TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Date: ____10/31/2014_____

Lead Agency (FHWA or State DOT): ___FHWA_____

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 # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* SPR-2(208)	**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)

Project Title: Pavement Subgrade Performance Study		
Name of Project Manager(s): Nadarajah Sivaneswaran	**Phone Number:** 202-493-3147	**E-Mail** n.sivaneswaran@dot.gov
Lead Agency Project ID: DTFH61-11-D-00009-T11004	**Other Project ID (i.e., contract #):**	**Project Start Date:** 1999
Original Project End Date: 09/30/2014	**Current Project End Date:** 8/31/2014	**Number of Extensions:**

Project schedule status:

☐ On schedule ☑ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$2,923,784.74	$2,840,265.55	98%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
$26,323.65 (1%)	$26,323.65	

Project Description:

The objective of SPR-2(208) was to develop prediction models for permanent deformation in the subgrade soil that incorporate the effect of soil type and moisture content. The full-scale experimental phase of the study was conducted at the Cold Region Research Laboratory (CRREL) of the U.S. Army Corps of Engineers in Hanover, New Hampshire, between 1999 and 2007. Four flexible pavements with the same granular base layer and asphalt concrete surface layer were built inside the Frost Effects Research Facility and were subjected to accelerated pavement testing (APT). The pavements were built with a combination of four soil types and three moisture levels, which resulted in a total of 12 sets of pavement sections, named cells. Each of the four soil types were placed in the pits of the facility at three moisture contents. For each cell, between four and six pavement sections, named windows, were subjected to accelerated pavement testing. The MARK HVS IV was used as the loading device. Up to four wheel load magnitudes were used for the windows in the same cell. The test sections were instrumented with stress, strain, moisture and temperature sensors. Surface rutting was monitored with a Laser Profilometer. Falling Weight Deflectometer (FWD) tests were performed on each pavement section before the application of accelerated traffic. The testing phase of the project was completed and the final deliverables were received in February 2007 (Cortez et al., 2007).

The final deliverables from the testing phase included a comprehensive database containing APT testing data of the four different subgrade soils under various moistures and loading conditions, along with a series of reports. Preliminary data analysis showed that the database provides a wealthy amount of information for pavement engineers and researchers in the development of advanced subgrade performance models. However, because of its complexity due to the number of variables involved, its sheer size, and some incomplete/missing data, the potential use of the database couldn't be realized without a detail assessment of the database. The Technical Advisory Committee (TAC) of the TPF thus requested the FHWA to conduct an independent assessment of the database and to develop a work plan for future data analysis. The objectives of the database assessment were to 1) review the data variables, its completeness and to document them; 2) to obtain/assemble/input additional available laboratory test results and missing data and 3) with the assessment complete, to develop a detailed work plan for future data analysis and modeling. The data assessment task was completed in October 2010 and this resulted in a comprehensive report documenting the entire study effort to date, including detail documentation of APT and laboratory test data, and a Microsoft Access database with data for further analysis (Romanoschi, 2010).

The TAC met during the January 2011 Transportation Research Board Annual Meeting and recommended the final phase of this TPF to develop empirical models for permanent deformation in subgrade soils consistent and for use with the NCHRP 1-37A Mechanistic-Empirical Pavement Design Guide (MEPDG) and more fundamentally based mechanistic models for advancing the science of pavement design.

A Task Order under an existing IDIQ contract was awarded in January 2012 to Engineering & Software Consultants, Inc. to conduct the final phase of this study to:

1. Develop empirical models for permanent deformation in subgrade soils consistent and for use with the NCHRP 1-37A Mechanistic-Empirical Pavement Design Guide (MEPDG) and the associated model parameters for the subgrade soils tested in SPR-2(208) and validate them using the performance data collected.
2. Develop fundamentally based mechanistic models for the determination of permanent deformation in subgrade soils under repeated traffic loading and validate them through finite element modeling and the performance data collected for advancing the science of pavement design.

The TAC met during the January 2012 Transportation Research Board Annual Meeting where the research team conducting work under new TO presented their work plan and received feedback

The new TO consisted of the following five tasks:
Task 1: Comprehensive review of SPR-2(208) products
Task 2: Development of empirical and mechanistic models for permanent deformation in subgrade soils
Task 3: Advanced laboratory testing of subgrade soils for the determination of model parameters
Task 4: Finite element modeling (FEM) of permanent deformation accumulation for calibration and validation of model and model parameters
Task 5: Develop and submit a final report to document the entire research effort

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

Task 1: Comprehensive review of SPR-2(208) products
None this Quarter.

Task 2: Development of empirical and mechanistic models for permanent deformation in subgrade soils
None this Quarter.

Subtask 2.1 – Development of new empirical models
The statistical analysis continued with the development of new models which incorporate the Optimum Moisture Content as an independent variable. A paper was submitted for presentation at the 2015 TRB Annual Meeting and for publication in the Journal of the Transportation Research Board.

Some models, other than those included in the paper submitted for publication and presentation at the 2015 TRN meeting have been investigated.

Subtask 2.2 – Development of fundamentally based mechanistic models

Model Development:
The procedure to calculate parameters for the Drucker-Prager Cap Model was implemented in a MATLAB program. A method to predict friction angles under different water contents by using Soil Water Characteristic Curve (SWCC) and suction stress characteristics curve (SSCC) was developed. This was also done using MATLAB. For each soil, 2 different UCS samples with different water contents were tested. CU Triaxial test for CRREL soil A-7-5 and for A-6 were completed. Equipment problems prevented the personnel from doing A-4.

The parameters for Drucker-Prager Cap Model for CRREL soils under different water contents were investigated: (1) Completed literature review of the influence of suction on shear strength. (2) Performed direct shear tests on CRREL soils and continued with the investigation of the influence of moisture content on ultimate failure by performing UCS and Triaxial tests. (3) Parameters of Cap surface were determined by both introducing suction stress and performing triaxial tests. MATLAB programming for calculating the parameters of Drucker-Prager Cap Model under different water contents is ongoing.

Direct shear tests were performed on CRREL soils and Pullman silts under different water content levels. The main parts of MATLAB programming for calculating parameters of Drucker-Prager Cap Model under different water contents have been completed. Another approach of obtaining soil-water characteristic curve (SWCC) is in progress. The literature review of the relationship between moduli and moisture content has been started.

Model Implementation:

Task 4: Finite element modeling of permanent deformation accumulation
Simulation of pavement model with multi-layers has been started.

Simulation of quarter multi-layers pavement model with Drucker-Prager Cap Model by using FE methods in ABAQUS softw was continued. 3D symmetric model has been built and the simulation of this model has started.

Simulation on 3D half model with ABAQUS has started. Performance of wheel loads on different CRREL soils have been simulated and compared to the tests performed in SPR2-208.

Task 5: Develop and submit a final report to document the entire research effort
The preparation of the final report for the research project has started.

Anticipated work next quarter:

1. Laboratory tests will be completed and the data reviewed and used for numerical simulation on SPR-2(208) project. Matlab Program for model parameters will be developed for future application.
2. Numerical simulation using ABAQUS will continue. All tests for determining parameters of Drucker-Prager Cap Model will be finished.
3. The work on the final report for the project will continue.

Significant Results:

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).

Potential Implementation:

1. Empirical models for permanent deformation in subgrade soils consistent and for use with the NCHRP 1-37A Mechanistic-Empirical Pavement Design Guide (MEPDG) and the associated model parameters for the subgrade soils tested in SPR-2(208).

2. Fundamentally based mechanistic models for the determination of permanent deformation in subgrade soils under repeated traffic loading for advancing the science of pavement design.

3. Fully documented APT performance and laboratory test data in a Microsoft Access database for future model validation and calibration.