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) X Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title: Improving the Foundation Layers for Concrete Pavement		
Project Manager: David White	**Phone:** 294-1463	**E-mail:** djwhite@iastate.edu
Project Investigator: David White	**Phone:** 294-1463	**E-mail:** djwhite@iastate.edu

Lead Agency Project ID: Addendum 352	**Other Project ID (i.e., contract #):**	**Project Start Date:** 3/16/09
Original Project End Date: 3/15/14	**Current Project End Date:**	**Number of Extensions:**

Project schedule status:

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

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$700,000	$256,456	60%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$24,614		8%

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.):

Significant effort was made this quarter in terms of laboratory testing, analysis of laboratory and field test results, and project reports. Field testing was conducted on the US Highway 30 pavement foundation layer construction project near Ames, Iowa. This is the tenth field project evaluated to date.

The main research activities during this quarter involved the following [related research task number is in the parenthesis]:

- Conducting laboratory testing (frost-heave/thaw-weakening and cyclic triaxial testing) on samples obtained from the field projects [Sub Task 1.5],
- Fabrication of laboratory large scale lateral flow permeameter and frost-heave/thaw-weakening test setup[Sub Task 1.5],
- Updating the I-94 project report with cyclic triaxial laboratory test results and analysis [Sub Tasks 1.5, 3.1, 3.2, 3.4]
- Conducting in-situ test data analysis on three other field projects (Iowa I-35, Michigan I-96, and Pennsylvania SR-22) and developing field project reports [Sub Tasks 1.5, 1.7, 3.1, 3.2, 3.4,]
- Organizing field data to conduct performance evaluation using M-EPDG and finite element methods [Sub Task 2.3]
- Installing temperature sensors on Iowa Hwy 30 project and conducting in-situ testing [Sub Task 3.1],

Laboratory testing:

Laboratory frost-heave and thaw-weakening test setup: Fabrication of the laboratory testing equipment was completed for the evaluation of frost heave and thaw weakening according to ASTM D5918. The fabrication required acquiring individual parts, according to the standard, since there is no commercially available test setup.

Laboratory Frost-Heave and Thaw-Weakening Testing: A trial test was performed to verify that the equipment was working properly. Once the trial test results were analyzed, testing on materials from the project sites began. During this quarter, three samples were tested on materials obtained from Iowa I-29, Michigan I-96, and Wisconsin US-10. The test is performed over a five day period that constitutes two freezing and thawing cycles. During the testing period, the temperature profile and heaving of the samples is continuously recorded and the data is automatically saved on a data logger. Temperature is being measured using thermocouples and heave is being monitoring using laser displacement sensors. Once the test period is completed, a CBR test is performed on each sample. The post freeze-thaw CBR is compared to the CBR of the material at its optimum moisture content to determine the magnitude of the loss in

strength. The ability of the sample to resist frost heave and thaw weakening is being evaluated based on the heave rate of the sample and the post freeze-thaw CBR value.

Cyclic Triaxial and Aggregate Degradation Testing: Cyclic triaxial testing with 100,000 loading cycles at a deviator stress levels of 6 psi or 9 psi at a confining stress of 3 psi was conducted on seven samples obtained from the open-graded drainage course layer on the Michigan I-94 project. In addition, particle size analysis tests were conducted on the samples before and after cyclic triaxial testing to evaluate the particle degradation under repeated loading. Each cyclic load test was conducted with a unique series of test parameters to compare with others and evaluate the effect of a single test parameter. These parameters included: (a) fines content, (b) dry unit weight, and (c) deviator stress. Fines content was varied from 2% to 8% at every 2% increments without varying the compacted dry unit weight, moisture content, and deviator/confining stresses. Similarly, to evaluate the effect of dry unit weight, specimens were prepared at 90% and 100% relative density. All specimens were prepared at a moisture content of 3.3% which is the mean value from field measurements. The results from these tests have been analyzed and were incorporated into the I-94 field project report. Similar tests are being conducted on materials obtained from all field project sites to derive relationships between permanent deformation/particle degradation properties and fines content, dry unit weight, and deviator stress.

Laboratory large scale lateral flow permeameter:
Further enhancements and modifications to the system plumbing design have been made during this quarter to ensure workability and usability of system for a wide range of materials. Various components were ordered/acquired for fabrication and suitability testing. Completion of setup will occur early next quarter. It is anticipated that testing of material collected from various project sites will also occur in the next quarter.

Field project reports and data analysis overview:
During the last quarter, we communicated with the state DOT project contacts to fill out a table with the design assumptions and values. The table composed of design assumptions/values used for traffic loads, design period, pavement surface layer properties, and foundation layer properties (i.e., base layer thickness, base layer modulus, subgrade resilient modulus, coefficient of drainage, etc.). The purpose of this table was to compare the actual measured modulus and drainage parameters in the field with the design assumed values. We obtained this design related information on all projects except on California I-15 project where such information was not available. The project involved placing precast PCC panels over an existing foundation layer and therefore no additional design was reportedly performed.

Data analysis on the Michigan I-94 project has been updated based on the feedback received from Michigan DOT, which included comparing the field moduli values from LWD, FWD, and PLT measurements and also empirically estimated moduli values from DCP measurements, laboratory values from resilient modulus tests, and field/laboratory permeability measurements, with the design assumptions. The draft report prepared on the I-94 project during the last quarter has been updated with this new information. In addition, results from cyclic triaxial and aggregate degradation tests conducted on the Michigan I-94 base material were analyzed and included in the report. Similar analysis is being conducted on the Michigan I-96, Pennsylvania SR-22, Wisconsin US10, Iowa I-29, California I-15, and Iowa I-35 project field and laboratory data. Field project reports for each of these project sites will be developed during the next quarter.

Pavement performance testing*:*
Due to a mechanical problem with the FWD, the five sites in Iowa were not tested during this quarter. The problem has been fixed and a schedule is being prepared for FWD and DCP testing on Iowa seasonal test sites early next quarter.

Field Testing on US Highway 30, Iowa*:*

Field testing was initiated on the US Highway 30 pavement foundation layer reconstruction project, near Ames, Iowa (note that forensic testing was conducted in 2009 on this same project alignment to evaluate frost-heave on the old pavement and drainage characteristics of the existing underlying base layers). This project involves removing the existing asphalt pavement, undercutting the existing subgrade by about 12 inches, and placing about 12 inches of recycled asphalt/concrete mixture modified subbase, 6 inches of recycled concrete subbase, and PCC surface layer. A temperature probe array was installed in the foundation layers on this project. Eight sensors were placed horizontally on top of the 12" modified subbase layer at every 2 ft intervals from the center of the pavement to the end of the shoulder lane to evaluate temperature variations across the pavement width. In addition, six sensors were placed vertically below the top of the 12" modified subbase layer down in to subgrade to a depth of about four feet below the bottom the pavement. A data logger is currently being programmed to setup onsite to continuously (every 1 hour) record the temperature in the foundation layers. This will be setup early next quarter and we anticipate continuing to monitor the temperatures until end of next year. Data obtained from these temperature probes will allow for comparisons to be made with laboratory testing as well as help coordinate field testing during peak freezing/thawing periods. Additional field testing to characterize the stiffness and permeability characteristics of the foundation layers is being planned for early next quarter.

Field data to conduct performance evaluation using M-EPDG and finite element analysis:

Field testing on most of the field projects included capturing spatial variability of foundation layer stiffness characteristics with dense grid testing. Geo-spatial semivariogram analysis of all field data has been completed. These semivariogram data will be utilized in finite element analysis (ISLAB 2000) to study how systematic changes in non-uniformity of foundation layer stiffness changes the stress states in the slab. A mathematical model for assigning support values in 2-D space for implementation into ISLAB2000 based on semi-variograms has been developed. This allows for idealized modeling of non-uniformity based on various theoretical semi-variograms. This is especially important in understanding the systematic effects of non-uniformity on slab stress development. A 3-D finite element analysis has been under development also during this quarter. The 3-D model will give an insight into how subgrade support especially non-uniformity effects the performance of concrete slabs particularly when the concrete slabs have an initial, partial-depth crack (top or bottom-initiated).

Anticipated work next quarter:

- Complete data analysis for the field projects and develop project reports for TAC review and comments.
- Conduct periodic performance monitoring testing in Iowa.
- Finish field testing on US30 pavement foundation layer reconstruction project in Iowa.
- Plan field testing on two additional project sites (field testing on 9 project sites is completed, and one project site is under way).
- Plan follow-up performance testing in US422, MI I-94 & I-96, and WI US-10 projects.
- Complete fabrication and test large scale lateral flow permeameter, then conduct horizontal permeability testing on samples from numerous project sites.
- Continue frost-heave, CBR, cyclic triaxial, and aggregate degradation testing on samples collected from all field project sites.
- Field data will be used to analyze the slab stresses due to the spatial variation of soil modulus measure from the field projects. Concurrently semi-variogram examples will be constructed and run in ISLAB2000 to look at more idealized cases of how systematic changes in non-uniformity change the stress state in the slab. 3-D finite element analysis on partially-cracked slabs will be run to determine the effects of support on failure of concrete pavements.
- A research team meeting is schedule at ISU for August 16-17, 2011 to update the design manual outline and organize field data for the FEA.

Significant Results:

A field data report with detailed results and analysis on the Michigan I-94 pavement foundation layer reconstruction project is being finalized to be submitted for review to the TAC members.

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).