TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Minnesota Department of Transportation (MnDOT)

INSTRUCTIONS:
Lead Agency contacts should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project TPF-5 (504)	**Transportation Pooled Fund Program - Report Period:** ☐ Quarter 1 (January 1 – March 31) ☒ Quarter 2 (April 1 – June 30) ☐ Quarter 3 (July 1 – September 30) ☐ Quarter 4 (October 1 – December 31)
TPF Study Number and Title: TPF-5 (504) – Continuous Bituminous Pavement Stripping Assessment Through Non-Destructive Testing	

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Lead Agency Project ID: TPF1550	**Other Project ID (i.e., contract #):**	**Project Start Date:** May 1, 2023 – Start date
Original Project Start Date:	**Original Project End Date:**	**If Extension has been requested, updated project End Date:**

Project schedule status:

☐ On schedule ☐ On revised schedule ☒ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Funds Expended This Quarter	Percentage of Work Completed to Date
$900,000 (GA joined)	$0	5%

Project Description:
Stripping is a critical pavement subsurface distress affecting the performance and durability of asphalt pavement systems: full-depth asphalt, recycled, or composite. In full-depth asphalt pavements, stripping can be caused by moisture infiltration in the pavement system, leading to the loss of bond between the aggregate particles and the asphalt binder composing the mixture. The bond failure leads to the formation of an unbonded mixture and ultimately reduces the pavement bearing capacity. In asphalt overlays over concrete (composite), stripping is generally caused by moisture trapped in the interface above the concrete. Stripping leads to the formation of potholes, cracking, slippage cracking, tearing, and ultimately reduced strength and serviceability of pavements if not detected and addressed early.
Over the years, substantial progress has been made in developing bituminous mixtures less prone to stripping, thanks mainly to improved material selection tools, anti-stripping additives, modified asphalt binders, and improved drainage

practices. However, stripping continues to be a dominant issue in pavement design and scoping processes for various reasons. To cite a few examples: a) placing new stripping-resistant mixtures on top of old bituminous mixtures that are likely to be affected by stripping; b) increased use of recycled and multi-recycled materials; and c) asphalt overlays on concrete and d) quality control-related section or spot failures (i.e., binder content deficiency).

The most challenging aspect of stripping is that it initiates at the bottom or middle of bituminous layers and propagates upward. Hence, it is almost impossible to detect and quantify at early stages through visual inspections or traditional pavement forensic investigation tools. Once the problem manifests itself on the top surface of the pavement, it is generally too late for minor localized treatments. The lack of appropriate diagnostic tools for stripping makes developing proper pavement rehabilitation plans challenging. For instance, without knowing the stripping's extent, severity, and depth, it becomes challenging to select an appropriate mill depth for a new overlay or a proper rehabilitation strategy (i.e., full reconstruction, mill and overlay, cold recycling).

Fortunately, new advanced non-destructive evaluation (NDE) technologies are becoming increasingly accessible and suitable for solving complex pavement issues. The Strategic Highway Research Program 2 (SHRP2) study R06D (Heitzman, et al. 2012) vetted the capability of several NDE technologies to evaluate pavements affected by delamination: stripping and debonding. Debonding is a similar failure that occurs when the tacking between the pavement layers (lifts) is inadequate. However, the affected layers generally remain physically quasi-intact in debonding, while the layers exhibit full or partial deterioration in stripping. Out of eight (8) vetted tools, two (2) provided promising results for identifying and quantifying stripping: the 3D-Ground Penetrating Radar (3D-GPR), an air-launched antenna array with frequency sweep measurements and the Impact Echo/Spectral Analysis of Surface Waves (IE/SASW) scanning system. Among these two technologies, 3D-GPR provided the added advantage of continuous full-lane width data collection in a single pass at safe traffic traveling speeds. Furthermore, the ability of 3D-GPR to scan full-lane width resulted in higher chances of detecting stripping locations than more traditional single-channel 2D-GPR systems. While in the case of debonding, 3D-GPR was less effective and offered good information only in wet conditions. The IE/SASW was most effective at identifying discontinuities when the pavement was cold and stiff. However, it required lane closure and did not provide continuous full-lane coverage.

After the R06D study, several states (FL, TX, NM, CA, KY and MN) participated in an Implementation Assistance Program (IAP) sponsored by FHWA and AASHTO, aimed at determining if the 3D-GPR and the IE/SASW technologies met "proof of concept" and were ready for national implementation. The study concluded that the 3D-GPR system met the criteria for high-speed data collection. The IE/SASW system significantly improved data collection speed but still requires lane closure. The IAP identified several drawbacks and concerns that need to be addressed to effectively use 3D-GPR in detecting stripping at project and network levels. The recommended needs for improvements are listed below:

- Develop standard practices for testing pavement using 3D-GPR and other companion NDE technologies such as Traffic Speed Deflectometer and Falling Weight Deflectometer
- Establish proper equipment calibration and data quality verification (i.e., coring locations and numbers) procedures to improve the accuracy of the output
- Develop a standard algorithm for automated processing of 3D-GPR data and detection of stripping. At present, identifying stripping in the bituminous layers is accomplished through a visual examination of the GPR images. This process is significantly dependent on the person's experience interpreting the images, time-consuming and labor-intensive, and difficult to adopt in state agencies' practices.
- Determine the need and benefits of linking the 3D-GPR data to other NDE technologies. 3D-GPR alone cannot identify stripping all the time and at all subsurface moisture conditions. In addition, 3D-GPR is only readily available to some road agencies. Hence, it is important to continue evaluating other NDE technologies that could fill in the blank spots of 3D-GPR. The other NDE technologies proposed for this study are TSD, FWD, 1D-GPR, IE/SASW, and PASP.
- Develop specifications and implementation plans and promote the use of 3D-GPR for testing stripping
- Facilitate communication between vendors and agencies to enable vendors to make improvements to their hardware and software
- Establish a national user group to provide a venue for experts in NDE technologies to advance GPR and other NDE technologies in local and national road authorities.

In September 2021, FHWA sponsored a well-attended Virtual Peer Exchange to gather updates on Post-R06D advancements from state agencies, universities, research institutions, consultants and vendor perspectives. The meeting noted that several state transportation agencies, including the Minnesota Department of Transportation (MNDOT), are working toward incorporating 3D-GPR in their project scoping process and addressing stripping and other subsurface pavement issues in their roadways. The group reiterated the need to address the IAP recommendations through a national pool fund study. MnDOT was selected to lead and manage the pool fund study efforts, including drafting and advancing the present proposal. MnDOT recognizes the opportunities and challenges of this effort and believes they are best addressed in collaboration with other agencies and stakeholders.

Project Objectives:

The primary objective of the proposed pooled-fund project is to establish a research consortium focused on addressing the R06D and IAP recommendations. As per the IAP and R06D findings and recommendations, particular emphasis will be placed on using 3D-GPR, which is particularly suitable for high-speed continuous and lane-width data collection and is already being incorporated in project scoping processes for thickness determination. Nevertheless, other NDE technologies, such as FWD and TSD, will also be considered to complement, evaluate, verify and validate the 3D-GPR findings. Similarly, recognizing that 3D-GPR alone cannot identify stripping all the time and at all subsurface moisture conditions, the study will also investigate using IE/SASW, MIRA, and Thermal Imaging for localized spot verifications. Furthermore, the proposed pool fund study will include contemporary 2D and 3D-GPR testing on limited projects to compare and identify advantages and disadvantages. The tools (i.e., equipment, testing procedures, data processing algorithms, specifications) advanced through this project will assist state transportation agencies in rapidly and confidently detecting the extent, depth, and severity of stripping in their roads. The set goals are to be accomplished by:

- Developing a methodology for rapid and automatic stripping detection based on 3D-GPR and other NDE technologies such as Falling Weight Deflectometer (FWD) and Traffic Speed Deflectometer (TSD). The development will be based on the experience and needs of participants so that the developed methodology can effectively and efficiently support their pavement evaluation program.
- Developing a software for automated processing of 3D-GPR data and detection of stripping
- Verifying and validating the developed methodology on projects selected by the participating agencies. The more states, the stronger the methodology
- Providing participating agencies guidelines on data collection and analysis protocols
- Drafting AASHTO specification.
- Facilitating and supporting communication between experts in NDE technologies, state engineers and vendors to advance the use of GPR for inspecting pavement subsurface issues
- Providing training and technical assistance that includes providing support for specification development and strategies for agency full implementation
- Conducting technology promotion for the technologies

Recognizing that 3D-GPR and TSD may only be readily available to some participating states, the study will allocate a portion of the pool fund to hire consulting firms for 3D-GPR and TSD surveys on the projects considered in this study.

Scope of Work:

The work plan will be finalized and approved by the pool fund panel. While the details and scope of the objectives will be further defined during the first task of the project, it is anticipated that the project will include the followings:

- Task 1 – Finalizing the Scope of Work
- Task 2 – Survey and Literature Review
- Task 3 – Building GPR Signal Stripping Signature Database
- Task 4 – Building and Evaluating Artificially Stripped Section in MN ROAD
- Task 5 – Development of a Software for Automated Detection and Quantification of Stripping
- Task 6 – Data collection on Roads from Participant States
- Task 7- Review, Analysis, Data Fusion, and Interpretation of the collected data
- Task 8 – Development of AASHTO Specification - Testing and Analysis Procedures
- Task 9 – Training and Technical Assistance
- Task 10 – Support and Communication
- Task 11 – Strategic Technology Promotion

A summary of the technical and non-technical project activities is given in the complete workplan (See website)

The pool fund study accomplished four major preparation works in the second quarter. The activities were primarily conducted by the MnDOT team without cost to the pool fund study. The main activities conducted in the past quarter are discussed below:

- **Task 2**: MnDOT team, building on the work that started during the R06D final virtual meeting with QES, selected and finalized survey questions that would benefit the study. The questionnaires were sent out to all the partners and friends of the study for further discussion and deliberation. The final version of the questionnaires will come out from the August 11, 2023, virtual meeting. The meeting will also determine on how to share the questions and how to collect and analyze the responses.

- **Task 4**: of the pool fund study aims to recreate typical full-depth bituminous and bituminous overlayed concrete pavements affected by stripping originating at the interfaces. The study envisions accomplishing the stated objective by identifying, producing and installing materials or mixes that closely simulate the conditions of stripping in actual pavements: failure of bonds between the binder and aggregate particles, loss of fine particles, continuously increasing void contents, loss of bearing capacity and deterioration etc. To accomplish this, the MnDOT team responsible for the TPF-5(504) pool fund study reviewed the previous R06D study to assess its benefits, challenges, and lessons learned. Additionally, the team engaged in an extensive and productive discussion with Mike Heinzman, the principal investigator of the R06D study, who graciously shared valuable insights regarding the successes and failures encountered during the construction and testing of field and laboratory samples in the previous study. Furthermore, a concise literature review was conducted to identify the factors contributing to pavement stripping and how this phenomenon manifests itself. Based on the insights gained from the above activities, the MnDOT team selected a suitable site within the MnROAD test facility for constructing a new test section. Forensic investigation, including GPR and FWD surveys and analyses, was performed to evaluate the conditions of the existing road to determine whether to build or completely replace it with new layers. Afterward, the MnDOT team developed preliminary drawings and plans, which underwent rigorous review, modification, and discussion in multiple meetings involving experts from various backgrounds, including MROAD construction operations, pavement design, materials, flexible pavement, and rigid pavement expertise. The documents containing the proposed construction plan, along with a detailed description of the factors considered and the works expected during the construction, can be found on the website. The documents also include a list of the people consulted in developing and reviewing the construction plan. Following internal deliberation on the feasibility and constructability of the proposed plans, the MnDOT team is now circulating the plan documents to the state members, manufacturers, and supporters of the pool fund study to gather additional feedback, suggestions for adding or removing factors, and a consensus on proceeding with the construction of the test sections. The plan will be officially discussed, amended and approved on the August 11, 2023, virtual meeting. All partners and friends of the study are invited to provide feedback.

- **Task 6**: MnDOT joined the TPF-5 (385) pool fund study. The MnDOT team, which is directly participating in the TSD pool fund study, selected several MN roads to be tested using the TSD device. Multiple of these roads are known to be affected by stripping and will be considered for the stripping pool fund study.Data collection is expected to occur in August 2023 and will include approximately 300 miles of roads

- **Task 10-11:** The MnDOT team created a website dedicated to supporting the pool fund study. You can access the website here:https://www.dot.state.mn.us/materials/nde-stripping-evaluation/. The website will serve as a repository for various resources, including documents, papers, videos, imagery, meeting notes, presentations, calendars, manuals, lists of manufacturers and equipment involved in the study, and information about organizations supporting the study. These materials are important to the understanding and promotion of the NDT (Non-Destructive Testing) technologies investigated in the pool fund study.

- **Task 10-11:** Virtual meeting called for August 11, 2023. The date was selected based on a widely participated Doodle survey.

Anticipated work next quarter:
The project activities are expected to start next in the next quarter:

- **Task 10-11:** Gather the feedbacks and inputs obtained from the August 2023 meeting. These information will be summarized and utilized to guide the efforts undertaken in the third quarter (Q3)

- **Task 2**: Send out the survey questionaries, and gather and analyze results

- **Task 4**: Draft and post contract bids for the construction of concrete slabs and the bituminous pavement
- **Task 4**: If the conditions allow it, commence the construction operation for the MnROAD stripping test section

- **Task 5**: Start and advance the process of identifying, selecting, and assigning a team responsible for the development and validation of software for automated detection of stripping.

- **Task 6**: Obtain, organize and start analyzing the TSD data related to the MnDOT roads selected for this study

- **Task 10-11:** Plan and execute the first in person meeting

Significant Results:

- Final detailed draft construction plans for the MnROAD stripping test sections.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

The time required to set up a working account for the pool fund study was underestimated. Not having an active account d the works. However, the MnDOT team initiated and advanced several works without waiting for the accounts to be ready.

Potential Implementation:

The final objective of the pool fund study is to develop testing procedures and algorithms (software) that can reliably and automatically detect stripping and other moisture-related damages from 3D-GPR images of bituminous and composite pavements. This will significantly improve the use of 3D-GPR in project scoping practices beyond just measuring the layer thickness. State engineers will have data that can better support their rehabilitation selection processes and will be able to quickly identify sections of the road that require particular attention and thus avoid one-solution-fits-all approaches