Center for Transportation Infrastructure and Safety

Air-Launched GPR Evaluation for Rapid Assessment of MoDOT Bridge Decks

by

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A National University Transportation Center at Missouri University of Science and Technology

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16. Abstract

The overarching goal of this study is to demonstrate that advanced nondestructive testing/evaluation (NDT/NDE) techniques can be rapidly, effectively, and economically implemented as part of routine MoDOT bridge deck surveys to determine the general condition of bridge decks. This study extends the work of a separate study (*Nondestructive Evaluation of MoDOT Bridge Decks - Pilot Study,* MoDOT Award TRyy1308) focused on NDT/NDE techniques for comprehensive bridge deck assessment. It is envisioned that the condition assessment conducted in the present study will be utilized as reconnaissance to identify and rank those bridges requiring a more detailed investigation, which will enable MoDOT to optimize the use of resources and reduce the cost of bridge deck evaluation. Results of this study will be used to evaluate the feasibility of a large scale, long-term program (multi-year, routine basis) that incorporates NDE techniques into MoDOT bridge deck surveys for the purpose of reducing cost on assessment and maintenance of bridge decks.

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ABSTRACT

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At the time of this report, data collection is underway. This report presents a summary of the work to date and future work that will be conducted in this project. Final results will be published at a later date. This study is sponsored by the Missouri Department of Transportation and the National University Transportation Center at the Missouri University of Science and Technology in Rolla, Missouri.

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1. INTRODUCTION

1.1 Project Goal

The overarching goal of this study is to demonstrate that advanced nondestructive testing/evaluation (NDT/NDE) techniques can be rapidly, effectively, and economically implemented as part of routine MoDOT bridge deck surveys to determine the general condition of bridge decks. This study extends the work of a separate study (*Nondestructive Evaluation of MoDOT Bridge Decks - Pilot Study*, MoDOT Award TRyy1308) focused on NDT/NDE techniques for comprehensive bridge deck assessment. It is envisioned that the condition assessment conducted in the present study will be utilized as reconnaissance to identify and rank those bridges requiring a more detailed investigation, which will enable MoDOT to optimize the use of resources and reduce the cost of bridge deck evaluation.

Results of this study will be used to evaluate the feasibility of a large scale, long-term program (multi-year, routine basis) that incorporates NDE techniques into MoDOT bridge deck surveys for the purpose of reducing cost on assessment and maintenance of bridge decks.

1.2 Background

Data used to assess the structural condition of concrete bridge decks can be collected using various methods such as visual examination, surface sounding, removal and evaluation of material samples, and noninvasive imaging. Nondestructive testing (NDT) techniques, in particular, can enable rapid and comprehensive data collection. With respect to concrete structures, NDT methods have been used most commonly to determine member dimensions; location of cracking, delamination, and debonding; degree of concrete consolidation and presence of voids; steel reinforcement size and location; corrosion of reinforcement; and extent of damage from exposure to freezing and thawing, fire, or chemicals (ACI Committee 228, 1998).

Selection of appropriate NDT techniques for a given investigation objective is crucial for the effective use of resources. In this study, the use of ground penetrating radar (GPR) is investigated to determine the general condition of MoDOT bridge decks because it is well-suited to rapidly determine the relative condition of the deck in order to identify areas of degradation and corrosion. Two types of GPR have been used in bridge deck investigations: air-launched GPR, and ground-coupled GPR. An air-launched GPR antenna is useful to acquire lower volumes of data at relatively high speeds with slightly lower resolution measurements, while the use of a ground-coupled GPR antenna enables higher resolution at lower data acquisition speeds.

Lane closures are generally required during bridge deck surveys with ground-coupled GPR, and data acquisition of the entire bridge deck can require several hours, as demonstrated in a recent study by the investigators (Sneed et al. 2014). On the other hand, air-launched GPR data can be acquired more rapidly, and therefore it is usually preferred in bridge deck investigations so that the impact on traffic can be minimized. Air-launched GPR has previously been utilized in evaluation of MoDOT bridge decks by consultants to MoDOT. Recent studies have shown that air-launched GPR can be an effective and efficient technology for bridge deck inspection (Gehrig et al., 2004; Barnes and Trottier, 2004; Barnes et al., 2008; Tarussov et al., 2013).

1.3 Project Objectives

The objectives of this study are to demonstrate the utility of the air-launched GPR tool in rapidly evaluating the general condition of MoDOT bridge decks and confirm that it can be implemented as part of a long-term program that enables faster, better, and more cost-effective bridge deck assessments. The results of the deck evaluation conducted using air-launched GPR will enable better, more cost-effective decisions regarding different repair or treatment options. Results will also enable more cost-effective decisions regarding whether a more comprehensive bridge deck investigation should be conducted on a given bridge. Additional research objectives are to compare and contrast the results acquired using air-launched GPR with those acquired using ground-coupled GPR as part of a separate project reported by Sneed et al. (2014) in terms of accuracy and ease in evaluating the existing condition of bridge decks.

1.4 Scope of Work

This project included the investigation of ten bridge decks. Five of the bridge decks investigated were the same as those that were investigated as part of a previous study by the investigators (Sneed et al. 2014), and five were different. The following work was performed for each investigation:

- A general visual investigation of the top surface of the bridge deck, including general visual observations and photo documentation

- GPR scans using two GSSI 2.0 GHz air-launched antennae mounted to vehicle

At the time of this report, seven bridges were selected for investigation, and data were acquired on six bridges. The bridges were selected by MoDOT and researchers from Missouri S&T. Bridges investigated and dates of investigation are summarized in Table 1-1, and the locations of the bridges are shown in Figure 1-1.

Table 1-1 Summary of Bridges Investigated

Bridge	**Date of Investigation**	**Weather Conditions**	**Notes**
A0569	07/30/2014	61-81° F, absence of rain	Previously investigated in the project reported in Sneed et al. (2014)
A2111	*TBD*	*TBD*	
A3405	10/16/2013	40-56° F, absence of rain	Previously investigated in the project reported in Sneed et al. (2014)
	04/27/2014	62-75° F, light rain	
	06/05/2014	64-72° F, light rain	
A3406	10/16/2013	40-56° F, absence of rain	Previously investigated in the project reported in Sneed et al. (2014)
	02/02/2014	30-37° F, light rain	
A4780	07/31/14	61-84° F, absence of rain	
A4781	07/31/14	61-84° F, absence of rain	
K0197	10/16/2013	40-56° F, absence of rain	Previously investigated in the project reported in Sneed et al. (2014)
	06/05/2014	64-72° F, light rain	
TBD			
TBD			
TBD			

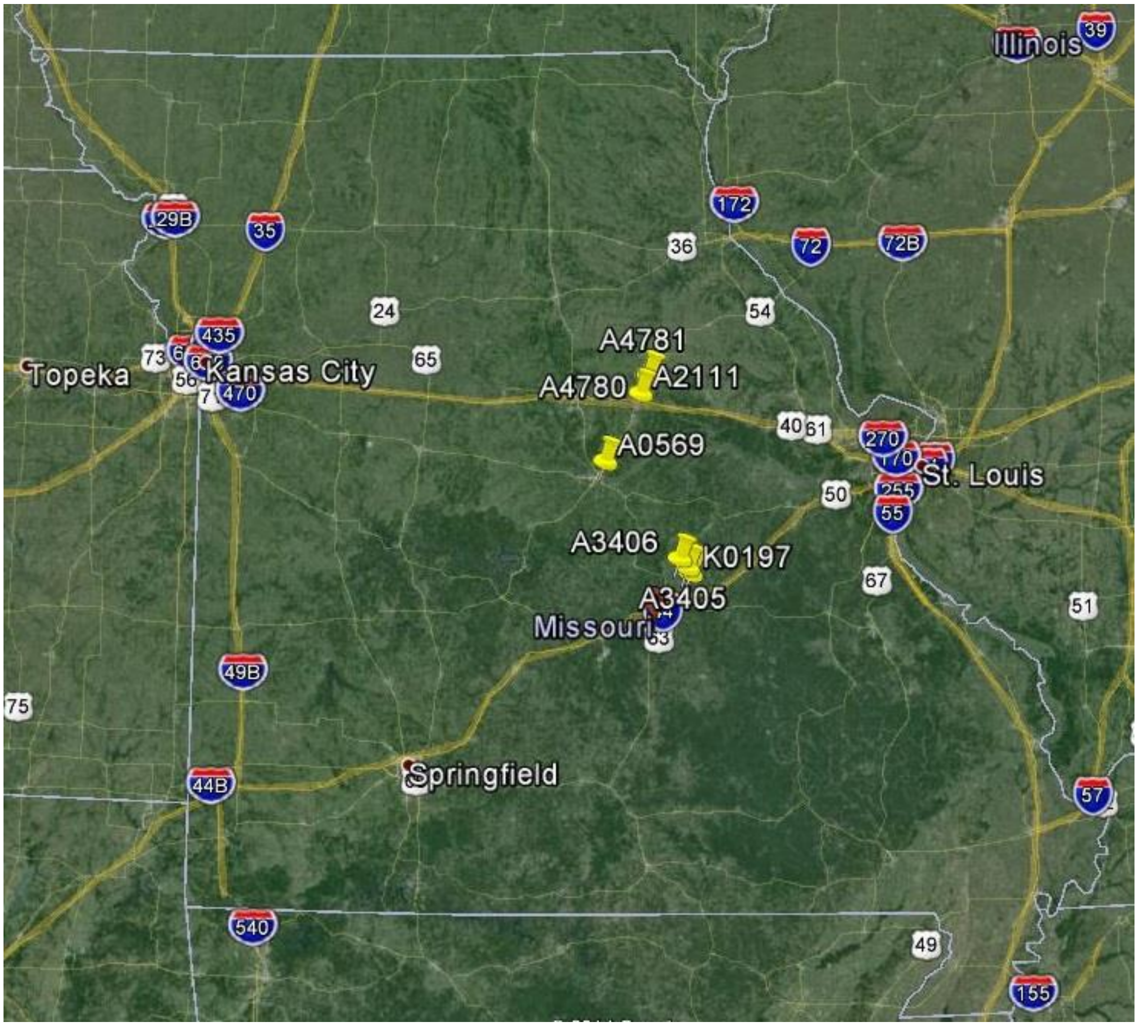

Figure 1-1 Map of Bridge Locations (Source: Google Earth)

2. BRIDGE DECK INFORMATION

2.1 Methodology

Prior to conducting the field investigations, the as-built drawings, Structural Inventory and Appraisal Sheets, and inspection history for each bridge deck were provided to the researchers by MoDOT and were reviewed. Computer aided design (CAD) drawings of each bridge deck were created using as-built drawings provided by MoDOT. The base map drawings include important structural elements of each bridge, including bents, main support beams, deck outline, and deck reinforcement (top mat), along with the curb and barrier wall. After the investigation of each bridge is completed and the data are interpreted, the base maps will be used to display the GPR reflection amplitude maps based on the top reinforcing bar in the transverse bridge direction (Chapter 3).

2.2 Bridge Deck Descriptions

This section includes details of each bridge investigated. AADT values reported in this section are based on values recorded for 2013 with the exception of Bridge A2111, for which values recorded were for 2012.

2.2.1 Bridge A0569

Figure 2-1 shows an overview of Bridge A0569 during the deck investigation. Details of Bridge A0569 are summarized in Table 2-1.

Figure 2-1 Bridge A0569 Overview of Bridge Deck Observed During Field Investigation

Table 2-1 Bridge A0569 Details

Nearest City	Jefferson City
County	Cole
Roadway Carried	Clark Avenue
Feature Intersected	U.S. 50
Year Constructed	1959
Reconstructed Year	Never Reconstructed
Number of Driving Lanes	3
Direction of Traffic	Two-Way
AADT	6,927
AADT Truck Percent	10%
Structure Length	139 ft. – 0 in.
Total Deck Width	57 ft. – 8 in.
Curb to Curb Br. Width	48 ft. – 10 in.
Main Structure Material Type	Concrete
Main Structure Construction Type	Frame
Number of Main Spans	1
Number of Approach Spans	0
Deck Material	Concrete CIP
Designed Slab Thickness	6.5 in.
Wearing Surface	Bituminous
Orientation of Top Reinforcement Layer	Transverse
Designed Depth to Top Transverse Reinforcement	1.75 in. (without asphalt overlay)
Slab Reinforcement, Transverse Direction	#5 @ 6 in. o.c. top and bottom main span, #5 @ 5 in. o.c. top and bottom abutments
Slab Reinforcement, Longitudinal Direction	#5 top and bottom main span and abutments, spacing varies
Other Information	Asphalt wearing surface was extensively deteriorated at the time of the NDE investigation. Many locations of asphalt rutting and shoving were observed, along with many cracks and potholes.

2.2.2 Bridge A2111

Details of Bridge A2111 are summarized in Table 2-2.

Table 2-2 Bridge A2111 Details

Nearest City	Fulton
County	Callaway
Roadway Carried	U.S. 54 East
Feature Intersected	Abandoned Railroad
Year Constructed	1968
Reconstructed Year	Never Reconstructed
Number of Driving Lanes	2
Direction of Traffic	One-Way
AADT	4,806
AADT Truck Percent	20%
Structure Length	176 ft. – 0 in.
Total Deck Width	46 ft. – 10 in.
Curb to Curb Br. Width	43 ft. – 11 in.
Main Structure Material Type	Steel Continuous
Main Structure Construction Type	Stringer/Multibeam - Grd
Number of Main Spans	3
Number of Approach Spans	0
Deck Material	Concrete CIP
Designed Slab Thickness	7.5 in.
Wearing Surface	Monolithic Concrete
Orientation of Top Reinforcement Layer	Transverse
Designed Depth to Top Transverse Reinforcement	1.875 in.
Slab Reinforcement, Transverse Direction	#5 @ 5 in. o.c. top and bottom
Slab Reinforcement, Longitudinal Direction	#4 @ 6 in. o.c. top over bents, #4 @ 12 in. o.c. top otherwise; #5 bottom, spacing varies
Other Information	-

2.2.3 Bridge A3405

Figure 2-2 shows an overview of Bridge A3405 during the deck investigation. Longitudinal and transverse cracks were noted on the top surface of the deck were. Most of the cracks had been filled with asphalt. Some concrete patches were also observed. Details of Bridge A3405 are summarized in Table 2-3.

Figure 2-2 Bridge A3405 Overview of Bridge Deck Observed During Field Investigation

Table 2-3 Bridge A3405 Details

Nearest City	St. James
County	Maries
Roadway Carried	MO 68
Feature Intersected	Coppedge Creek
Year Constructed	1975
Reconstructed Year	Never Reconstructed
Number of Driving Lanes	2
Direction of Traffic	Two-Way
AADT	2,860
AADT Truck Percent	21%
Structure Length	144 ft. – 0 in.
Total Deck Width	46 ft. – 10 in.
Curb to Curb Br. Width	43 ft. – 11 in.
Main Structure Material Type	Concrete Continuous
Main Structure Construction Type	Slab
Number of Main Spans	4
Number of Approach Spans	0
Deck Material	Concrete CIP
Designed Slab Thickness	14.5 in.
Wearing Surface	Monolithic Concrete
Orientation of Top Reinforcement Layer	Longitudinal
Designed Depth to Top Transverse Reinforcement	3.375 in.
Slab Reinforcement, Transverse Direction	#5 @ 9 in. o.c. top and bottom
Slab Reinforcement, Longitudinal Direction	#10 @ 6 in. o.c. top over bents, #5 @ 9 in. o.c. top otherwise; #9 @ 18 in. o.c. bottom over bents, #9 & #10 @ 6 in. o.c. bottom otherwise
Other Information	-

2.2.4 Bridge A3406

The top surface of the deck of Bridge A3406 appeared to be heavily deteriorated. Numerous transverse cracks and concrete patches were observed. The majority of the cracks were filled with oil or bitumen. Figure 2-3 shows an overview of the deck during the field investigation. Details of Bridge A3406 are summarized in Table 2-4.

Figure 2-3 Bridge A3406 Overview of Bridge Deck Observed During Field Investigation

Table 2-4 Bridge A3406 Details

Nearest City	Vichy
County	Maries
Roadway Carried	MO 68
Feature Intersected	Lanes Creek
Year Constructed	1976
Reconstructed Year	Never Reconstructed
Number of Driving Lanes	2
Direction of Traffic	Two-Way
AADT	1,156
AADT Truck Percent	21%
Structure Length	163 ft. – 0 in.
Total Deck Width	46 ft. – 10 in.
Curb to Curb Br. Width	43 ft. – 11 in.
Main Structure Material Type	Prestressed Concrete Continuous
Main Structure Construction Type	Stringer/Multibeam - Grd
Number of Main Spans	3
Number of Approach Spans	0
Deck Material	Concrete CIP
Designed Slab Thickness	7.5 in.
Wearing Surface	Monolithic Concrete
Orientation of Top Reinforcement Layer	Transverse
Designed Depth to Top Transverse Reinforcement	1.875 in.
Slab Reinforcement, Transverse Direction	#5 @ 5 in. o.c. top and bottom
Slab Reinforcement, Longitudinal Direction	#4 @ 6 in. o.c. top over bents, #4 @ 12 in. o.c. top otherwise; #5 bottom, spacing varies
Other Information	-

2.2.5 Bridge A4780

Figure 2-4 shows an overview of Bridge A4780 during the deck investigation. Details of Bridge A4780 are summarized in Table 2-5.

Figure 2-4 Bridge A4780 Overview of Bridge Deck Observed During Field Investigation

Table 2-5 Bridge A4780 Details

Nearest City	Kingdom City
County	Callaway
Roadway Carried	U.S. 54
Feature Intersected	Auxvasse Creek
Year Constructed	1990
Reconstructed Year	2013
Number of Driving Lanes	2
Direction of Traffic	One-Way
AADT	4,326
AADT Truck Percent	23%
Structure Length	304 ft. – 0 in.
Total Deck Width	41 ft. – 3 in.
Curb to Curb Br. Width	38 ft. – 8 in.
Main Structure Material Type	Prestressed Concrete Continuous
Main Structure Construction Type	Stringer/Multibeam - Grd
Number of Main Spans	5
Number of Approach Spans	0
Deck Material	Concrete CIP and PC panels
Designed Slab Thickness	8.5 in.
Wearing Surface	Monolithic Concrete
Orientation of Top Reinforcement Layer	Longitudinal
Designed Depth to Top Transverse Reinforcement	3.625 in.
Slab Reinforcement, Transverse Direction	#5 @ 5 in. o.c. top in CIP concrete; 0.375 in. dia. strand @ 4 in. o.c. bottom in PC panel
Slab Reinforcement, Longitudinal Direction	Bar size and spacing varies top over bents and otherwise top in CIP concrete; #3 @ 6 in. o.c. bottom in PC panel
Other Information	2013 reconstruction consisted of half soled repair, along with an epoxy polymer concrete overlay with a minimum thickness of 0.25 in.

2.2.6 Bridge A4781

Figure 2-5 shows an overview of Bridge A4781 during the deck investigation. Details of Bridge A4781 are summarized in Table 2-6.

Figure 2-5 Bridge A4781 Overview of Bridge Deck Observed During Field Investigation

Table 2-6 Bridge A4781 Details

Nearest City	Kingdom City
County	Callaway
Roadway Carried	U.S. 54
Feature Intersected	Auxvasse Creek
Year Constructed	1990
Reconstructed Year	2013
Number of Driving Lanes	2
Direction of Traffic	One-Way
AADT	4573
AADT Truck Percent	13%
Structure Length	304 ft. – 0 in.
Total Deck Width	41 ft. – 3 in.
Curb to Curb Br. Width	38 ft. – 8 in.
Main Structure Material Type	Prestressed Concrete Continuous
Main Structure Construction Type	Stringer/Multibeam - Grd
Number of Main Spans	5
Number of Approach Spans	0
Deck Material	Concrete CIP and PC panels
Designed Slab Thickness	8.5 in.
Wearing Surface	Monolithic Concrete
Orientation of Top Reinforcement Layer	Longitudinal
Designed Depth to Top Transverse Reinforcement	3.625 in.
Slab Reinforcement, Transverse Direction	#5 @ 5 in. o.c. top in CIP concrete; 0.375 in. dia. strand @ 4 in. o.c. bottom in PC panel
Slab Reinforcement, Longitudinal Direction	Bar size and spacing varies top over bents and otherwise top in CIP concrete; #3 @ 6 in. o.c. bottom in PC panel
Other Information	2013 reconstruction consisted of half soled repair, along with an epoxy polymer concrete overlay with a minimum thickness of 0.25 in.

2.2.7 Bridge K0197

Figure 2-6 shows an overview of Bridge K0197 during the deck investigation. Details of Bridge K0197 are summarized in Table 2-7.

Figure 2-6 Bridge K0197 Overview of Bridge Deck Observed During Field Investigation

Table 2-7 Bridge K0197 Details

Nearest City	St. James
County	Phelps
Roadway Carried	MO 68
Feature Intersected	Bourbeuse River
Year Constructed	1965
Reconstructed Year	1984
Number of Driving Lanes	2
Direction of Traffic	Two-Way
AADT	2,524
AADT Truck Percent	18%
Structure Length	207 ft. – 0 in.
Total Deck Width	32 ft. – 5 in.
Curb to Curb Br. Width	29 ft. – 10 in.
Main Structure Material Type	Steel Continuous
Main Structure Construction Type	Stringer/Multibeam - Grd
Number of Main Spans	3
Number of Approach Spans	0
Deck Material	Concrete CIP
Designed Slab Thickness	7.5 in.
Wearing Surface	Bituminous
Orientation of Top Reinforcement Layer	Longitudinal
Designed Depth to Top Transverse Reinforcement	2.5 in. (without asphalt overlay)
Designed Slab Reinforcement, Transverse Direction	#6 @ 6.5 in. o.c. top and bottom
Designed Slab Reinforcement, Longitudinal Direction	#4 @ 6 in. o.c. top over bents, #4 @ 12 in. o.c. top otherwise; #4 bottom, spacing varies
Other Information	1984 reconstruction consisted of half soled and full depth repair, along with an asphalt overlay with a minimum thickness of 1.5 in. At the time of the NDE investigation, the asphalt was approximately 2.5 in. thick and appeared to be in good condition based on visual inspection.

3. GROUND PENETRATING RADAR

3.1 Overview

Ground penetrating radar (GPR) is a non-destructive geophysical tool that uses pulsed electromagnetic (EM) signals to penetrate into a medium and measure amplitude and two-way travel time of reflections from the interface of materials with different dielectric properties (Shin and Grivas, 2003). In this project, the pulses of electromagnetic radiation that are emitted are partially reflected by the top of the bridge deck, the base of the deck, and from features such as embedded reinforcing steel bar (rebar) and delaminations. Analysis of the reflected signal (magnitude and arrival time) enables the operator to estimate the depth to each reflector and to assess the overall condition of the bridge deck. The most significant output of the GPR investigation is a map depicting variations in the amplitude of the reflection from the top of the transverse layer of rebar. Based on the interpretation of the amplitude map, the interpreter is able to identify areas of the bridge deck that appear to be deteriorated relative to other areas.

3.2 Methodology

Two air-launched 2.0 GHz GPR antennae mounted to a vehicle were used to investigate each bridge deck. The GPR antennae are shown in Figure 3-1. The primary objective the GPR investigations was to evaluate the capability of the GPR tool to rapidly and reliably assess the condition of the bridge deck.

Five of the bridge decks investigated had previously been investigated as part of a separate study (Sneed et al.) as identified in Table 1-1. The previous investigation was conducted within two years prior to the present investigation. Data were acquired in the previous investigation with a ground-coupled 1.5 GHz GSSI GPR antenna. The maximum time difference between the previous investigation and the present investigation was 19 months. No repair was conducted on the bridges between the previous and present investigations.

In the present study, data were acquired with air-launched GPR at a relatively low speed to achieve the relatively high accuracy. For the five bridge decks that were previously investigated, this approach enables comparison of the results acquired using air-launched GPR with those acquired using ground-coupled GPR (Sneed et al. 2014) in terms of accuracy and ease in evaluating the existing condition of bridge decks. Accordingly, this approach attempts to establish a “best-case” correlation between the two data sets.

As shown in Table 1-1, data were acquired from bridges A3405, A3406, and K0197 on more than one date. These three bridges were the first that were investigated in this project. The reason for acquiring data on multiple dates was to test the GPR equipment and to develop a methodology for acquiring the data.

Figure 3-1 Photo of 2.0 GHz GSSI Antennae Mounted to Vehicle

4. CONCLUDING REMARKS

4.1 Summary

This study investigated the use of air-launched GPR in the assessment of MoDOT bridge decks. The project includes the investigation of a suite of ten bridge decks, five of which had undergone a comprehensive investigation by the investigators using several NDT techniques including high-frequency ground-coupled GPR, visual evaluation, and core control (Sneed et al. 2014) within the previous 19 months. Results acquired using air-launched GPR will be compared and contrasted with those acquired using ground-coupled GPR in terms of accuracy and ease in evaluating the existing condition of bridge decks. Further, this work will help establish the value of the use of air-launched GPR in evaluating MoDOT bridges in the future.

4.2 Ongoing and Future Work

At the time of this report, data have been acquired on six of the 10 bridge decks. Data from three of the bridge decks have been processed and appear to be good quality and consist with the ground-coupled GPR data from the previous study (Sneed et al. 2014). Discussion is underway with MoDOT to identify and schedule the remaining bridges.

Once data have been acquired from all bridge decks, the following work will be performed:

- Air-launched GPR data will be processed and interpreted for each bridge deck. For each bridge deck, results will be presented in the form of a 2-D map of the reflection amplitudes from the top layer of reinforcing steel.
- Air-launched GPR data and ground-coupled GPR data will be compared and contrasted.
- Parameters will be recommended for air-launched GPR data acquisition, processing, and interpretation

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