

TRANSPORTATION POOLED FUND PROGRAM QUARTERLY PROGRESS REPORT

Date: 1/31/2014

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>(i.e., SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX))</i> SPR-2(208)	Transportation Pooled Fund Program - Report Period: <input type="checkbox"/> Quarter 1 (January 1 – March 31) <input type="checkbox"/> Quarter 2 (April 1 – June 30) <input type="checkbox"/> Quarter 3 (July 1 – September 30) <input checked="" type="checkbox"/> 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	\$2,764,313.00	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
\$12,496.08 (0.5%)	\$12,496.08	

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

Review of SPR-2(208) was carried out as needed.

Task 2: Development of empirical and mechanistic models for permanent deformation in subgrade soils

Subtask 2.1 – Development of new empirical models

New empirical models to predict the permanent strain was investigated, by looking at the permanent deformation as the dependent variable and the number of passes and elastic strain as independent variables. Non-linear regression analysis was conducted. A revised report of the work conducted but not included in the Interim Report was prepared for the meeting with the Technical Advisory Panel that will take place in January 2014.

Subtask 2.2 – Development of fundamentally based mechanistic models

Model Development:

The model for sands has been completed and the existing model in Abaque FE for clay is adopted.

Model Implementation:

A peer review journal paper was prepared from this project study. It describes development and implementation of a constitutive model to predict the behavior of unsaturated sands based on critical state and bounding surface concepts and incorporates parameters to account for sand fabric and suction. It also presents verification of model with a wide range of test data and detail study of unsaturated sandy soil behavior.

The model has been implemented and verified on several published test data.

A revised interim report was prepared and submitted. This revised interim report addresses comments raised by TAC members on the original report (for the period of January 12, 2012 to February 15, 2013). It also includes some additional material from recent analyses that address many of the comments. Results obtained in the last quarter period are also incorporated in the revised report.

Task 4: Finite element modeling of permanent deformation accumulation

Efforts continued to simulate repeated loading in 3D FE model and evaluate subgrade permanent deformation variation with load cycles. The student, Sutharsan, who worked on the project, graduated in December with his Ph.D. He has trained a new student, Yilong Liu, on the use of his FE models. Note that Yilong was not supported during this period. But he is ready for taking up the project beginning January 2014. The predictions of clay behavior are not good thus far. The reason for this is being investigated and is being planned to be resolved.

Anticipated work next quarter:

- The research of the next period will start with literature review to develop test method and collect data for further numerical simulations.
- The characteristics of the studied soils, such as optimum moisture content, maximum dry density, Atterberg Limits, compressibility index and suction will be obtained as input values for numerical model.
- A series of triaxial tests on the 4 types of soils will be performed to collect parameters of numerical models. Different conditions including moisture contents, cell pressure and sensitivity of fabric will be checked.
- Repeated Loading with increasing value of load will also be tested and simulated.
- Previous research will be revised to consider the modulus of base and determine the shape of the saturation influence curve. Sensitivity analysis will also be taken into consideration.

Significant Results:

The models have been implemented and verified on several published test data.

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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.