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REGARDING	Implementation Close Out of SHRP2 Product: Nondestructive Testing for Concrete Bridge Decks (R06A)

Overview of Product Activity - Executive Summary

The R06A product, Nondestructive Testing for Concrete Bridge Decks (R06A) was intended to provide funding to state DOT's to implement one or more of the Nondestructive testing (NDT) technologies previously identified as being applicable to the rapid and accurate evaluation of bridge deck concrete condition. It has been previously recognized that the number of concrete bridge decks that are in poor structural condition is one of the biggest challenges facing state and local agencies across the country. It was expected that a number of states would adopt the R06A product and other NDT methods as a means to improve the accuracy and speed of bridge deck condition rating and deterioration mapping while also increasing safety to workers and the travelling public. The NDT results from these evaluations are expected to be used in asset management programs for long term use as well as in project-level evaluations to determine repair/replacement decisions and scopes of work.

The R06A product was made available through SHRP2 in a Round 4 and Round 7. Round 4 involved 8 states, while Round 7 was a total of 14 states. It should be noted that two of the Round 7 states were also Round 4 states (Oregon and Iowa).

The list of states participating are shown below

Round 4	Round 7
Indiana	Alabama
Pennsylvania	Arkansas
Iowa	Delaware
Missouri	Georgia
Virginia	Hawaii
Florida	Iowa (also in Round 4)
Louisiana	Kentucky
Oregon	North Carolina
	Nebraska
	North Dakota
	New Mexico
	New York
	Oregon (also in Round 4)
	California

The award amounts per state were higher in Round 4 that in Round 7. The total awards were :

- **Round 4** – Each state was awarded $100,000.00 plus unspecified SME support of over 24 hours
- **Round 7** – each state was awarded $30,000.00 plus 8 hours of dedicated SME support

Output

- Technical Assistance
  - Technical meetings with States (how many and which ones)

    Technical assistance meetings were held with all of the Round 4 states, and most of the Round 7 states. For Round 4, the technical meetings and training occurred in a single site visit, with typically involved a 2 day combination of office training and presentations followed by field demonstrations and additional training in the testing methods available. The SME produced the content for all of the technical training events. The actual topics covered varied somewhat from state to state depending on the specific areas of interest each state had, but generally included an overview of the NDT methods available, how they were applied, what information could be obtained from each, and some ideas about relative speed and cost for each method.

    For Round 7, the training and presentations were updated to reflect the latest results available at the time of each training event. The events for Round 7 were typically done in a single day for each state, but still included an office portion followed by a shorter field demonstration.

    In addition to the formal technical assistance training and demonstrations, there was also SME support provided to the awardees in the form of RFP review, data review and discussion, report review, recommendations about technology applicability, etc. This support gave the states much greater confidence in both the deployment of choice of the methods as well as in the results obtained.

  - Technical Working Group conference calls and webinars

    One webinar was held that covered both R06A and R06G (Tunnel NDT). This webinar was held to introduce the R06 A and G products to new states prior to the start of Round 7. The webinar presented an overview of the test methods used on bridge decks as well as a summary of the results available at that time from the work of Round 4 states. The SME provided the technical content for webinar, as well as presenting the technical material during the webinar. A second R06A webinar was held April 30, 2019 to close out the product support and allow several states to present their findings.

  - Knowledge transfers/Peer-exchanges

    As part of the R06A product, there was a single Peer Exchange held in Portland, Oregon. The details of this Peer Exchange are available in the Peer Exchange Report, and are summarized below:

    The peer exchange was held in Portland, Oregon on January 30-31, 2019 and was hosted by the Oregon DOT. It featured presentations from 14 states who participated in either Round 4, Round 7, or both rounds as well as introductory discussion, a summary presentation overview of the test methods to be presented, and a final discussion of the "Next Steps". Of the 14 state presentations, 10 were presented on-site by representatives of the states and the remaining 4 were presented in abstentia by the SME representatives.

    Each state DOT presentation showed the methods that the given state used, with most presenting typical data examples and comparisons to other evaluation methods and “traditional” tools such as hammer sounding and chain drag. There was a very lively question and answer session following each presentation. Finally, the peer exchange wrapped up with an open discussion of “Next Steps” to continue to use and refine the technology and apply it in ways that meet the needs of each state DOT. In addition to specific plans articulated by certain states who already have procedures and projects in place for ongoing NDT of bridges, there were a number of more general suggestions. These included looking for Pooled Fund research options from other sources beyond SHRP2, such as SPNR funding. Note that some

of these would require a State DOT to take the lead. Other suggestions included forming a user group of some sort, as well as FHWA support. The state of Alabama would like to construct a mock-up bridge with known defects and conditions to allow for improved training, verification of equipment, and research of new methods.

Overall, the peer exchange showed that the NDT methods employed by the IAP states did indeed result in usable data that provided information beyond what has been available from traditional methods such as chain drag and visual inspection.

- Field Activities
  - Demonstrations
    - The field activities for the R06A product primarily consisted of live demonstrations of selections of the various test methods available for evaluation of bridge decks. The actual methods demonstrated depended on the individual states and their needs. In some cases, actual data was collected and analyzed for a portion of a specific bridge deck to allow the state to see "real" data on a typical deck.
    - Some additional field work was also conducted for Round 4 states to support their implementation activities. Part of this additional field work by the SME was to document (via video and photo) the implementation activities of some of the states. In other cases, field visits were made to assist the states in using purchased equipment to provide additional training and technical assistance where needed to allow a higher degree of confidence in the collection and interpretation of the data as well as improve the utility of the results in overall bridge deck assessment.
- Ad hoc Activities
  - Community of Interest activities
    - As part of the overall R06A effort, the SME prepared a number of presentations that were given at public events such as conferences. These included annual TRB meetings and other events. A list of the specific events attended where presentations were made is shown below:
    - Transportation Research Board (TRB), 2016
    - Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), 2016
    - International Bridge Conference (IBC), 2016
    - American Society for Nondestructive Testing, SNT 2016
    - Transportation Research Board (TRB), 2017
    - Transportation Research Board (TRB), 2018

Outcomes

The major outcome of the R06A program was the education of state DOT's in the advantages and best use of various NDT methods in bridge deck evaluations. For many of the states the introduction of NDT methods as facilitated by the R06A program led to the ongoing use of NDT at larger scales on additional bridge decks beyond those covered by the R06A efforts. Most of the states involved submitted a formal report or other closeout documentation of their results. A description of the R06A work in each state along with a summary of the results as submitted by the states and planned future efforts is presented below by Round and state. Individual state reports were submitted as separate deliverables for this effort.

Round 4 States

Florida:

Florida performed several NDT methods as part of their R06A implementation. These were primarily GPR and IR, but also included IE testing. The initial part of the work was the purchase of 3 IR cameras and for training on the use of these cameras. They then hired a consultant to provide GPR, IR, and IE scanning services on bridge decks. As a part of their R06A effort, Florida designed and built a mock deck slab to help with "calibrating" the eyes of the IR camera users and to use for future Infrared Inspection Training. The mock bridge deck section had objects that were placed at various depths in the concrete slab. They found that they could not see the deeper objects but could clearly see the shallower ones. Through this research (and trial and error) they determined that they could not clearly see a delamination if it was deeper than approximately 3 inches. This is in line with other state's experiences, and is one of the limitations of the IR technology. The Florida DOT IR users also discovered that the IR method is very effective at mapping delaminations and other defects present on the underside of bridge decks and other substructure elements. Because of their marine environment (and lack of use of deicing salts), the chlorides on Florida bridges can ingress from the deck bottom as likely as from the top, leading to more bottom deck deterioration compared to many other states. Mapping out bottom deck delaminations with IR allows them to avoid the use of lifts and other time consuming, expensive hands-on evaluation methods for deck bottoms.

Future Plans: Florida plans to continue to use the IR cameras they purchased, as well as to continue to use GPR to supplement the IR testing. They will also be using IR for bridge deck bottom evaluations and substructure element evaluations.

Indiana:

Indiana DOT used the Ground Penetrating radar (GPR) method to evaluate bridge decks for their implementation on the R06A work. The GPR work was contracted out rather than done in house. Testing was completed on 230 bridge decks by the end of the R06A contract period, 30 of which were done with SHRP2 funding and the remaining with state follow-on funding. The GPR testing has been used by inspectors to better refine the NBIS ratings given to bridges, as well as to assess the deterioration of the deck concrete under concrete overlays that are common in this state.

Future Plans: Indiana plans to continue to evaluate additional decks with GPR (likely about 100/year) with some additional testing with Impact Echo (IE) planned as well. They also plan to follow several bridge decks through construction and into the service life after with periodic GPR evaluations to establish a better correlation between the GPR “deterioration percentages” and the patching needs for their decks.

Iowa:

The Iowa DOT used two NDE methods it their investigations. These included IE testing using an Impact Echo Scanner (IES) which they purchased as well as GPR testing from a contractor. The NDE was done at the "project" level only, meaning that testing was done on a detailed level on specific bridges to perform a detailed condition assessment. The primary goal was to determine the area of "Class A" (top 1/2 of deck concrete repair) vs. "Class B" (full depth repair) required on each deck. Iowa uses a concrete overlay on most of its bridges, so the issue of the overlay debonding complicated the assessment of the underlying deck. Iowa found that the IR method was not effective for their bridges, primarily due to the reflectivity of the concrete used in the overlays, but also complicated by debonded overlay areas.

Future Plans: Iowa plans to continue testing bridge decks with its IES system as well as additional GPR testing. One important observation from their testing was to "Make sure the technology you use answers the actual question (need) you have".

Louisiana:

The Louisiana DOT has a relatively unusual situation, in that many of their bridges are VERY long - with several over 20 miles in length. This limits the "traditional" evaluation methods that can be used (such as chain dragging/hammer sounding). The NDT methods put forward as part of the R06A effort fit their needs well.

LADOT used primarily GPR testing at near-highway speeds as a screening tool to determine the current status of several of their longer bridges. Testing of almost 70 lane miles was done in 4 nights of work, and showed minimal issues with deterioration. LADOT is somewhat fortunate in being in an area where bridges are over fresh water and also not exposed to deicing salts. This is thought to minimize the issues they have with their bridges.

Future Plans: The LADOT plans to continue to use GPR, with some supplementary IR, to evaluate more bridge decks. The information obtained from this program-level screening will drive future budgetary planning. This is especially important for Louisiana due to the very high costs associated with major maintenance and/or replacement of these very long bridges. One of the concerns brought up by the LADOT was the challenge of picking qualified contractors for NDT services and what criteria to use.

Missouri:

Missouri planned to conduct resistivity tests on concrete bridge decks to verify the condition of concrete treatments. They have not completed their investigation efforts at this time.

Oregon:

The Oregon DOT used a wide range of NDT methods as part of their R06A evaluations. These methods included GPR, IE, Spectral Analysis of Surface Waves (SASW), Resistivity, and two versions of IR testing - Scanning and IR-UTD. The IR=UTD is a stay-in-place IR system that overcomes some of the limitations of a scanning system by performing continuous IR monitoring of a single bridge span over a longer period of time. This minimizes limitations due to weather and shading. The ODOT has been using NDT primarily as a project level tool, rather than as a program level screening tool. They have found that NDT tools have increased significantly the accuracy of required repair extents. The IR-UTD, for example, was able to more than pay for itself in eliminating cost overruns during rehabilitation work. The NDT results are used to better define the "CS" ratings of bridge deck repair areas to define repair quantities.

Future Plans: The Oregon DOT plans to continue to use the NDT tools they currently have to better refine repair quantities and assess bridge decks at the project level. There are no immediate plans to expand the use of NDT for rapid assessment of large numbers of bridges. ODOT is also planning on using the FHWA RABIT for a one week demonstration of bridge decks next year. One request from ODOT is the development of better or standardized tools and language that can be used in contracting for NDT work. They are also interested in further definition of what typical "deliverables" from an NDT evaluation should look like or be specified.

Pennsylvania:

PennDOT used IR and GPR for their bridge deck evaluations. One primary purpose was to determine whether a deck was repairable or if it had to be replaced. GPR in particular was found to be very useful for this on their bridges. The GPR method was also used to map out areas of the deck with corrosion potential (high chlorides in the concrete). Investigations with GPR versus chain drag/hammer sounding confirmed what other DOT's have found - there is often not a good correlation between delaminations and GPR "deteriorated" areas. This is primarily due to the methods measuring two different conditions - GPR measuring chloride levels in the concrete (likely future issues), and sounding mapping out delaminations that have already occurred and are relatively severe. The NDT methods were found to be very useful in getting answers about deck condition that could not be obtained by traditional methods.

Future Plans: PennDOT plans to continue using NDT methods for bridge evaluations in the future, but has identified several issues that, if resolved, would make the testing much more effective and reliable. The first of these is the need for the development of a deterioration model that is applicable to NBIS ratings but based on NDT results. They also would like to have access to a library of standardized specs, contract documents, etc. Finally, PennDOT, like other DOT's has expressed the need for a better way to select vendors. This might include accreditation from some reliable source, standardized qualifications forms or information, etc.

Virginia:

Virginia performed both network level and project level evaluation of bridge decks as part of their R06A effort. For both types of evaluations, the work was contracted out rather than carried out in-house. Testing was carried out with both GPR and IR, on a total of about 25 bridge decks spread throughout the state. The data collected is still being analyzed to develop final results for input into damage and deterioration ratings for each deck.

Future Plans: The next phase of the work for Virginia will involve comparing the results of the NDT scans with the results of conventional deck investigations for selected bridges. They are also planning on using the lessons learned from the SHRP2 R06A project to develop a standing on-call contract for the districts within the state to use in evaluating bridge decks.

Round 7 States

Iowa:

Iowa participated in both Round 4 and Round 7. Their Round 7 work was a continuation of the work done in Round 4, with additional bridge decks scanned with GPR and IES.

Oregon:

Oregon participated in both Round 4 and Round 7. Their Round 7 work was a continuation of the work done in Round 4, with additional bridge decks scanned with GPR and IR, including additional IR-UTD scanning.

Alabama:

Alabama purchased a wide range of equipment for use in bridge deck evaluation and is doing all of the work in-house. The equipment purchased includes GPR (both vehicle-mounted air coupled and manually scanning Ground Coupled systems), IE, IES (hand scanning Impact Echo system), and an IR camera. They have performed extensive testing on bridge decks, and found that useful information is obtained from NDT methods about 85-90% of the time. Alabama has trained a number of personnel on the NDT equipment, generally taking advantage of the equipment manufacturer's training programs. One issue they have had recently was the incorrect identification of steel cover depth on several new bridges. They are looking into the cause of this issue.

Future Plans: Alabama would like to construct a mockup bridge with known defects and conditions present to allow training of personnel, calibration and verification of equipment, and to try out new testing methods and systems on. This mockup bridge would join the NCAT facility for pavement evaluation research and which is also in Alabama.

Arkansas:

Arkansas DOT is working with their University partners to perform GPR testing for bridge deck evaluation and complete their investigations. University Staff turnover and project delays have affected this effort. The pilot project selected for R06A is for the evaluation of a major bridge deck (87,000 ADT) which is roughly 430,000 sq. ft. with 6 lanes and 4 shoulders.

California:

CALTRANS has a long history of using various NDT methods as part of their bridge, utility, and roadway maintenance programs. For the SHRP2 effort, they combined funding from several SHRP2 programs (R01B, R06A, R06D, and R06G) to purchase a 3-D radar multi-channel antenna GPR scanning system. This system has been mounted into a vehicle with a redundant distance tracking system to allow scanning of pavements and bridge decks for thickness, integrity, rebar, utilities, and other elements. In addition to the GPR system, CALTRANS also purchased an IE system for use on bridge decks for project level condition evaluation. At this time of the Peer Exchange, the system had been purchased and assembled, but had not been used on any bridge decks yet for detailed analysis. The system has been used on pavements, and has been shown to quickly collect useable data with accurate positioning information.

Future Plans: CALTRANS plans on using the GPR system for high-speed program-level evaluations of bridge decks across their system. They also plan to work on defining the effective businesses practices necessary to bring the technology forward for routine use. Based on their experience, they expect this objective to be one of the most challenging, because the technologies represent a major change to the normal order of business. They expect to extend training to engineering groups who will be the end consumers of the technologies, and get buy-in from those users to accept them as part of the routine testing and investigations programs.

Delaware:

Delaware expressed the desire to have a better understanding of the true condition of their bridge deck inventory. They had previously used IE testing through consultant agreements with success and believed the technology to be a good tool for determining deck condition. As part of the R06A effort, they initially wanted to also try the IR test method as well as to train inspectors to eventually incorporate these techniques into the overall inspection practice at specified intervals.

The R06A effort concentrated on the use of IR testing on a bridge deck previously tested by IE to allow direct comparison of results. They had a contractor provide a cart for rolling IR imaging of the deck and provide the training on the equipment , as well as provide training on data analysis and the use of the results.

Future Plans: Delaware, as noted above, has used NDT prior to the start of the R06A effort but now would like to use it in an expanded way with IR incorporated into their testing capabilities. They now own an IR camera and have the training and setups to properly use it for bridge deck evaluations.

Georgia:

Georgia DOT completed consultant bridge testing in the fall of 2017. The results were inconclusive, but training was completed at the bridge location. They bought equipment for IE testing and GDOT is interested in acquiring more equipment in this area. They have reported that they will be preparing a close out report/documentation shortly and submitting it to the SME.

Hawaii:

Hawaii is planning on performing GPR and IE testing on several bridge decks. They have had on-site training and demonstrations of the various NDT methods on a highway bridge, but have not completed the field testing portion of their R06A work at this time.

Kentucky:

Kentucky used a combination of GPR and IR for their initial R06A evaluations and will also be using IE scanning of a single bridge deck after the completion of the Peer Exchange. The GPR testing was done at the project level on specific bridges to better define the extent, locations, and nature of the deterioration. The GPR testing results presented showed a very good correlation between GPR-indicated issues and confirmed delaminations and other problems. Typically, the GPR results indicated larger areas affected compared to hammer sounding (higher sensitivity). However, on one deck, the GPR testing was reported to have allowed them to better define the extent of deterioration such that an estimated 17 million dollar full replacement turned into a 3 million dollar partial replacement. The IR scanning was also found to be useful, but the weather conditions in KY limited the time during which IR testing was useful. Based on an on-line tool, it was estimated that only 62 days per year (on average) would be 'ideal" for IR testing. The IR method was also found to be very useful for substructure delamination mapping, without lifts or ladders.

Future Plans: Kentucky plans to continue to evaluate bridge decks with GPR, and will be using the IR method for (as a minimum) evaluation of sub-structure elements. They will also be performing IE scanning testing on a single bridge later in the February to compare the results to the GPR scanning already done and to known issues. They will be concentrating the future NDT work on larger bridge decks where the potential for cost savings is greatest.

North Carolina:

North Carolina hired consultants to perform bridge deck evaluations for the R06A effort. The evaluations were separated into two phases. Phase I consisted of high-speed scanning surveys to quantify and map concrete deterioration, delamination, patching, and spalling. For this effort, the NDT methods used included IR, GPR, and high-resolution video (HRV). The results of this initial phase were compiled and then used for comparison to tests done with more traditional methods in Phase II. The Phase II effort included manual chain drag, deck acoustic response (SounDAR, which is a form of automated hammer sounding), chloride penetration testing, and rebound hammer testing (for in place strength estimation). The results of the GPR testing agreed well with the sounding results in terms of percentages, but the IR results tended to significantly under-predict the area of the delamination. One major benefit was reduced impact on traffic for the high-speed NDT methods compared to traditional methods. Another benefit was the ability to better visualize the results, with graphical representations of the deteriorated areas being made available.

Future Plans: NCDOT plans on using NDT on future high-value bridge projects to better define the scope of the effort needed. They will also use NDT when traffic impacts must be minimized. In the longer term, use of NDT for asset management is being considered as well as the incorporation of NDT results into NBIS data bases.

Nebraska:

NDOT seeks to implement a process of strategically programming their bridge deck assets for repair, maintenance and preservation. To accomplish this, they are very open to the use of NDT, as it provides quantitative information to allow them to make data driven decisions. The R06A program was the right vehicle to start this process, which would ideally be implemented in a phased approach. As part of this process, Nebraska used contractors to perform NDT methods for both network level as well as project level assessments. The network level scans were done with high-speed GPR and IR scanning methods along with simultaneous high-speed video data collection. The results were used to select a small number of bridges for detailed project-level NDT assessments. The project level NDT was performed on 3 bridge decks, and consisted of a very wide range of NDT and traditional evaluation methods. These included Deck Acoustic Response, Soundar, Chain Drag, Electrical Resistivity, Ground Coupled GPR, Vertical Impedance Testing (to look at rebar, delaminations, and cracks), and a coring program. The results of the Program Level (Phase I) inspections were found to be usable for long term degradation potential, approximate quantities for repair, and identification of bridges for further inspection. The Project Level inspection (Phase II) was found to be primarily useful for high resolution information on bridge deck condition (including degradation areas and severities) as well as in estimating quantities for immediate repair .

Future Plans: Nebraska plans to continue using NDT methods in both program and project level assessments of bridge decks. They are working with contractor and University partners to improve data collection and analysis tools. One possible tool mentioned is the future use of aerial drones for IR investigations of bridge decks while still under traffic.

North Dakota:

NDDOT used their R06A funds to purchase a high-performance hand-held IR camera, along with a manufacturer's training program. They then used this IR camera on a number of bridge decks to assess the area of delamination in the decks. These results were compared to traditional chain dragging methods, and found to be very similar. They also did identify several limitations of IR testing. These include the dependence on weather conditions and the need to be aware of surface effects (striping, signage, etc.) that can appear in IR images and cause confusion. The IR imaging was found to reduce the subjectivity inherent in chain dragging and similar methods. The IR camera was also tried out very successfully in evaluations of hard-to-reach areas of the bridge substructure and deck underside areas, leading to additional areas of applicability.

Future Plans: NDDOT plans to continue using IR imaging on bridge decks for delamination detection and area determination. They will also continue to use it for substructure evaluations. They also plan to expand the use of IR into the evaluation of other bridge elements such as barrier walls. In the long term, they plan on incorporating into their ongoing bridge evaluation program to assist with assessments.

New Mexico:

New Mexico used primarily GPR for their bridge deck evaluations but had a somewhat different experience with this testing compared to other states. New Mexico found that the GPR-determined deterioration areas did not often agree with the hammer sounding and visual inspections. It was not uncommon for their GPR results to show no evidence of apparent or potential deterioration while the visual and sounding results showed significant actual delaminations. One of the main reasons for this was apparently due to the limited use of chloride-containing de-icing salts in many of the bridge deck areas until more recently. Since the GPR method maps primarily chlorides in decks, it will not match the sounding results if no chlorides are present. They did note that GPR provided the "potential" for future deterioration, rather than mapping the current deterioration, and thus was not as useful for repair quantities.

Future Plans: New Mexico currently has access to a push-cart-based GPR system, and plans on continuing to use it for further bridge deck evaluations. New Mexico also uses concrete overlays on many of its decks, which interferes with visual inspection. They are still looking for good tools to use to evaluate the concrete deck condition underneath the overlay.

New York:

New York had as its goal going into the R06A program to "Identify non-destructive testing technologies that can reduce cost and time associated with bridge deck evaluations while improving the accuracy and condition assessment of these inspections". The end result desired was to complete deck evaluations faster, with more accuracy and with fewer resources, and to increase safety while decreasing the impact on the public. Initial testing was done for R06A using IE Scanning, Chain Dragging, Rapid Automated Sounding, and SounDAR testing. Additional testing was also done BY NYDOT personnel with GPR and Coring for comparison. The results showed similar top delamination percentages for all methods used, and these results were then also used to create a repair plan for the bridge.

Future Plans: NYDOT plans to continue to use some of the methods used (such as IE Scanning) to assist on future large-scale bridge deck evaluations, and may purchase equipment for NDT . There are no immediate plans for wide-spread use of NDT for system-level evaluations.

Other Recommendations for Future Activities and/or Programs

At the R06A Peer Exchange, a majority of the states who participated in the product attended or sent presentations. The timing was such that most of the states, even from Round 7, had completed their work. Thus, the Peer Exchange was an ideal environment for the exchange of ideas and plans for "next Steps" to be taken in the area of NDT of bridge decks. The last portion of the exchange was devoted to discussions about future applications and uses of the technologies for on-going operations as well as barriers and issues that might delay or interfere with the use of these technologies on a wide scale.

Either as part of their individual presentations and report outs, or in the overall next steps discussion, many states articulated specific plans to continue to use the NDT methods from the R06A product, with most planning on expanding the use. Some of these states have already developed procedures and plans for specific projects for ongoing NDT of bridges. However, there were also a number of participants who had additional suggestions for the future implementation of these NDT methods. These included looking for Pooled Fund research options from other sources beyond SHRP2, such as SPNR funding. Note that some of these would require a State DOT to take the lead. Other suggestions included forming a user group of some sort, as well as FHWA support. The state of Alabama would like to construct a mock-up bridge with known defects and conditions to allow for improved training, verification of equipment, and research of new methods. One of the most repeated requests was for the development of standardized language for RFPs and contract documents, to make sure that the deliverables provided at the end meet the actual needs of the state agency requesting the work. Another common request was for an improved means for selecting vendors for NDT services. There is a great deal of uncertainty in the current selection criteria of time of experience, past job performance and/or other qualifications.

It should be noted that the experience of the states with NDT varied widely, with methods that works very well in some states not giving very usable data in other states. This variation in experience seemed to have some dependence on geographical areas as well as bridge deck construction and overall type as well as typical structural details. One final observation relating to this is that the results show that there is not a single "silver bullet" NDT program that will work for all states in all situations at this time, but that there are now a number of tools available. Generally, for a given situation, at least one (if not more) of these NDT tools will provide the information needed.

Overall Future Needs:

The discussions throughout the Peer Exchange, as well as at the end, illuminated a number of future needs to allow the most effective use of NDT for bridge deck evaluation. These included:

- **Sensitivity study**: This could be part of pooled fund. The need was brought up to have a way to answer questions about the sensitivity of each method to various types and degrees of deterioration. There was also the desire to know what else NDT can be used on for bridge evaluation (Using IR on the substructure is one example of this).
- **Specifications needed:** A number of DOT representatives expressed the desire for standardized specifications for NDT contracts. These specs should also include sample "typical deliverables".
- **How to select NDT consultants - Qualifications? Years of Experience? Other? :** This issue also came up repeatedly – the difficulty in selecting qualified vendors for NDT services and need for a more standardized process for vendor selection.
- **Quality acceptance use:** Which states are using which methods for this and is there a standardized way to apply these methods and the results.
- **Hardware and software improvements:** Improvements to simplify data analysis and presentation are desired, as well as on-going hardware improvements.
- **Equipment precision and accuracy:** The need to better define these parameters for NDT results was expressed.
- **How to include NDE in EDC** - include in next round of EDC Round 6

Benefits

The R06A product was planned to provide states with funding to implement known-effective NDT methods that had previously been researched and determined to be effective for bridge deck evaluations. The final results of the Round 4 and Round 7 implementation show that the effective use of NDT in bridge deck evaluation is not the same for all states, locations, and bridge deck types. One of the major outcomes of the product was a much better understanding of which methods are effective in a given situation, and types of evaluations and deterioration modes each of the NDT methods is most useful for measuring. As an example of this, it became very clear that while GPR testing can be very valuable, the method and the results from this test are often misunderstood. Based on the preliminary evaluations done on bridge decks prior to the start of the R06A Round 4, most DOT's expected the GPR results to closely mirror the results of traditional evaluation methods such as hammer sounding. The reality for this particular method is that it is measuring a very different set of conditions compared to hammer sounding. These conditions can line up almost exactly in some situations but in others can be quite different. It was found that in several cases where the GPR method was thought to not be effective, it was actually working perfectly but the results were being mis-interpreted. Education and understanding of the meaning and real use of the GPR results was one of the more important outcomes of this product which should result in more wide-spread use and acceptance of this particular method.

An additional area in which expectations and outcomes did not always match was in the speed of testing. While certain NDT methods can be done at highway speeds with little to no traffic interruption, there are many very useful methods that still require traffic control and lane shutdowns to implement. These methods were found to

provide information that traditional methods did not provide (such as mapping deeper delaminations in decks) but the expectation of many agencies was that all of the NDT methods could be done at highway speeds.

One final area where the expectations differed from the actual outcome was the variation in results and experiences with NDT from state to state. It became very clear when hearing about the results of NDT investigations in the various states that a given test method that provided very valuable, actionable results for some states appeared to not provide nearly as much useful information in others. Some of these discrepancies were due to simple misunderstandings of the test methods and what they were measuring - for example the expectation that GPR results would always accurately map delaminations when actually GPR is most sensitive to chloride concentrations (that are related to FUTURE delaminations as much as current conditions). Other discrepancies appeared to be geography and weather related. for example, the results of IR testing varied, partly due to the methods' dependency on the correct weather conditions for it to be effective. It also became clear how sensitive this method is to shading from trees and other nearby objects that were more prevalent in some states compared to others.

Several states did report significant cost savings from the use of NDT methods, even at the smaller scale of the R06A efforts. As an example, the state of Kentucky reported that on one bridge deck, the use of the NDT GPR testing was reported to have allowed them to better define the extent of deterioration such that an estimated 17 million dollar full deck replacement became instead a 3 million dollar partial deck replacement.

Appendix A: Attendee Lists

Oregon Peer Exchange

SHRP2 Non Destructive Testing for Bridge Decks (R06A) Peer Exchange - Portland, Oregon January 30-31, 2019			
First Name	**Last Name**	**Organization/Agency**	**Email Address**
John	Adkins	Oregon DOT	john.h.adkins@odot.state.or.us
Kean	Ashurst	Kentucky Transportation Center	kean.ashurst@uky.edu
Hoda	Azari	FHWA	hoda.azari@dot.gov
Andrew	Blower	Oregon DOT	andrew.blower@odot.state.or.us
Haylye	Brown	Louisiana DOT	haylye.brown@la.gov
Rebecca	Burrow	Oregon DOT	Rebecca.Burrow@odot.state.or.us
Kevin	Chesnik	ARA	kchesnik@ara.com
Jamie	Creech	Kentucky Transportation Center	jamie.creech@uky.edu
Kathy	Crowell	New Mexico DOT	kathy.crowell@state.nm.us
Paul	Fisk	NDT Corporation	Paul.Fisk@NDTCorporation.com
Jeremy	Hughes	Pennsylvania DOT District 12	jerhughes@pa.gov
Pamela	Hutton	AASHTO	phutton@aashto.org
Bruce	Johnson	Oregon DOT	bruce.v.johnson@odot.state.or.us
Melissa	Moncada	Jacobs	Melissa.Moncada@jacobs.com
Albert	Nako	Oregon DOT	Albert.NAKO@odot.state.or.us
Larry	Olson	Olson Engineering, Inc.	Larry.Olson@OlsonEngineering.com
Sergio	Rodriguez	Alabama DOT	rodriguezs@dot.state.al.us
Joshua	Rogers	Kentucky Transportation Cabinet	josh.rogers@ky.gov
Dennis	Sack	Olson Engineering	dennis.sack@olsonengineering.com
David	Snoke	North Carolina DOT	dsnoke@ncdot.gov
Randall	Strain	Indiana DOT	rstrain@indot.in.gov
Michael	Todsen	Iowa DOT	michael.todsen@iowadot.us
Jason	Volz	Nebraska DOT	jason.volz@nebraska.gov
Corey	Withroe	Oregon DOT	corey.r.withroe@odot.state.or.us

Appendix B: Meeting Agendas

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Nondestructive Testing for Concrete Bridge Decks (R06A)

Hilton Portland Downtown
921 SW Sixth Ave, Portland, OR 97204

DAY 1 – Wednesday January 30, 2019

Time	Topic/Presentation	Speaker
8:00 AM–8:30 AM	**Welcoming Remarks** • (Meeting Goals, Agenda Review, Introductions) • ODOT • FHWA • AASHTO	*Kevin Chesnik, ARA* *Bruce Johnson ODOT* *Hoda Azari, FHWA* *Pam Hutton, AASHTO*
8:30 AM–9:15 AM	**Overview Technologies for NDT of Bridges R06A** • Background • Limitations Enhancements, etc.	*Dennis Sack, Olson Engineering*
9:15 AM–10:00 AM	**Oregon DOT Presentation & Discussion**	*Corey Withroe (Oregon)*
10:00 AM–10:15 AM	**Break**	
10:15 AM–12:00 PM	**Iowa DOT and Louisiana DOT Presentations & Discussion**	*Michael Todsen (Iowa)* *Haylye Brown (Louisiana)*
12:00 PM–1:00 PM	**Lunch at Nearby Venues**	
1:00 PM–3:00 PM	**Kentucky DOT, New Mexico DOT and Pennsylvania DOT Presentations & Discussion**	*Brad Rister (Kentucky)* *Kathy Crowell (New Mexico)* *Jeremy Hughes (Pennsylvania)*
3:00 PM–3:15 PM	**Break**	
3:15 PM–4:45 PM	**Group Discussion** • FHWA/Olson list of Questions	*Kevin Chesnik, Facilitator*
5:00 PM	**Day 1 Summary and Adjourn**	*Kevin Chesnik*
6:00 PM	**Optional Group Dinner at Yard House 888 SW 5th Ave**	

Nondestructive Testing for Concrete Bridge Decks (R06A)

DAY 2 – Thursday January 31, 2018

Time	Topic/Presentation	Speaker
8:00 AM–8: 15 AM	**Review Day 1 Highlights**	*Kevin Chesnik, ARA*
8:15 AM–10:00 AM	**Indiana DOT, Alabama DOT and Nebraska DOT Presentations & Discussion**	*Randall Strain (Indiana)* *Sergio Rodriguez (Alabama)* *Jason Volz (Nebraska)*
10:00 AM–10:15 AM	**Break**	
10:15 AM– 12:00 PM	**Olson presents on behalf of Virginia DOT, New York DOT and North Dakota DOT.**	*Jeffrey Milton (Virginia)* *Dan Jones (New York)* *Nancy Huether (North Dakota)* ***Olson Engineering to do these presentations.***
12:00 PM–1:00 PM	**Lunch**	
1:00 PM–2:30 PM	**Olson presents on behalf of North Carolina DOT and California DOT Presentations**	*David Snoke (North Carolina)* *Bill Owen (California)* ***Olson Engineering to do these presentations.***
2:30 PM–2:45 PM	**Break**	
2:45 PM–4:00 PM	**Moving Forward NDT for Bridges** • Brainstorming • Pooled Fund Research options • Sensitivity Studies - What needs to be evaluated further? • Specification Needs • Quality Acceptance use • Hardware and Software Improvements ▪ Equipment Precision and Accuracy	All
4:00 PM–4:30 PM	**Closing Remarks**	*Kevin Chesnik, ARA* *Andrew Blower, ODOT* *Hoda Azari, FHWA* *Pam Hutton, AASHTO*
4:30 PM	**Adjourn and/or Head to Airport**	

Nondestructive Testing for Concrete Bridge Decks (R06A)

Implementation Support Meeting and Training

New Mexico Department of Transportation

Agenda: October 30, 2018

8.30 – 10.00am	**Welcome and Introduction to NDT State-of-the-Practice**	

	• Introductions
	  ○ Welcome and Participant Introductions
	  ○ Introduction to SHRP2 Round 7 IAP Program
		Dennis Sack

	• Summary of the SHRP2 R06A research • Summary of NMDOT SHRP2 Project and Planning	Dennis Sack Kathy Crowell

	• Current Practice for Bridge Deck Evaluation
	  ○ Problem Statement and Current Assessment Techniques
	  ○ Bridge Deck Deterioration Modes
	  ○ Overview of a Bridge Deck Asset Management System
		Dennis Sack

	• Break (10 minutes)	
10.00 am – 12.00pm	**Overview of Most Common NDT Technologies for Concrete Bridge Decks**	
	• Impact Echo (30 minutes) • Spectral Analysis of Surface Waves (SASW) (20 minutes) • Ground Penetrating Radar (20 minutes) • Infrared Thermography (20 minutes) • Discussion (30 minutes)	Dennis Sack Dennis Sack
12.00 pm – 1.30 pm	**Lunch Break and Transport to the Demo Site**	
1.30 pm– 3.45 pm	**Demo of Equipment on a Concrete Bridge Deck, Bridge 07947**	
	Impact Echo Scanning and Single Point Systems, Ground Penetrating Radar, Infrared Thermography, Spectral Analysis of Surface Waves	Dennis Sack
3.45 pm – 4.00 pm	**On-site Wrap-up and Discussion**	