Environmental Impacts on the Performance of Pavement Foundation Layers – Phase I

Revised Interim REPORT for Tasks 1: Initial Memorandum on Expected Research Benefits and Potential Implementation Steps

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CHAPTER 1: INTRODUCTION

1.1. RESEARCH PROJECT ABSTRACT AND OBJECTIVES

Seasonal freeze-thaw weakening and changes in saturation level from environmental fluctuations have a significant effect on pavement foundation performance. The seasonal freeze-thaw cycles cause extensive damage to the pavement from frost-related problems such as frost heave, frost boils, thaw weakening, total rutting, and degradation of mechanical properties. Changes in saturation level of pavement foundation geomaterials during freeze-thaw cycles can influence the performance of pavement foundation layers significantly. It is crucial to monitor the changes in water content, temperature, and matric suction of aggregate base and subgrade soils to be able to predict the frost depth, freezing and thawing times and mechanical property changes.

This project has two main goals: (1) develop a model to predict the maximum/minimum frozen soil depths and (2) freezing and thawing duration via use of standard climate data that includes precipitation, shortwave radiation, and air temperature.

During this phase (Phase I), the research team will extract the environmental data collected by MnROAD test facility over the years and determine whether it is necessary to build new test sections that is installed with finer environmental sensors to improve the reliability of numerical models to predict the freeze-thaw cycle numbers, freeze time and thaw time, and frost depth and be used for pavement analyses.

Modeling analyses will be conducted to determine whether results are impacted significantly at different dimension conditions. Then, the research team will provide recommendation whether finer environmental sensor installation and monitoring is required considering sensor location, e.g., installation at the two edges, center and between edges and center of the roadway cross-section and different depths. For instance, sensors may be recommended to be placed in every 6 inches in depth up to 10 ft. Thus, as a result, the lateral and vertical variations of these environmental data will be monitored and tied to the elastic modulus data.

1.2. ORGANIZATION OF THE MEMO

This memorandum consists of three chapters. The next two chapters include benefits of this research and the implementation process.

CHAPTER 2: EXPECTED RESEARCH BENEFITS

2.1. HOW DOES THIS RESEARCH BENEFIT TAXPAYERS OF THE NRRA MEMBER STATES?

The benefits of the proposed project will be to improve the quality, longevity, and state of good repair of roadways, which constitute a vital component of the nations` infrastructure. The field monitoring data will produce a better understanding of the evolution of freezing and thawing soil zones beneath roadways. The computational models developed in this study will help DOTs work towards predicting the depth and duration of soil freezing/thawing. As a result, maintenance costs associated with repairing traffic-related damage to thawing roads can be reduced.

With further research, the modeling analyses will determine whether more detailed Phase II study needs to be conducted. It is expected that with more detailed phase study in the future the computational models developed in this phase could be incorporated into the pavement Mechanistic Empirical Pavement Design Guide (MEPDG) for improved climate modeling and prediction of freeze-thaw related damage to pavements.

2.2. INITIAL PROJECTION OF EXPECTED BENEFITS

The following benefits are initially expected to be accomplished by end of this project:

- **Construction Savings:** Proper integration of freeze-thaw effect in pavement design would yield to more reliable pavement performance predictions. Thus, more accurate pavement design can be achieved which would result in construction savings.

- **Operation and Maintenance Savings:** Similar to construction savings, taking freeze-thaw effect into pavement design would result in proper pavement design and ultimately less maintenance cost. In addition, the model that will be developed for freeze-thaw cycles and frost depth penetration would aid to determine when load restrictions would be applied and allowed.

- **Decrease Engineering/Administrative Cost:** The proposed model tool will be user friendly which would minimize the engineering cost for pavement foundation design.

2.3. EXPECTED TECHNICAL OUTCOME

The following items below will be provided at the end of this study:

- A database that includes the following data
    - Material Data
        - Material Type
        - General Gradation Characteristics
    - Climate Data
        - Air Temperature
        - Precipitation
        - Wind Speed
        - Relative Humidity (if available)
    - Sensor Data
        - Temperature
        - Water Content
        - Matrix Suction (if available)
- Modelling Tool
    - Prediction of Number of Freeze-Thaw Cycles at Certain Depths
    - Prediction of Frost Depth
    - Prediction of Freeze and Thaw Periods
- Final Report

CHAPTER 3: POTENTIAL IMPLEMENTATION STEPS

3.1. SUMMARY OF RESEARCH METHODOLOGY (SCOPE)

The overall research methodology is proposed by a highly-qualified team with expertise in pavement systems and geotechnical engineering at Michigan State University (MSU) and the Geoengineering Consultant, LLC. The methodology primarily involves collecting field data and conducting modeling to predict frost depth, freeze/thaw cycles. Based on the results of this study it will be determined whether more detailed environmental sensor installation and monitoring is required to develop a more reliable model.

The proposed team has been working on MnDOT data for years and very familiar with the process. This phase of the project contains four tasks: (1) initial memorandum on expected research benefits and potential implementation steps, (2) collection of field data from MnDOT, (3) modeling, and (4) final report.

3.2. IMPLEMENTATION

Implementation of each task is shown below:

- Under Task 2, moisture content, temperature, and matric suction potential data and elastic modulus (if available) and pavement surface conditions (if available). The degree of saturation level (moisture content) is the most influential parameter on pavement design. Therefore, it is very important to collect these parameters properly along with temperature data.

- Under Task 3, a model will be developed and run over a range of conditions, calibrated through adjustments to the model parameters (e.g. moisture, matric suction, temperature). The goal of this task will be to develop a forecasting model that will allow frost depth and timing to be predicted based on input soil, pavement base layer, and weather data.

  Using the measured data (e.g. moisture, temperature, matric suction) as input, the project team will then begin developing and calibrating preliminary computational models for predicting frost depths and freeze/thaw durations/cycles. For greater practical implementation by other states, the forecasting accuracy of the computational models adopted will also be examined using only freely available above-ground weather data from the National Weather Service (e.g., temperature, precipitation, humidity, and wind speed) as inputs.

- Task 4 will provide all results and recommendations and manual about the use of the developed tool.