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UTRC Research Study C-08-21
Modeling Mechanistic Properties of
Unbound Pavement Materials for NYS

MEMORANDUM

To: Makbul Hossain

From: David P. Orr

Subject: Draft Plan of Work

Date: 19 May 2011

cc: TWG, Lynne Irwin

This memorandum serves as the Technical Memorandum deliverable requirement of Task 1 of the UTRC Research Study C-08-21: Modeling Mechanistic Properties of Unbound Pavement Materials for New York State. An updated literature review failed to find any significant materials to change the work plan, but these items may be useful during the modeling phase and will be included in the final report from Task 4. This Plan of Work is being submitted to the NYSDOT Project Manager (PM), Makbul Hossain, and the Technical Working Group (TWG) for review and comment. The comments of the PM and TWG will be incorporated into this document and a final Plan of Work will be submitted.

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Introduction

Working with a technical working group consisting of representatives from the New York State Department of Transportation (NYSDOT), and the Federal Highway Administration (FHWA), the Cornell University Local Roads Program is conducting research on the seasonal variation of unbound pavement materials properties in New York State. This project will increase the applicability of the seasonal pavement materials models that were developed for the New York State Department of Transportation (NYSDOT) in an earlier research project entitled #C-01-54, Seasonal Variations of In Situ Materials Properties (Orr and Irwin 2006).

The models from that project were designed to help NYSDOT implement the new mechanistic-empirical pavement design guide (MEPDG) while still being applicable with the existing NYSDOT Comprehensive Pavement Design Manual (CPDM). This project will expand on earlier research results, creating models of seasonal change in unbound (subbase and subgrade) layer moduli applicable across approximately 90 percent of the area of New York State.

Overview

This refined plan of work lays out the experimental design to be used by the Cornell University Local Roads Program to meet the project objectives.

The primary goal is to expand the inference space of the models of seasonal change in unbound (subbase and subgrade) layer moduli for use in mechanistic pavement design. Information gained from the initial study shall be used to focus the activities of this project. The project goals are similar to those from the initial study.

- Revise and update the matrix of the soil and climatic zones important to pavement design in New York State.
- Using a practical set of evaluation tests at a site; determine an effective resilient modulus of subgrade for use in the 2000 NYSDOT *Comprehensive Pavement Design Manual (CPDM),* Chapter 4: New Pavement Design.
- Using a practical set of evaluation tests at a site, determine a predictive seasonal model of resilient modulus of unbound materials to be used in mechanistically-based new and reconstruction pavement design. The seasonal model could provide input for one of the hierarchical levels in the new AASHTO *Mechanistic-Empirical Pavement Design Guide* (MEPDG).
- Provide software tools and training for NYSDOT engineers to facilitate the implementation of this research.

The study is divided into four tasks, with Task 2 being future divided into three subtasks. It is Task 2 which is the primary focus of this memorandum.

Table 1 shows the inference space of the previously developed seasonal model and the associated ranges for all of New York State. Figure 1 provides a graphic representation of these ranges for all of New York State and the current inference space (dark bars) for the quantifiable variables based upon an analysis of the data collected previously. Figure 2 shows the frost depth areas outside the inference space from the previously developed models.

Table 1 – Inference Space of Seasonal Model and Range for New York State

Site Characteristic or Test Value	Full Range in New York State	Range of Seasonal Model
Surface Material	Asphalt, Concrete, or Composite	Marshal Mix Design Asphalt Only
Subbase (granular)	Fines: 0 - 30% PI: 0 - 20	Fines Content: 0-20% PI: 0-8
Subgrade	Fines: 0 - 100% PI: 0 - 45	Fines Content: 5-95% PI: 0-12
Site Drainage	Poor to Excellent	Good to Excellent
Average Frost Depth	330 – 1300 mm	600 – 1,100 mm

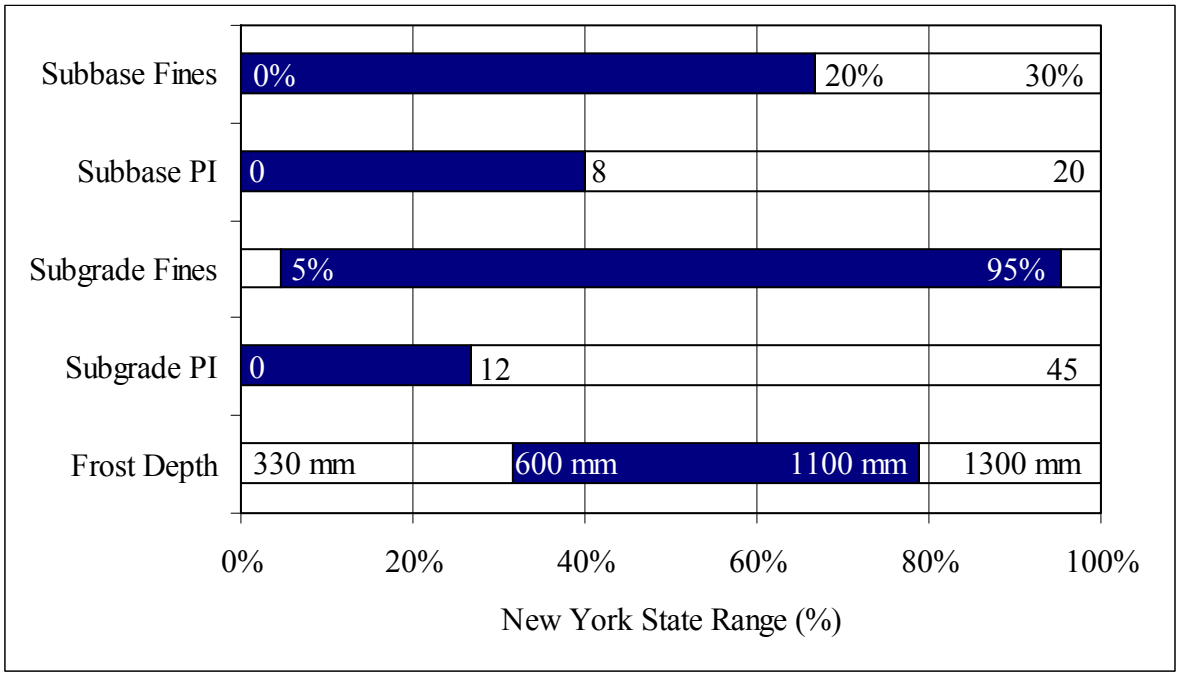

Figure 1 – Graphical Chart of Inference Space Within New York State

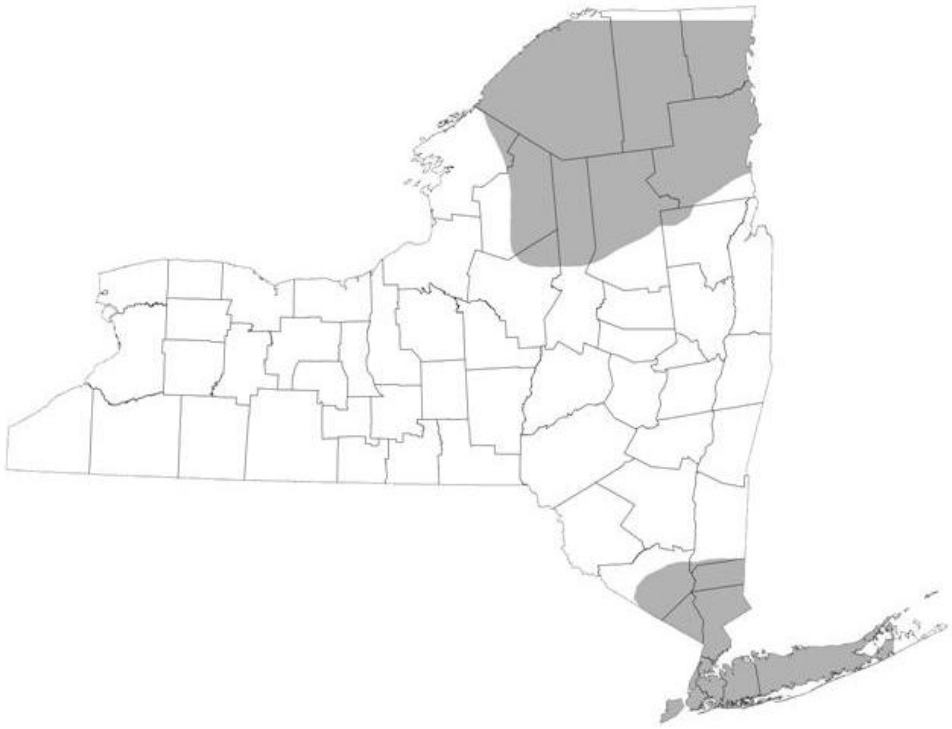

Figure 2 – Areas where seasonal models are out of range (in grey) due to average frost depth. In the Adirondacks the frost depth is too deep, and Downstate it is too shallow.

Task 2 – Execute the Work Plan Developed in Task 1

This task is the bulk of the project and is broken into three subtasks. In order to keep the lines of communication open and to allow for the most flexibility, Cornell proposes providing a technical memorandum for each component of the research. These memoranda will form the basis of the final report.

Task 2.1 – Select Sites and Conduct Seasonal Testing to Expand Models

Task 2.1a – Evaluate NYSDOT Seasonal Monitoring Test Site Data

Obtain all of the data available to date from the 95 NYSDOT Seasonal Monitoring test sites that have four or more sets of FWD test data collected at different times of the year. For those sites that have complete traffic, layer thickness and geotechnical laboratory test data the Consultant shall backcalculate the FWD data to obtain layer moduli. Compare the resultant backcalculated moduli with predicted moduli using the initial seasonal models to determine where the models seem to give accurate results (i.e., within ±20 percent of the backcalculated data) and where they do not. The seasonal monitoring data shall later be used to verify the accuracy of the final seasonal models from this project.

Task 2.1a Deliverable – Memorandum of Backcalculation Results

A technical memorandum of the backcalculation analysis will be provided to NYSDOT. The results will also be provided in a spreadsheet (Microsoft Excel) format. If desired, the data may be placed into a database (Microsoft Access) format. The memorandum will outline the procedures used in the backcalculation analysis.

Task 2.1b – Locate Test Sites, Initial Site Investigation, and FWD Data Collection

Develop four FWD test locations selected to expand the range of the variables in the seasonal pavement design models. At least one of the locations should have two paired test sections, one with good and one with poor drainage. Each of the test locations must meet the following criteria.

- A NOAA first-order weather station within five miles, if possible. The weather station should be among those used to develop the GIS mapping.
- A flexible (asphalt concrete) pavement in good condition. The overall thickness of the pavement (surface plus subbase) should not exceed two-thirds of the anticipated frost depth. The site should be on native subgrade and not on fill.
- Level terrain with clear sight distance for safe traffic control.

In order to satisfy the project objectives as well as to maximize efficiency and minimize travel time, two of the sites should be located in or close to the Adirondack Region and two locations should be in the Downstate Region.

Generate a list of six or more possible FWD testing locations. With the assistance of NYSDOT geotechnical crews, conduct a site investigation at up to six locations. During the investigation at each location that appears feasible as a test site, a frost depth tube shall be installed for later use. Cornell will provide the materials for the frost tube while NYSDOT will provide the cover in the pavement. The figures below show the cap and cover installed at the Tioga County site during the earlier research.

Utilizing the site investigation data, Cornell with the NYSDOT PM and TWG, shall mutually agree on the final selection of the four test locations. Cornell will perform laboratory materials characterization involving index testing of soil samples taken from each selected site. The protocol for this testing shall be the same as was used in the initial study.

At each finalized test site, Cornell will set up a schedule to insure that twenty-four (24) FWD tests are made over a 12-month period. On site traffic control shall be provided by NYSDOT. This will require coordinated scheduling with the local NYSDOT Residencies. The FWD testing should begin at each test site as soon as possible after finalization of the locations. After FWD testing, but before leaving the test site, Cornell will complete a preliminary set of data processing, including initial backcalculation. Detailed back-calculation will be done within two weeks after site testing, with a goal of one week if possible.

Task 2.1a Deliverables – Memoranda of FWD Testing Operations, Site Selection, and Data Analysis

Cornell will provide a technical memorandum outlining the FWD testing and analysis operations. This memo will provide information on the testing sites as well as the FWD operational procedure.

Once the final sites are chosen, a memorandum outlining the expected project inference space will provided to NYSDOT. The data in Figure 1, Figure 2, and Table 1 from this memo will be updated to show the expected inference space.

A brief, technical memorandum and spreadsheet detailing the results from backcalculation analysis will be provided for the four testing sites. Interim analysis will be provided upon request to NYSDOT. As a minimum, updates to the FWD operational schedule and data analysis will be provide each quarter to NYSDOT.

Task 2.2 – Data Analysis and Modeling

Task 2.2a – Enhancements of the Cornell Pavement Frost Model

Cornell will use the frost tube data from the four test sites along with additional data from the Long-Tern Pavement Performance (LTPP) database to refine the Cornell Pavement Frost Model developed in the initial study with the objective to further validate the model. Enhancements to the Cornell Pavement Frost Model will be made to more thoroughly take into account elevational affects. A software tool to allow pavement designers to use the Cornell Pavement Frost Model will be developed. Updated climatic data will be obtained and incorporated into the model.

Task 2.2a Deliverable – Memorandum of Updated Frost Model and Software Tool

A technical memorandum will outline the changes and updates to the Cornell Pavement Frost Model. The memorandum will provide basis instructions for the use of the model, but will not be a software manual.

A Windows based software tool will be provided to allow use of the Cornell Pavement Frost Model. It may be self-standing or tied into ArcGIS, but final determination of this will be determined after discussions with the TWG. If self-standing, a context sensitive help will be included with the software. If part of GIS, a small help manual will be provided with the GIS layer information.

Task 2.2b – Expansion of the Seasonal Pavement Moduli Models

Cornell will refine the seasonal pavement models for unbound materials. It is anticipated that plasticity index, angularity and site drainage may need to be added as factors in the model.

Task 2.2a Deliverable – Memorandum of Updated Seasonal Pavement Models

A technical memorandum will outline the updated seasonal pavement models. The memo will include analysis of each test site, a review of the sites from the earlier study, #C-01-54, Seasonal Variations of In Situ Materials Properties, and the proposed updated seasonal pavement models.

A draft version of the memo with only the analysis of each site will be provided to the TWG shortly after FWD testing is completed. A second draft will include the analysis of the data from the previous sites along with the proposed new models. After comments are received from the TWG, a final technical memorandum will be provided.

Task 2.3 – GIS Mapping Review

Cornell will work with appropriate NYSDOT personnel to assure that the data retrieval system (report generator) is working correctly and it is compatible with NYSDOT's current version of GIS.

Task 2.3 Deliverable – GIS data from Task 2.2

All of the data from Task 2.2 that is spatial in nature will be provided to NYSDOT in ArcGIS format. A technical memorandum will outline the data provided. As a minimum the data will include the following.

- Mean annual air temperature
- Mean annual precipitation
- Air-freezing index
- Number of frost days (days with average temperature below freezing)
- Thornthwaite moisture index
- Average relative humidity
- Seasonal lengths from pavement design models (each season)

Task 3 – Software Development and Training

Develop a Windows-based computer program to replace the current Excel spreadsheet for implementation of the seasonal models and the Cornell Frost Depth Model. Cornell will work with NYSDOT Information Technology (IT) personnel to ensure compatibility with NYSDOT IT requirements. Output from the computer program should be as compatible as possible with the NYSDOT CPDM and the AASHTOware version of the MEPDG (also known as DARwin ME).

A training program for NYSDOT Regional geotechnical and materials engineers will be given on-line and on-site as is appropriate. The training shall cover the use of the GIS report generation tool, the seasonal models computer program, and application of the models to CPDM design methodology.

The Consultant shall develop a training program for NYSDOT Regional geotechnical and materials engineers in consultation with the NYSDOT PM and TWG. The training shall cover the use of the GIS report generation tool, the seasonal models computer program, and application of the models to CPDM design methodology. The training shall be held as soon as practical after completion of Task 2.3.

Task 3 Deliverable

A Windows based software tool will be provided to use the updated seasonal pavement design models. A context sensitive help will be included with the software. The help will include how to use with ArcGIS or obtain data from ArcGIS. The final determination of which of the two to use will be made in consultation with the TWG.

Task 4 – Final Report

All of the technical memoranda and other information developed in Tasks 1-3 will be incorporated into a final report. In addition to these data, the final report will contain recommendations and information germane to use of the any models, software, or other analysis involved in this project.

Task 4 – Deliverable

A draft Final Report, as described above, in MS Word format, will be provided to the NYSDOT PM and TWG for review and comment. Upon review and acceptance by the NYSDOT, Cornell will submit the Final Report, electronically, in PDF format along with fifteen (15) hard copies.

The Final Report shall meet the requirements of the Task Assignment. The seasonal data (including the backcalculation results) shall be provided in an Access database or Excel spreadsheets compatible with the current version being supported by NYSDOT. Any GIS maps shall be in the current ArcGIS format supported by NYSDOT. Any software, and accompanying help, will be compatible with the version of Windows being used by NYSDOT at the time of acceptance of the Final Report.

References

Orr, D. P., and Irwin, L. H. (2006). "Seasonal Variations of In Situ Materials Properties in New York State: Final Report." Cornell Local Roads Program, Ithaca, NY.