TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Date: ____10/31/2013_____

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:** 11/30/2014	**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	$2,751,816.92	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
$29,906.36 (1%)	$29,906.36	

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.):

The TO's Quarterly Progress Report for May – July 2013 was received.

Develop fundamentally based mechanistic models for the determination of permanent deformation in subgrade soils under repeated traffic

Draft Interim Report was received from the research team in July and TAC provided substantial review comments to the research team in August. The research team addressed review comments and the revised interim report was received and has been posted to the TPF website for this project.

TAC provided substantive and significant comments to the research team based on the Interim Report and the research team has been addressing those comments and this meeting offers us the opportunity to hear from the research team, assess progress and provide technical feedback for the remaining tasks. The suggestion is to have the research team provide the study status, response to the TAC Interim Report co

Efforts continued on incorporating suction and fabric effects to the critical state two-surface plasticity model.

Model behavior was studied in a fundamental way using undrained repeated cyclic triaxial simulation results and unsaturated repeated drained triaxial simulation results. Influences of sample preparation method and relative density on undrained repeated cyclic triaxial loadings were studied. Furthermore, influences of sample preparation method, relative density and saturation level on unsaturated repeated drained triaxial loadings were studied.

Repeated drained triaxial loading results were related to subgrade permanent deformation due to repeated loadings.

In order to quantify the difference in observed performance of unsaturated sands for various levels of saturation, a modified initial state parameter for unsaturated sand was developed. Its use to practice is highlighted.

New fine mesh 3D finite element model was developed to simulate the moving pressure loading in APT test section and moving pressure loading was successfully simulated but the time needs to simulate is unacceptable. Thus, same loading was simulated in the fine mesh 3D FE model and previously developed coarse mesh 3D FE model to compare the performance of these two 3D FE models. Results showed that differences are not significant. It was decided to go with the coarse mesh 3D FE model.

Repeated moving pressure loading of 80kN was simulated with coarse mesh 3D FE model for two difference soil types (high plasticity silt and low plasticity silt) up to 250 loading cycles. Vertical permanent deformation variation with loading cycles were obtained and compared with test data.

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)

There is no activity to report. The interim report was reviewed by the TAC and a response was prepared.

Anticipated work next quarter:

The following work will be carried out over the next quarterly period:

- 3D FE simulations will be carried out to simulate repeated traffic loading in APT test section for different soil types.
- Vertical permanent deformation varies with number of loading cycles will be obtained from 3D FE simulations. Simulation results obtained from repeated traffic loading on APT test section will be verified with available test data (Cortez, 2007 and Romanoschi, 2010).

Significant Results:

New fine mesh 3D FE model was developed to simulate moving pressure loading. Elastic analysis was carried out to compare the efficiency of coarse and fine mesh 3D FE model. Based on the results, coarse mesh was selected to simulate moving pressure loading in the future.

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.