TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): ____IOWA DOT_____

INSTRUCTIONS:

Project Managers and/or research project investigators 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(183)*	**Transportation Pooled Fund Program - Report Period:** Quarter 1 (January 1 – March 31, 2016) X Quarter 2 (April 1 – June 30, 2016) Quarter 3 (July 1 – September 30, 2016) Quarter 4 (October 1 – December 31, 2016)

Project Title: Improving the Foundation Layers for Concrete Pavement		
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Lead Agency Project ID: RT 0314	**Other Project ID (i.e., contract #):** Addendum 352	**Project Start Date:** 3/16/09
Original Project End Date: 3/15/14	**Current Project End Date:** 12/31/2017	**Number of Extensions:** On-going pooled fund project

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule X Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$875,000	$867,718	98

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$224.		1

Project Description:

The objective of this research is to improve the construction methods, economic analysis and selection of materials, in-situ testing and evaluation, and development of performance-related specifications for the pavement foundation layers. The outcome of this study will be conclusive findings that make pavement foundations more durable, uniform, constructible, and economical. Although the focus of this research will be PCC concrete pavement foundations, the results will likely have applicability to ACC pavement foundations and, potentially, unpaved roads. All aspects of the foundation layers will be investigated including thickness, material properties, permeability, modulus/stiffness, strength, volumetric stability and durability. Forensic and in-situ testing plans will be conceived to incorporate measurements using existing and emerging technologies (e.g. intelligent compaction) to evaluate performance related parameters as opposed to just index or indirectly related parameter values. Field investigations will be conducted in each participating state. The results of the study will be compatible with each state's pavement design methodology and capable for use with the Mechanistic-Empirical Pavement Design Guide (MEPDG). Evaluating pavement foundation design input parameters at each site will provide a link between what is actually constructed and what is assumed during design. There are many inputs to the pavement design related to foundation layers and this project will provide improved guidelines for each of these. The study will benefit greatly from maximizing the wide range of field conditions possible within the framework of a pooled fund study.

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

This quarters main progress is a graduate (PhD) students' research on spatial analysis of the field measurements obtained from the project sites and the manual of practice.

The graduate students work focused on studying the spatial analysis aspect in detail to understand if there are similarities in how the different engineering parameter values (modulus, CBR, dry density, and moisture content) spatially vary in situ and how they are linked to the different materials (base [virgin vs. recycled] and subgrade). This evaluation focused on geostatistical modeling of the spatial variability using semivariograms and studying spatial anisotropy in situ. The anisotropy aspect provided information regarding how measurements varied in the longitudinal direction (direction of travel and roller compaction) versus in the transverse direction. These aspects are important to understand as it provides information for use in the Manual of Practice as to what to expect as typical values of variability in situ when performing the different QA test measurements that are being recommended in the manual.

Anticipated work next quarter:

- Manual of practice

Significant Results:

Circumstance affecting project or budget (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).

TAC committee:

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Goal	Key Engineering Challenges	Key Design Objectives	Failure Mechanisms	Pavement Distress (1),(2), (3), (4), (5), (7)	Contributing Factors	Measurement/ Quantify	Key Parameter Values	Controls/Measures	Key Requirements (specifications)

(1) Miller, J., and Bellinger, W. (2003). Distress Identification manual for Long-Terms Pavement performance Program, FHWA-RD-03-031, June 2003.
(2) Md/DOT Distress Identification Manual, February 2003.
(3) Smith, K., Harrington, D., Pierce, L., Ram, P., and Smith, K. (2014). Concrete Pavement Preservation Guide, 2nd Edition, FHWA DTFH61-12-H-00010, September 2014.
(4) AASHTO R36, Standard Practice for Evaluating Faulting of Concrete Pavements
(5) AASHTO PP68, Standard Practice for Collecting Images of Pavement Surfaces for Distress Detection
(6) Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures. Appendix JJ: Transverse Joint Faulting Model
(7) Appendix A NCHRPw_35
(8) Geotechnical Aspects of Pavements, FHAW NHI-05-037

The field studies and analysis generated from this project show that pavement foundations vary greatly and depend on agencies experience and knowledge. To move toward mechanistic pavement foundation design and acceptance, new approaches will be required. This flow chart provides a framework to design, construction, and verify mechanistic pavement foundation parameters

To design, construct and field verify economical pavement foundation systems that meet the pavement design performance requirements.

Long life pavements are (>40 years) are needed to provide sustainable solutions and require the pavement foundation system be designed and constructed to support future long life and pavement rehabilitation.

Pavement design is historically based on limited foundation measurements and materials, yet pavement foundation materials, loading conditions, and environmental factors result in complex engineering behavior.

Increased pavement layer thickness does not necessarily compensate for pavement foundation deficiencies.

Good pavement foundation drainage is essential for long term performance because erosion of the subbase/subgrade introduces a defect for which virtually no cost-effective mitigation solution is available.

Constructing and sustaining uniform pavement support is critical to long life pavement performance but requires special testing and characterization not currently part of specifications.

Plastic deformation/ settlement of the pavement foundation (subbase and subgrade) is not explicitly considered in pavement thickness design.

New technologies are needed to improve mechanistic characterization and pavement foundation construction.

Build in good drainage and eliminate erosion.

Select durable pavement foundation materials.

Effectively treat/stabilize site-specific marginal materials.

Maintain near-linear elastic behavior (limit plastic deformation).

Achieve the minimum design modulus (resilient modulus, modulus of subgrade reaction) for the life of the pavement (including seasonal changes and degradation).

Provide uniform slab support spatially and with time.

Characterize mechanistic parameters of the foundation materials/system to link quality inspection with mechanistic design.

Ensure statistically valid sampling for quality inspection practices

Account for differential settlement of the embankment foundation, embankment fill, and buried structures to limit total deformation of the pavement.

Use life-cycle economical analysis and design-construction-economical analysis to validate solution

Ensure constructability and adopt new technologies to solve current problems

Aggregate particle degradation (cyclic degradation)

Volumetric stability: Shrink-swell

Mechanical property sensitivity to moisture contents changes

Shear failure of materials

Poor/abrupt modulus transitions vertically between layers

Non-uniform support due to erosion

Non-uniform support due to frost heave and thaw weakening action

Erosion, fines migration, and pumping

Contamination

End of construction non-uniformity due to variable material conditions and poor construction practices

induced compressive and shear stresses from high transient vehicle loading

Consolidation of poorly compaction of embankment fill layers

Poor compaction adjacent to buried culverts and bridge approaches.

Soft, weak, normally consolidated embankment foundation soils

High stresses at subgrade layer

Pavement faulting at joint

Pavement faulting in panel at cracks

Pavement transverse cracking

Pavement longitudinal cracking

Pavement corner breaks

Pavement lane to shoulder drop off

Water bleeding and pumping

Pavement cracked and broken panels

Pavement punch out and localized distress

Pavement differential settlement and distortion

Pavement faulting at patches

Pavement heave

Pavement reflective cracking

Changes in environmental conditions (weather): air temperature, solar flux,

Ground water table fluctuations.

Availability of surface water

Material composition/ mineralogy and variable of materials

Aggregate particle shape and abrasion resistance

Friction angle, cohesions, and density

Erodibility (see MEPDG Class A to E) (6)

Moisture-suction relationship for foundation materials

Use of frost-susceptible materials.

Trapped water and pumping.

Poor lift thickness control, poor compaction, wet soils.

Non-uniform construction processes.

Plastic displacements and consolidation (Cc, Cv)

Layer thicknesses: 3D point cloud, GPS, direct measurement.

Soil classification, gradation, plasticity, passing #200.

Groundwater table location with GPR

In situ drainage assessment using field permeameters: GPT

Elastic modulus of the base layer (E) and resilient modulus (Mr) using PLT, FWD, LWD

Modulus of subgrade reaction (k_s) using PLT

Frost heave and susceptibility per laboratory testing and instrumentation

Environmental conditions: sensor instrumentation

Shear strength and lift thickness profiles using DCP

Mechanistic -based and calibrated intelligent compaction (IC)

Index value based intelligent compaction (IC)

Elastic theory analysis to limit stress at subgrade level to minimize permanent deformation.

Void detection and load transfer efficiency at crack and joints. FWD

For unbound granular subbase, limit fines content to < 8%

Subbase Resilient modulus > 50 ksi

Reduction in modulus < 80% upon field saturation test

Subbase frost heave < 0.1 in.

Permanent deformation in subgrade < 0.1 in.

Embankment differential settlement < 1 in. over 100 ft.

Erodibility (lab erosion index? Field test?) – link to erosion modeling

Ensure time to drainage at 50% < 2 hrs.

Measure weakest layer in top 2 m.

New construction methods and technologies needed control uniformity of support

Edge drainage systems and geocomposite drains.

Chemical stabilization: cement and others

Geosyntethic stabilization

Separation geosynthetics for fines migration and debonding

Crushed aggregate and crushed concrete blends

Erosion modeling and testing.

Provide capillary break

Thick foundations to provide frost protection

Use continuous measurement (e.g., IC) to identify weak areas and non-uniform areas for improvements.

See Geotechnical Solutions for Embankments over Soft Soils.

EICM inputs for PF

AMG construction to "customize" layer thicknesses

Perform economical analysis

Require achievement of mechanistic performance parameters be controlled and verified during construction

Require mechanistic modeling of drainage system

Require mechanistic extended testing of cyclic degradation of subbase materials

Require mechanistic erosion modeling and field verification.

Require mechanistic characterization of the embankment foundation, embankment fill (including buried structures) to limit permanent strain

Structure bid items and pay factors to control and incentive construction practices around achieving performance requirements.