TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Date: ____1/31/2013_____

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):	**Phone Number:**	**E-Mail**
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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	$2,655,265.73	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
$47,063.32 (2%)	$47,063.32	

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 August – October 2012 was received.

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

Simulation results with new sand model were validated with available test data. Initial validation of the model was carried out using triaxial compression test results with confining pressure of 100 kPa under both drained and undrained conditions up to 20 % axial strain. The test data was obtained from Verdugo and Ishihara (1996). It was shown that the simulated results match the test data well.

In order to verify the performance of the model for different combinations of sample preparation, relative density, mode of shear and confining pressures further analyses were conducted on test data reported by Yang et al. (2008)., The results showed good agreement. The corresponding stress strain relations were also compared and full details will be presented in the final report.

Linear elastic analysis was carried out in ABAQUS and vertical deformation results were validated with 3D Move (University of Nevada, 2012) in order to check the accuracy and efficiency of the 3D FE model of APT test section that was developed. Vertical deformation on top of asphalt layer matched very well with result obtained from 3D Move. This measurement was taken at the center of the test window and pressure loading was moved throughout the entire test window.

3D FE analyses were conducted to model loading at center test window and loading at side test window both with single wheel load and loading along entire wheel path. In addition, analyses also included simultaneous loading at center and side test window.

Repeated (Loading-unloading-Reloading) drained triaxial compression loading was successfully simulated with 50 and 100 kPa confining pressure. Same type of strain control loading was applied for bath samples. Sample with 100 kPa confining pressure shows 1.6 times more shear strength and 1.07 times more axial strain than sample with 50 kPa confining pressure at the end of loading.

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)

The development of empirical models for permanent deformation from the response and performance data collected during the PSPS project requires significant manipulation of the PSPS data in order to create a dataset to be used in the statistical analysis. This had to be done separately for each test cell, window and number of passes applied in the PSPS experiment.

After careful a careful investigation of the available data and the variables needed to develop the empirical models, it beca evident that two dataset must be created. The two separate datasets will allow the development of models having different independent variables.

The next step in the development of empirical models for permanent deformation is the non-linear regression analysis. SA be used only for non-linear models for which the model form is specified by the user. Therefore, SAS will be used only for m with form similar to those found in the literature review for the permanent deformation in granular materials and asphalt mix Specialized non-linear regression software can be used to develop new models. The preliminary evaluation of software specialized in non-linear regression suggested that TableCurve 3D may be the best software to be used in the non-linear regression analysis. DataFit and GraphPad are two other software packages that can be potentially used. The statistical analysis will be conducted in the next quarter.

Anticipated work next quarter:

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

- Continue with the evaluation and refinement of models.
- Continue numerical implementation of the constitutive models.
- Continue the development of empirical models for permanent deformation

Significant Results:

Newly implemented sand model was successfully validated with available triaxial test data for different shear mode, sample preparation method, confining stress and different density.

The developed FE model of APT test section was successfully validated with simulation results obtained by using 3D MOVE. When loading occurs in side window that is adjacent side wall of APT test cell, side wall affects the deformation.

Capability of newly implemented sand model to simulate the repeated loading was illustrated by successfully simulating repeated drained triaxial compression test.

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.