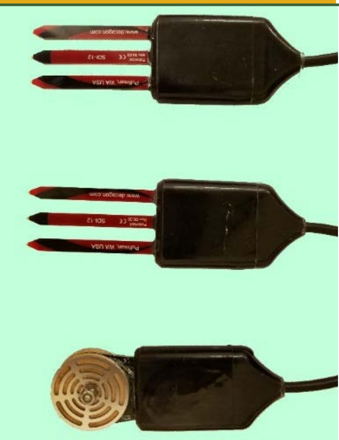
Transportation Consortium of South-Central States (Tran-SET)

Developing Implementable Climatic Input Data and Moisture Boundary Conditions for Pavement Analysis and Design

Developing a practical and implementable numerical model to evaluate the moisture regime within pavement subgrade in response to climate data



Highlight | Jan. 2019

Project No. 18POKS03

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POP: March 2018 – November 2019

Environmental conditions have a significant effect on the pavement performance. Of all the environmental factors, temperature and moisture have direct effect on the pavement layer and subgrade property. The current AASHTOWare Pavement ME software package utilizes the enhanced integrated climatic model (EICM) for applying the effects of climate on the pavement materials. The software uses historical climatic files that have been developed for each state in the US. However, these files are in most cases limited in number and region within each state, and therefore cannot represent the site-specific climate information. Furthermore, a number of states conducting research studies have found that there are significant discrepancies between the EICM predictions and measured values in the field. Therefore, there is a need to develop practical and implementable predictive models to study the moisture regime within the pavement subgrade in response to site specific climate data. This project will mainly focus on improving our understanding of environmental interactions with pavement systems to better predict the changes in pavement material properties over time.

Background

The Pavement ME software simulates temperature and moisture profiles in the pavement structure and subgrade over the design life of a pavement using the EICM. The major function of the EICM model in Pavement ME includes the prediction of the soil moisture content and soil water characteristics curve (SWCC) from the material grain size distribution and index properties, and the National Climatic Data Center (NCDC) database for sunshine, rainfall, wind speed, air temperature, and relative humidity. However, due to the multiple phenomena considered by this model and the complexity of the boundary conditions, the results from the EICM model are not well understood. AASHTO has recommended that the Pavement ME be adopted by state departments of transportation agencies in pavement design. Several states in the U.S. have conducted independent studies to validate the EICM and assessed the effects of water content change on the short- and long-term pavement performance. Some of these states are Minnesota, Idaho, New Jersey, Ohio, and Arkansas. All these states have encountered difficulties in matching the predictions made by the EICM for moisture content with field observations. Therefore, it is important to establish realistic estimates of expected subgrade moisture content to account for the effects of this variable on predicted pavement performance during the design stage. The project is specifically focused on the estimation of site-specific variation in environmental factors that can be used in predicting seasonal and long-term variations of pavement subgrade properties.

Project Summary

This project is mainly focused on improving the understanding of environmental interactions with pavement systems to better predict the changes in pavement material properties over time. Historical weather data for 77 Oklahoma Mesonet stations from 1994 to 2017 were collected and used as a basis to interpret the current soil moisture distribution. The suction profiles in the subgrade soil can be predicted theoretically by solving the moisture diffusion equation that governs the suction distribution in the soil. The computer software MATLAB was used to calculate the monthly average surface suction and solve the diffusion equation. The written codes can determine the distribution of soil suction throughout the unsaturated subgrade soil and calculate the diffusion coefficient from a single measurement of suction at any time. Figure 1 shows the monthly mean matric suctions for Lane station, Atoka county, Oklahoma during 2017.

The numerical modelling approach can predict the matric suction profiles and moisture boundary conditions in the pavement subgrade from measured suction data. These boundary conditions can involve the maximum and minimum variations of the surface moisture conditions as well as their variations with depth within the moisture active zone.

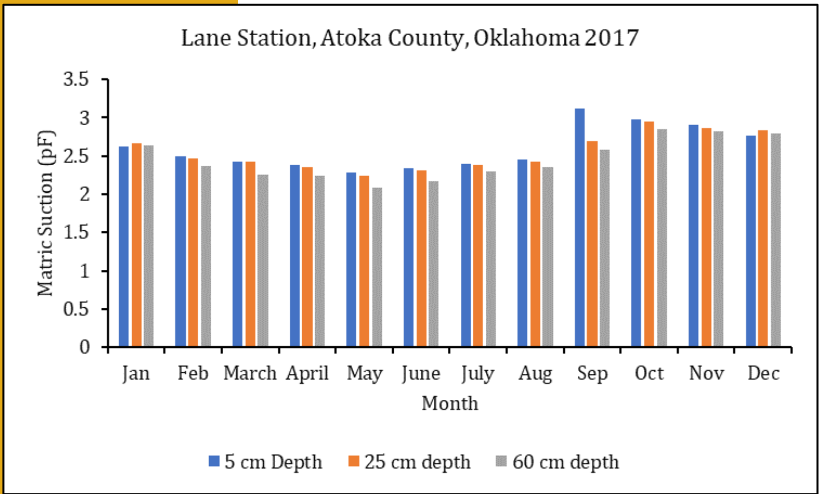

Figure 1. Monthly mean matric suction at 5 cm, 25 cm and 60 cm depths in LANE station, Atoka County, Oklahoma during 2017.

Status Update

The research team collected and assessed the Thornthwaite Moisture Index (TMI) from the historical climatic data obtained through 77 Oklahoma Mesonet weather stations from 1994 to 2017. Two commonly used models used to calculate the TMI values from the historical climatic data and contour maps are constructed. This was an extremely large cluster of climate data to evaluate and analyze. The matric suctions are computed from the climatic input data. The numerical modelling was utilized, and a Mitchell model was used to predict and calculate equilibrium matric suctions from measure suction data.

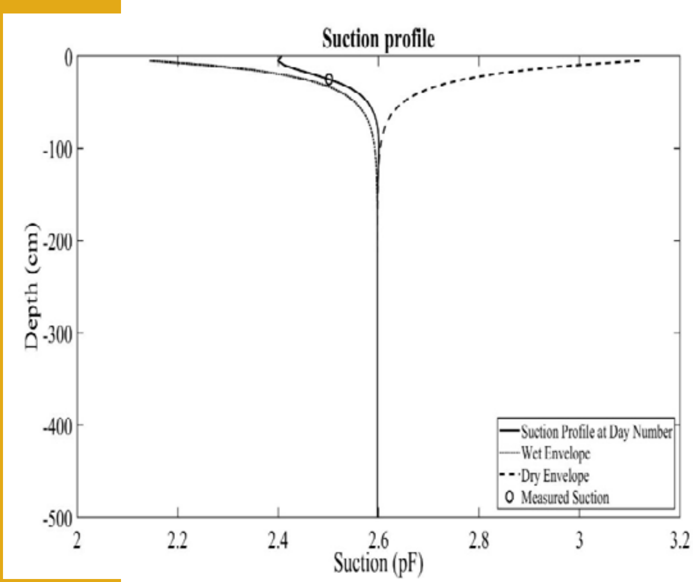

Figure 2. Suction distribution profile with respect to measured suction at 25 cm depth on 06/30/2017 at Lane, Atoka county, Oklahoma.

The suction distribution for LANE station from a suction measurement at depth of 25 cm was computed and plotted in Figure 2. The preliminary assessment of the suction profiles for the LANE station shows that measured suctions were successfully fitted with the predicted profile. The diffusion coefficient is crucial factor for constructing a suction profile and was obtained through solving the diffusion equation using measured data.

The next steps of the analysis will evaluate the in-situ suction values with respect to several environmental parameters, including relative humidity, annual precipitation, average temperature, windspeed, TMI, and clay content in searching for a correlation. In the correlation process, each data set will be plotted and evaluated for significant trends.

Impacts

This project has the potential to significantly enhance the current analysis of the climate and pavement system interaction. The work will provide a unique and practical moisture (suction) prediction model in subgrade soils in response to climatic effects. The proposed method has strong theoretical background in determining the moisture boundary conditions above and below the pavement system utilizing existing climate data, and in developing a sound theoretical model in predicting moisture variations within the subgrade soils.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.

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