TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Kansas DOT

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 #	**Transportation Pooled Fund Program - Report Period:**
TPF-5(503)	☒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(503) and Standardizing Rigid Inclusions For Transportation Projects: Phase I

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Lead Agency Project ID: Click or tap here to enter text.	**Other Project ID (i.e., contract #):** Click or tap here to enter text.	**Project Start Date:** **7/1/2023**
Original Project Start Date: Click or tap to enter a date.	**Original Project End Date:** **6/30/2025**	**If Extension has been requested, updated project End Date:** Click or tap to enter a 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
$240,000	$9,447	33%

Project Description:

Rigid inclusions are grouted or cemented columns used to improve loose or soft soils. They have been increasingly used in practice in the United States, mostly for embankment, retaining walls, and box culvert support in transportation applications. Several types of equipment and methods are available in the practice to install rigid inclusions with different trade names. Installation of rigid inclusions may cause full or partial displacement of their surrounding soils that disturb soils, neighboring rigid inclusions, and/or existing structures, depending on the type of equipment and method used, installation procedure, and type of soil. Rigid inclusions are often installed under a load transfer platform to support embankment or structure loads. The methodology and equipment-driven installation has been closely guarded and much is proprietary (commercial competitive advantage), which has left the DOTs dependent on and obligated to the contractor. No well-accepted design methods and construction specifications are available to assess and consider installation effects on their surrounding soils, neighboring rigid inclusions, and nearby existing structures, down drag forces in rigid inclusions under embankment or structure loads, and stability of embankments with side slopes supported by rigid inclusions. Research, including the state of the practice (Phase I) and full-scale field tests (Phase II), is needed to quantify rigid inclusion installation effects, develop design methods considering their effects on load transfer analysis, axial load capacity, and displacement calculations for vertical loads and evaluating the stability of rigid inclusion-supported embankments, and develop construction specifications for minimizing installation effects and improving long-term performance.

The main objectives of the Phase I study are to assess the state of the practice of rigid inclusions used for embankment and structure support, analyze existing data and design methods available in the literature or agencies, identify knowledge gaps and missing data and procedures, and develop a plan for full-scale field tests to be carried out in the Phase II study.

Tasks for this study include:

1) Literature Review and Assessment of Current Practices
2) Evaluating design methodologies
3) Developing a Full-scale Field Test Program

Progress this Quarter
(includes meetings, work plan status, contract status, significant progress, etc.):

The research team continued collecting references including case studies about the current practice of rigid inclusions in projects and performing further literature review. The research team completed an online survey based on the questionnaires developed in the previous quarter. The survey was distributed to 67 individuals with different affiliations (government agencies, research institutes, consulting firms, and contractors) and completed by 35 individuals (52% return rate). The research team performed statistical analysis of the survey data and the survey results were shared with three consultants for comments. The research team organized a virtual meeting with the steering committee to give them updates on the survey results and seek their inputs about the findings and future research activities. In addition, the research team has upgraded the numerical software and selected a case study for numerical model calibration.

Task 1: Literature Review and Assessment of Current Practices
The literature review work has been completed.

100% COMPLETE

Task 2: Evaluating Design Methodologies
The research team has started the numerical model calibration.

20% COMPLETE

Anticipated work next quarter:

The research team will complete the numerical model calibration and evaluate design methods available in the literature as compared with field data and numerical results. The research team will share and discuss the numerical results and design method evaluation with the consultants and KDOT engineers and seek for their inputs. After the meeting with the consultants, the research team will organize a virtual meeting with the steering committee to go over the numerical results and evaluation.

The research team will continue evaluating the design methodologies including numerical analysis of selected case studies as compared with the design methodologies.

Significant Results:

The literature review shows that different types of rigid inclusions have been used in the practice. Rigid inclusions (RIs) are typically designed as a system, which includes rigid inclusion elements and a load transfer platform. Much research has been done on load transfer mechanisms (soil arching and tensioned membrane) and critical heights above rigid inclusions to prevent differential settlement. A large number of methods including analytical and numerical methods are available to design load transfer platforms above rigid inclusions but these methods often yield significantly different results. Several studies examined the accuracy and differences of these design methods. However, limited research has been done on installation effects and slope stability of embankments supported by rigid inclusions. Recent projects have used a small area replacement ratio (less than 5%) for rigid inclusion elements. Rigid inclusion elements subjected to lateral loads and need for steel reinforcement have become a concern for some projects. How to consider lateral loads in design still requires further research.

The survey shows the following significant results:

- 94% respondents indicate that embankments are the most common application of RIs.
- 69% respondents indicate that drilled displacement columns are the most common type of RIs.
- 94% respondents indicate that reducing settlement is the main objective of RIs.
- 100% respondents think that clay is the soil type where RIs are commonly used.
- 77% respondents think that design-build is the most common contracting methods for RIs in projects.
- Approximately 60% respondents think that the conditions for using steel reinforcement in RIs are: slope stability, seismic load, and horizontal loads.

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).

No challenges have been encountered so far that might affect the completion of the project within the time, scope, and fiscal constraints set forth in the agreement.

Potential Implementation:

Not yet.