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) ☐ Quarter 2 (April 1 – June 30) ☐ Quarter 3 (July 1 – September 30) X Quarter 4 (October 4 – December 31), 2011

Project Title:
Improving the Foundation Layers for Concrete Pavement

Project Manager:	**Phone:**	**E-mail:**
David White	294-1463	djwhite@iastate.edu

Project Investigator:	**Phone:**	**E-mail:**
David White	294-1463	djwhite@iastate.edu

Lead Agency Project ID: RT314	**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:**	**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	$288,348.58	70

Quarterly Project Statistics:

Total Project Expenses This Quarter	**Total Amount of Funds Expended This Quarter**	**Percentage of Work Completed This Quarter**
$9,531.17		10

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.):

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 test setup[Sub Task 1.5],
- 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]
- Obtaining temperature sensor array data on Iowa Hwy 30 project and conducting in-situ testing [Sub Task 3.1].

<u>Laboratory testing:</u>

Laboratory Frost-Heave and Thaw-Weakening Testing: This quarter, three samples were successfully tested. Two samples were from the Iowa US-30 project and a third one being western Iowa loess sample. A fourth test on hydrated fly ash was interrupted due to equipment malfunction. The equipment is in the repair process and should be working again by the beginning of February. Description of the test procedure is provided in the previous QPRs. In brief, 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. 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.

Cyclic Triaxial and Aggregate Degradation Testing: Cyclic triaxial tests were conducted on recycled portland cement concrete (RPCC) subbase material obtained from the Iowa US30 project. Tests with 100,000 loading cycles were conducted on samples compacted to a target 80% and 85% relative densities, and with 15 psi confining pressure and 3 psi deviator stress, to evaluate the influence of density on the permanent deformation behavior of RPCC samples. Results showed permanent strains < 0.15% at the end of 100,000 loading cycles. Testing so far on the RPCC materials included varying deviator stresses from 3 to 15 psi. In all cases, the permanent strains were < 0.15%. A new higher load capacity actuator has been recently acquired to upgrade our cyclic triaxial testing system to conduct tests at higher deviator stresses (10 to 180 psi) per recommendations by NCHRP Report 598 on RPCC materials. The actuator is expected to arrive early next quarter. To analyze behavior of the RPCC materials at higher strains, unconsolidated undrained (UU) triaxial tests were conducted on eight samples of RPCC material following 1000 cycles of repeated cyclic triaxial testing. The 1000 cycles were applied using 3 psi cyclic deviator stress and 15 psi confining stress combinations, on four samples compacted to four target densities (80%, 85%, 90%, and 95% relative densities). Another four tests were conducted with 6, 9, 12, and 15 cyclic deviator stress and 15 psi confining stress combinations on samples compacted to 90% relative density. These tests were conducted to evaluate relationships between relative densities, applied cyclic deviator stress, permanent strain at the end of 1000 cycles and shear strength, and the results are being analyzed.

Particle size analysis tests have been conducted on all RPCC samples before and after testing to evaluate the particle degradation behavior under repeated loading. Tests were also conducted on samples after compaction (before loading) to assess the influence of compaction on particle breakage. Preliminary test results indicated that particle breakage was occurring mostly due to vibratory compaction of the material and particle degradation under cyclic loading (up to 100,000 cycles) was minimal.

Observations during sample preparation indicated a possibility of density gradient/variations in granular samples, particularly when compacted at lower densities, which could have an influence on the permanent deformation behavior. The AASHTO T307 procedure does not provide guidance on the minimum acceptable density variations between compacted layers. This density variation in the sample was checked by compacting layers in the sample using separation materials between each layer and then carefully excavating each layer down to the separation material to measure the density of each layer after compaction. Time for vibratory compaction was also monitored during this process. Filter paper was first used as the separation material between each layer. The filter paper was inhibiting compaction, so the variations in the time of compaction and density between layers were minimal. Different separation materials with low tear strength are being tried (e.g., aluminum foil, wrap, straps). Testing was conducted using these different separation materials and the results are being analyzed.

Laboratory large scale lateral flow permeameter:

During this quarter several improvements were made to the overall workability of the lateral flow permeameter. The permeameter has been tested twice for leaks and performance under vaccum pressures. Few leaks have been identified and fixed. A closed-cell compressible foam material was purchased to seal the sample-top plate interface during testing. The permeameter requires nearly 5ft3 of material and we do not have such quantities of materials from all project sites for testing. As an alternative, six different material types with varying gradation parameters (open to well graded sand to aggregate materials) have been identified to conduct field air permeability testing directly on samples compacted in the permeameter, prior to running a lateral flow test. This will provide direct comparison results between the field permeability testing device used on the projects and laboratory test results.

Pavement performance testing*:*

During this quarter, the five seasonal variations sites described in the previous QPRs were tested with FWD and DCP. A sixth site was added to the testing program from the Iowa US-30 project. The site location corresponds with the testing performed on the final compacted base layer in the previous quarter. The results will be used to show the change in pavement strength throughout the year.

Instrumentation on US Highway 30, Iowa*:*

A summary of instrumentation installed on the US30 project is provided in the last QPR. In brief, a temperature array with fourteen sensors to continuously record temperature changes both across the pavement width and in the foundation layers with depth was installed at the project site. A Campbell Scientific CR5000 data logger was installed on site to continuous record the temperature in the foundation layers at one hour intervals. Data is being periodically downloaded from the project.

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. Correlation of various field geospatial data from Michigan to foundation layer stiffness (k-value) was done in order to assess the actual support nonuniformity on the slab stresses using the ISLAB2000 finite element analysis. The 2D analysis with ISLAB2000 will give the potential for an as built section to have premature cracking relative to the assumed uniform condition,

In the earlier factorial analysis with 12 nonuniform support conditions, 3 axle configurations, 3 temperature curling magnitudes, and 2 load offsets, the slab tensile stresses could increase over 50 percent relative to the uniform support condition for certain combinations of the above factor levels. Another possible condition that can cause premature slab failure especially under nonuniform support is partially-cracked slabs. These cracks initiate at either the bottom (fatigue) or surface (shrinkage) and can be partial-or through the length cracks. These cracks could have been present shortly after construction or resulted from other mechanisms related to loading and the environment. 3D analysis has been done for a variety of loading cases for partially-cracked slabs in both the longitudinal and transversal direction for several critical nonuniform cases as well as for the uniform soft and stiff soil previously studied. The results of the 3D analysis are currently being coupled with a nonlinear concrete fracture method to predict the capacity of the slab for a given set of material, slab geometry, support, and load inputs. This analysis approach can directly give the slab's flexural load capacity for each case which can indicate the main factors in controlling failure of nonuniformly supported slabs.

Anticipated work next quarter:

- Continue frost-heave and thaw-weakening testing (emphasis on stabilizing materials)
- Continue frost-heave (with emphasis on stabilized materials), CBR, cyclic triaxial, and aggregate degradation testing on samples collected from all field project sites.
- Conduct periodic performance monitoring testing in Iowa (to capture freezing and thawing seasons).
- Complete laboratory lateral flow permeability testing on at least six relatively homogenous materials.
- Complete data analysis for the field projects and develop project reports
- Plan field testing on one additional project sites (field testing on 10 project sites is completed).
- Plan follow-up performance testing in US422, MI I-94 & I-96, and WI US-10 projects.
- Analysis with 2D finite element analysis (ISLAB2000) the intensive field data sites will be continued to link the potential for premature slab failure and the type of slab nonuniformity. 3-D finite element analysis on partially-cracked slabs will also be continued to determine the main support conditions, crack geometries, and loading configurations affecting failure of concrete pavements.

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).