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	

Lead Agency Contact: Eyoab Zegeye	**Lead Agency Phone Number:** 651-366-5517 (work)	**Lead Agency E-Mail** eyoab.zegeye@state.mn.us
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
$1,075,000 (FL and KY joined since last report)	$4,105.6	8%

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 was ~~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 several major planning and preparations works in the third quarter:

- **Task 2**: In Q2 2023, the survey questionnaires were finalized, approved during the August 11, 2023 meeting, and transformed into an online format in collaboration with MnDOT's LD. The online survey included structured multiple-choice and open-ended questions targeted at individuals knowledgeable about pavement project scoping challenges and tools. Shared with 40 members of the pool fund study and AASHTO COMP, it received

29 detailed responses. Currently analyzing these responses, the plan for Q4 includes compiling a report and publishing it on the TPF website. Key insights from responses will be used to enhance our project activities.

- **Task 4**: In Q2 2023, the preliminary construction plan for the MnROAD stripping test section received approval from TPF members during the August 11, 2023 meeting. A small working task group was also formed to develop this plan further and iron out the details. This task group includes senior engineers from MnROAD operations who will oversee the construction phase, ensuring a seamless transition from planning to implementation. Over the next few months, the working group will collaborate with MnROAD to refine the plan. Subsequently, preparations for contracting the jobs will commence, involving identifying contractors and materials required for the project.

- **Task 5**: Crafting an RFP for developing an analysis tool for automated detection and quantification of asphalt mixture stripping. In a closed meeting (only member agencies), the group discussed Task 5 of the project plan in depth. In particular, the group debated on the the following key points:
    - What features should the analysis tool include?
    - Should it be a stand-alone application or an embedded feature in other commercially available software applications?
    - Who should be tasked to develop these tools?
    - How should we identify and assign a team? Through a request for proposal (RFP)?
    - What type of 3D-GPR data will be utilized for this purpose?
    - Direct: data collected using the geoscope, i.e. *.rda
    - Indirect: data pre-processed in the Examiner, i.e., VOL, ASCII exports etc.
    - Is there any restriction to using the data
    - Data synching and fusion with other NDT data (i.e., FWD, TSD)

  As a result of these discussions, the group agreed to seek a qualified team responsible for accomplishing Task 5 through an RFP. were entrusted with the responsibility of formulating an RFP that encapsulated the crucial points discussed during the meeting, aligning with the project work plan. Subsequently, the RFP was promptly drafted and circulated among representatives from member states for their input and endorsement before sharing it with the larger group. Upon receiving and addressing the group's comments and suggestions, the RFP was sent out to MnDOT's accounting and contracting office to start the contracting process. Eventually, the RFP will be posted to the general public to ensure broader participation.

- **Task 6**:
    - In August 2023, under the TPF-5 (385) pool fund study, MnDOT collected data using the Traffic Speed Deflectometer Device (TSDD) data along an approximately 300-mile continuous route. Nine roads were surveyed, including a few known to be impacted by stripping, earmarked for the stripping pool fund study.
    - The group initiated identifying two roads per state suspected of stripping for inclusion in the study. MnDOT has distributed a project information request form (in spreadsheet format) to each participating state, and agency contacts are working with their agency to identify the roads and provide the requested information. Once this spreadsheet is completed, the group will determine and coordinate 3D-GPR and other testing. Already available data will be considered in determining the need for new data collection.

- **Task 10-11:** The MnDOT team is maintaining and keeping update the website dedicated to supporting the pool fund study. New material and meeting notes has been added. 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. If you have material (papers, reports etc.) that you think would be of interest to the group, please contact the project P.I.

- **Task 10-11:** During the Q3 2023 we had several meetings and also planned for the 1st in person meetng:
    - Virtual meeting August 11, 2023. The meeting, which was attended by 60 individuals (members and friends of the study) discussed the followings:
        - Introduction to the website
        - Review and discuss the proposed plan for controlled field Pavement test sections

- Discussion on the development of software/algorithms for automated stripping detection and quantification
- Discussing proposed survey questions on stripping and use of GPR and other NDT: draft survey developed in collaboration with QES, Inc. (Steve Koser and Dennis Morian) during the last virtual meeting (pre-pool fund study) has been attached to this email for your consideration.
- Updated from the state members:
- Discuss plans and topics for the first TPF5-504 In-Person

- MnROAD test section working task group meeting August 30, 2023. The meeting included a small group of individuals who volunteered to iron out details and finalize the approved construction plan for the MnROAD stripping test section. The group comprises Eyoab Zegeye (MnDOT), Shongtao Dai (MnDOT) Stephen Cooper (FHWA), Jeff Brunner (MnDOT), Jia Xiaoyang (TNDOT), Mike Heitzman (Kontour), Rami Chkaiban (ARA), Thomas Calhoon (MnDOT), Mike Vrtis (MnDOT/MnROAD), Jacob Calvert (MnDOT/MnROAD) and Ben Worel (MnDOT/MnROAD). The followings were discussed:
  - Precise start and end points for the test sections
  - Design of ramps before and after the test sections
  - Mix designs for concrete and host AC mixtures
  - Dimensions and locations of test sections, stripped elements, and plates
  - Material specifics for creating the stripped section
  - Placement and compaction of the stripped elements (Mike)
  - Design of moisture induction (Mike)
  - Potential sensor deployment
  - Construction timelines (are we ready to begin the construction works)
  - Schedule to commence contracting and construction work

- Closed (only member agencies) meeting September 29, 2023. The meeting, which was attended by representatives of the member agencies only, discussed in depth plans for the development of software/algorithms for automated stripping detection and quantification. The attendants were Eyoab Zegeye (MnDOT), Shongtao Dai (MnDOT), Hung-Wen Chung (FLDOT), Brin Hill (ILDOT), Ian Rish (GADOT)Jia XiaoYang (TNDOT), Cindy Smith (MSDOT), Stephen Cooper (FHWA), Jeff Brunner (MNDOT), Jonathan Varner (MODOT), John Senger (ILDOT), Hoda Azar (FHWA) and Guangming Wang (FLDOT). Accomplishment of this meeting are discussed above.

- Upcoming Joint fall Meeting TPF-5(504) and TPF-5 (443): Preparations for the upcoming collaborative fall meeting between TPF-5(504) and TPF-5 (443) involved close collaboration among the managers and teams overseeing these pooled fund studies, working in tandem with MnDOT. The purpose was to plan and coordinate a joint project update and peer exchange event. Key tasks encompassed:
  - Crafting a comprehensive meeting agenda.
  - Strategizing optimal dates for the meeting, scheduled to take place in the Twin Cities, Minnesota.
  - Identifying and inviting speakers to provide updates on advancements in Non-Destructive Testing (NDT) technologies pertinent to the pooled fund studies.
  - Facilitating travel authorization and managing reimbursement paperwork for attending members.
  - Securing suitable meeting venues and configuring online meeting capabilities.

Anticipated work next quarter:
The project activities that are expected to occur or start in the next quarter include:

- **Task 2**: Analyze and compile the survey results/responses
- **Task 4**: Continue finalizing the proposed plan for the MnROAD test sections and commence the preparation works including procuring materials and draft construction contracts
- **Task 5**: Post the RFP for developing automated data analysis tools for detection and quantification of stripping in bituminous pavements. 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 6**: Identify the roads from each state that will be considered in this study and commence the data collection efforts (new or gathering available data
- **Task 10-11:** In-person joint Joint fall Meeting TPF-5(504) and TPF-5 (443):

Significant Results:

- Online survey
- Construction plans for the MnROAD stripping test sections.
- RFP for developing automated analysis tool for the detection and quantification of stripping
- Planning and coordinating the upcoming TPF pool fund study
- TSD data collection in several member stataes on roads considered for this project

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 planning and preparation phase, although slightly extended, facilitated in-depth discussions and thorough deliberations proving beneficial for the project in the long run. The construction commencement of the MnROAD test sections was rescheduled to Spring 2024 due to considerations regarding the winter season and the comprehensive level of detail incorporated into the plan. Apart from this adjustment, the project continues to progress forward

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