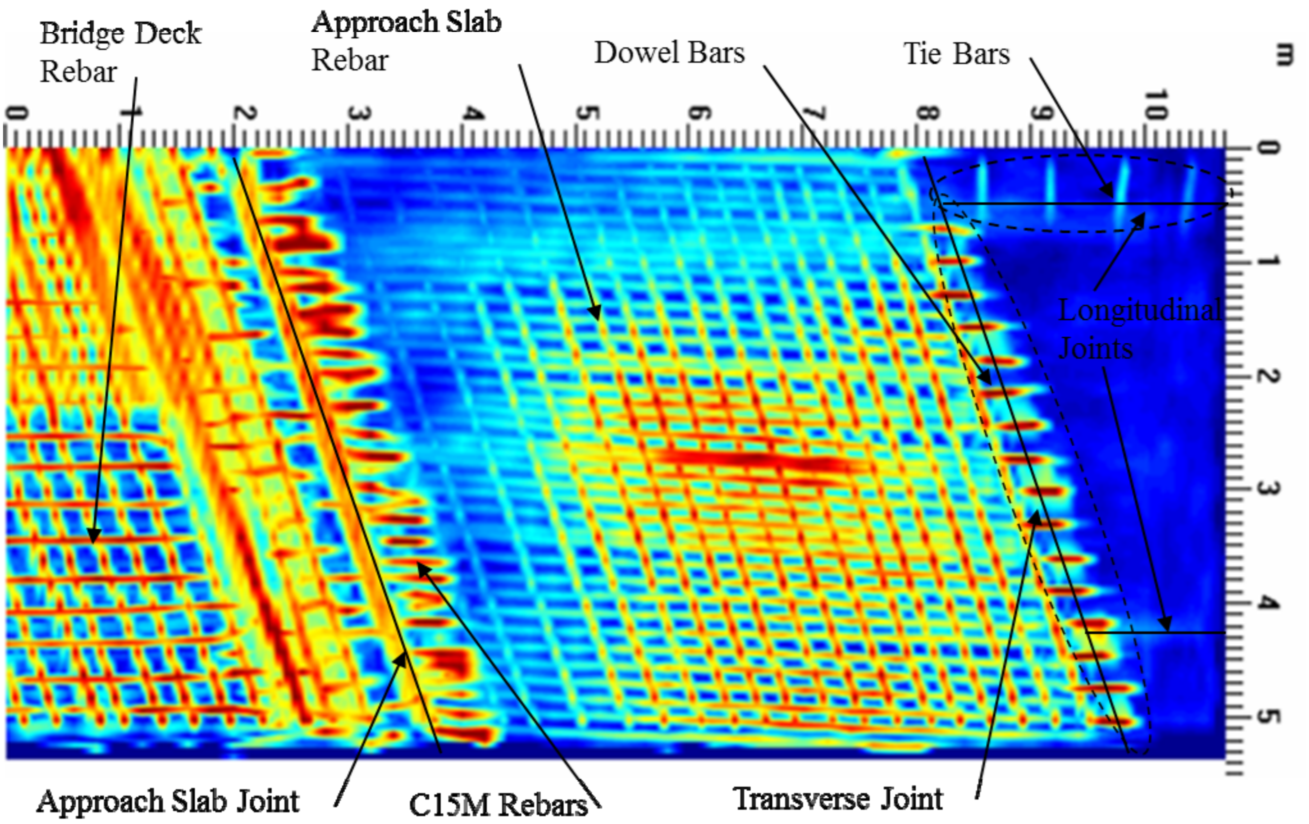

Figure 12: GPR Scan of a Bridge Deck with Approach Slab

Approach Slabs: Identifying Voids

Approach slabs are often a difficult section to construct. In most cases, these slabs tend to fail due to the settling of granular material under the slabs themselves. This can usually be attributed to improper backfilling and compaction against the retaining walls. This can be helpful in allowing preventative maintenance to take place to mitigate further deterioration of approach slabs. Figures 13 and 14 show scans of two different approach slabs that indicate voids present under the concrete.

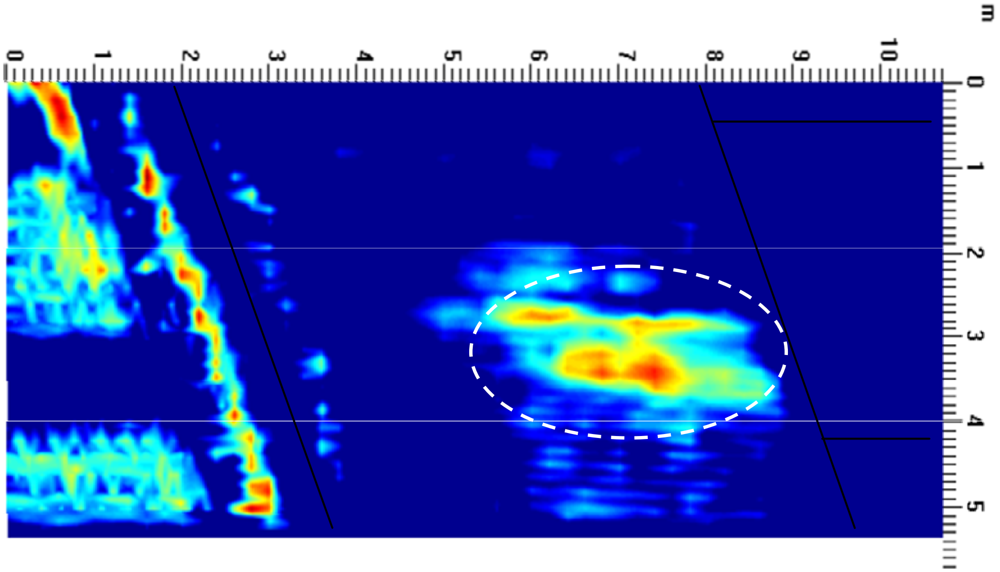

Figure 13: East Approach Slab of a Bridge Deck

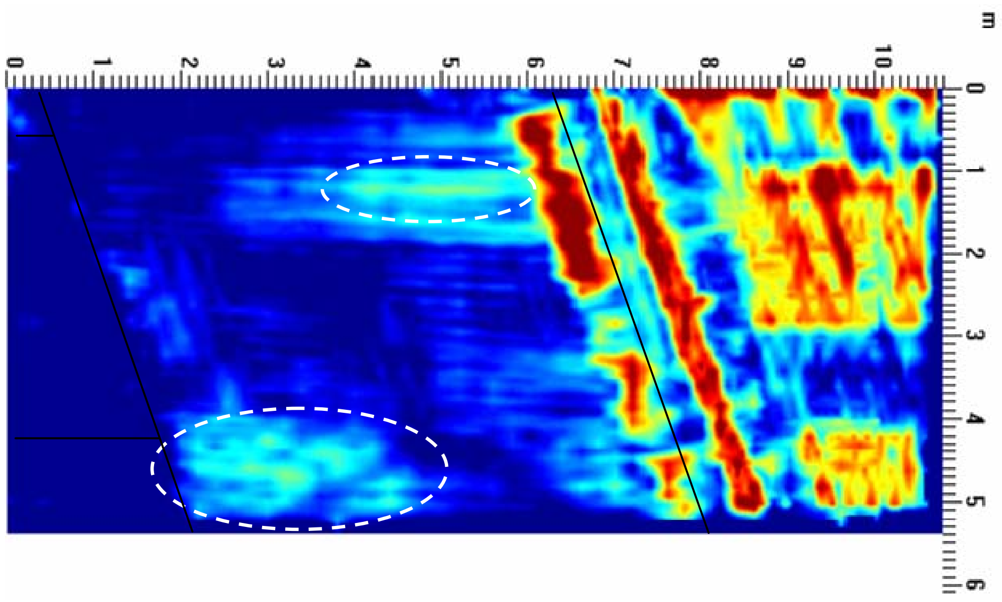

Figure 14: West Approach Slab of a Bridge Deck

CONCLUSIONS

As pavement infrastructure continues to age, new and innovative tool for pavement investigation are becoming necessary to aid engineers in pavement rehabilitation in an economy that requires quick, cost effective solutions that will assist in generating an all encompassing picture of what the thickness is of a pavement structure in need of rehabilitation.

Through the continued use of GPR, many more new and exciting applications of this technology are being developed to help improve the quality of transportation infrastructure. As the industry grows to understand and accept GPR technology, it is being used more frequently in field investigation practices.

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