Project Title: Environmental Impacts on the Performance of Pavement Foundation Layers-Phase 1 (Contract 1035211)

Principal Investigator:
Bora Cetin, Ph.D.
Co-Principal Investigator:
Tuncer Edil, Ph.D., PE
Kristen Cetin, Ph.D., PE

Research Team:
Debrudra Mitra

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SUMMARY REPORT for Q2 for 2020

The research team continues to improve their effort on development and validation of models to predict soil temperature at different depth, at a timestep of 15 minutes and evaluate the number of freeze-thaw cycles at individual depth. Based on the results obtained from the initial modeling effort, data augmentation has been done to improve the input data used for the prediction model. Three different variations of climate variables, i.e. the measured value, daily average value and variation of the actual value with respect to the corresponding daily average were selected as the input variables. *Air temperature*, *relative humidity*, *wind speed*, *rain,* and *net solar radiation* were selected as the climate variables. Time variables were divided in 4 different types, they were *week number*, *month number*, *day of week*, *timestep of day*. The correlated parameters among all the 19 mentioned variables were evaluated and the following 8 variables were selected for the temperature prediction: 1. *Day of Year (1 to 365)*, 2. *Timestep of day (1 to 4*24)*, 3. *Air temperature,* 4. *Solar radiation,* 5.*Variation in air temperature*, 6. *Variation in rain,* 7. *Variation in relative humidity,* and 8. *Variation in wind*.

Two different types of models have been created using these variables. In the first model (Model 1), the soil temperatures of a specific depth were selected as target variables where the data of the year 2018 was used as the training dataset and the data from January 2019 to April 2019 was used to test the performance of the model. In the second model (Model 2), the soil temperatures were predicted as a combination of two different models. The objective of one of the two models was to predict the daily average soil temperature, whereas the other model was used to predict the variation in temperature with respect to the daily average values. For the model of prediction of variation values, previously mentioned variables were used for the data prediction. Day of Year, Timestep, average air temperature, average relative humidity, average wind speed and average rain were used for predicting the daily average values. Fourth order polynomial regression model was used for all the models. Root mean square error (RMSE) were used to evaluate the performance the models. Two different filters have been used during the post processing of the output of the regression models. The objective of the filters was to reduce the variation in predicted temperature from one timestep to the next, by identifying a maximum variation in temperature that can occur across a timestep. For each depth analyzed, the measured temperature data was analyzed across the entire dataset to create a distribution of the change in temperature for each timestep. The temperature variations closer to the surface varied more greatly than those at the deeper depths. These distributions of variation in temperature were used, for each depth, to set an upper and lower filter for the model output. If, in the post processing, the fluctuation across two consecutive timesteps was higher than this variation, the second timestep's temperature value was reduced to the maximum value allowed by the filter. The RMSE values for both the models with and without the filter for all the six locations and several heights are shown in Figure 1.

Figure 1 shows the RMSE values calculated with respect to the measured values for six different depths at all the six test locations on MnRoad test facility. The lesser the RMSE value, the better is the model performance. The results show that the RMSE values for predicting the soil temperature reduces with an increase in depth. The RMSE values for Method 1 are the largest, as compared to the other methods. For 3-inch and 4-inch depth, RMSE values for Model 1 without filtration method was around 8 to 12°C, whereas after implementing both the filters, the RMSE values were reduced to half of the previous value, i.e. around 4 to 6°C. However, the Model 2 had much better prediction where the RMSE values were reduced to within 2 to 4°C. For medium to higher depth, Model 2 with the filtration method also had smaller RMSE values among all the 4 different variations of models for all the depths in all locations. For higher depths, the minimum RMSE values were around 2 to 1°C for 18.5-, 48-inch depth whereas it was less than 1°C for 72-inch depth. These results represented that the combination of the two models, prediction of the daily average values and variation with respect to the daily average values with both the filters had the best performance for temperature prediction among all the models implemented until now.

The variation in the number of freeze-thaw cycles has also been calculated for all the depths and all locations (Figure 2). Figure 2 depicts that for shallow sensors, i.e. for 3- and 4-inch Model 1 with the filtration method had better performance compared to the other models. On the other hand, for higher depths, the result of freeze-thaw cycles obtained from Model 2 with the filters were closer to the actual values compared to the other models. Thus, two different models can be used for the prediction of the number of freeze-thaw cycles, Model 1 with filters for lower depth and Model 2 with filters for higher depth. However, all the models were still overestimate the number of freeze-thaw cycles. Moving forward, a few different variations of models will be calculated. Soil temperatures at different depth will be combined to create a single prediction model and include depth of the soil as an input variable to the model.

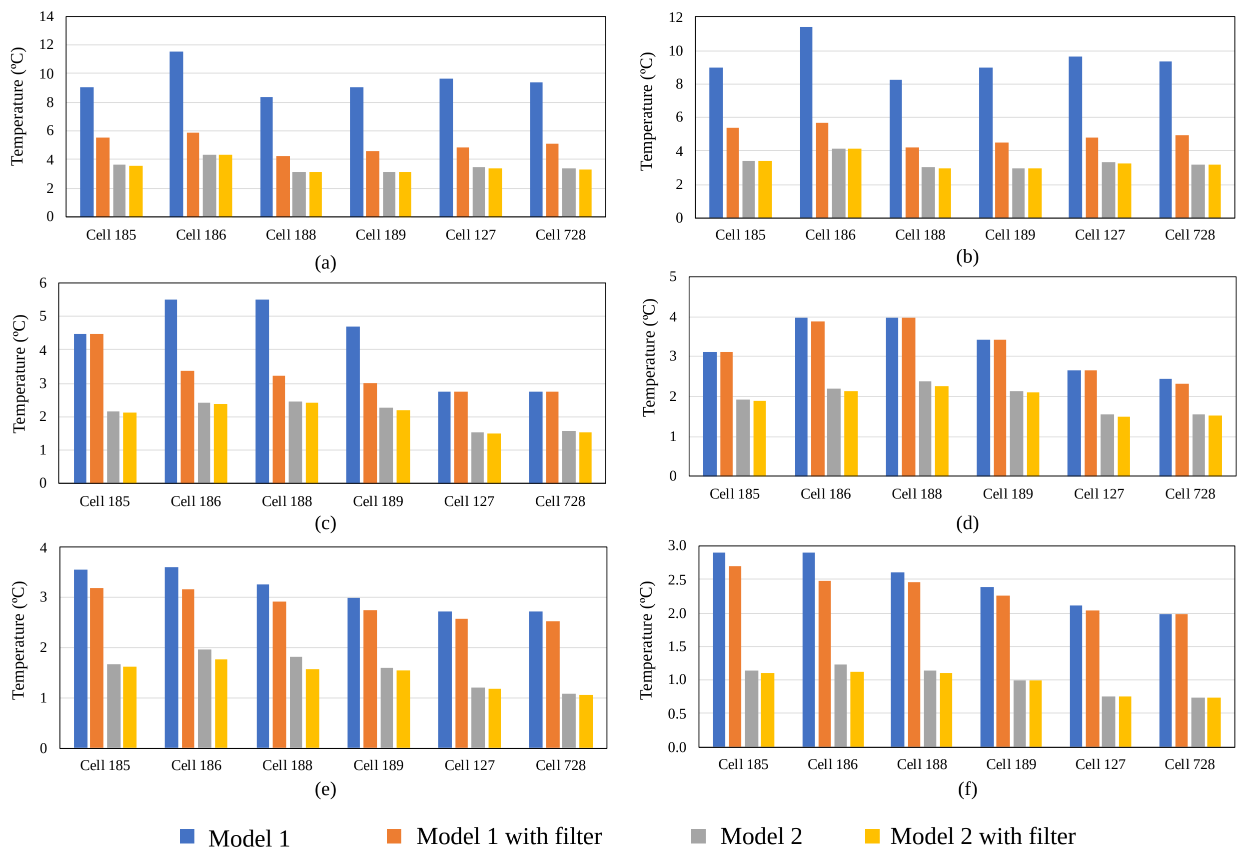

Figure 1. RMSE values for the depth of (a) 3 inch, (b) 4 inch, (c) 18.5 inch, (d) 24 inch, (e) 48 inch and (f) 72 inch in all the locations

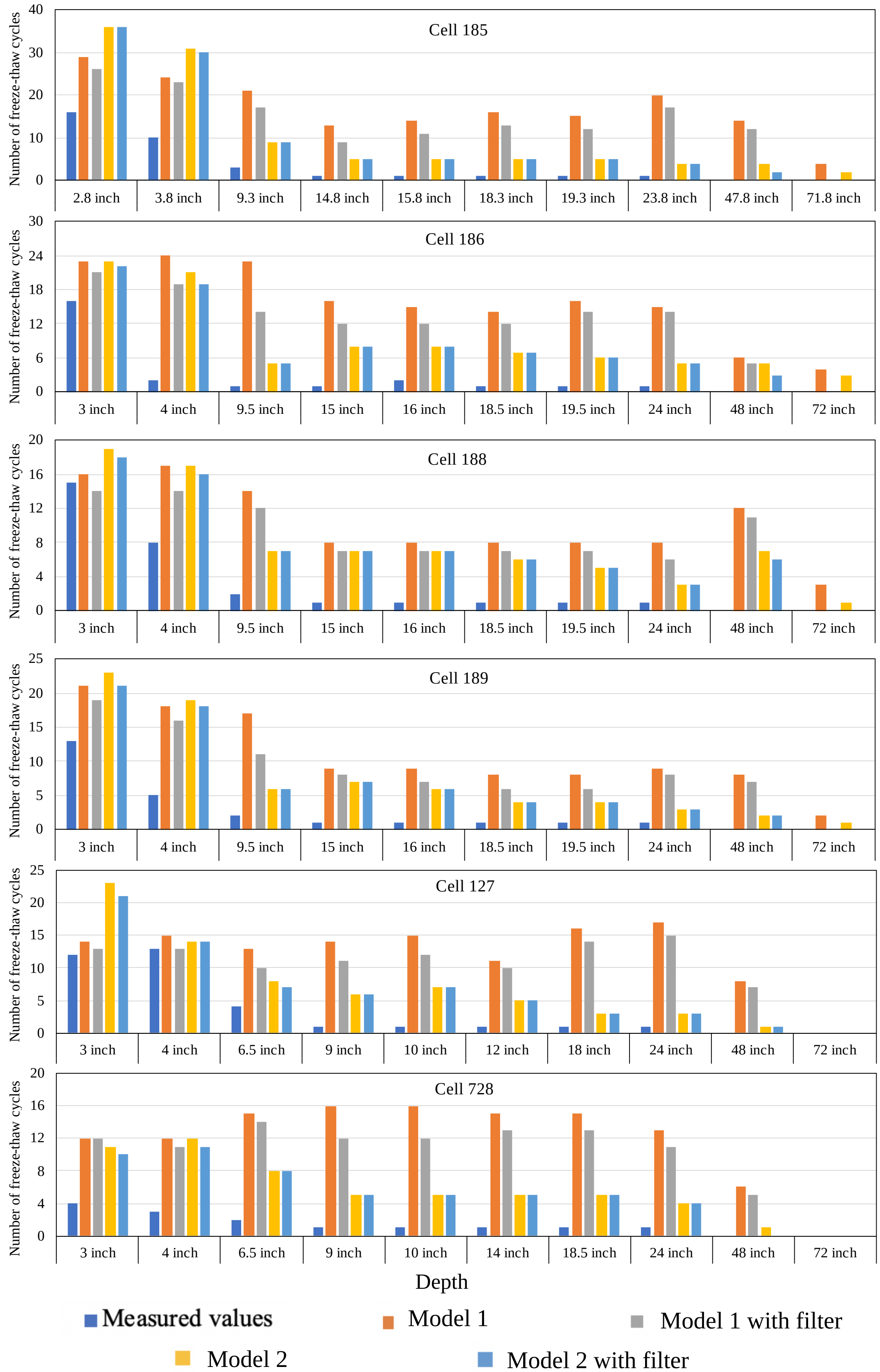

Figure 2. Number of freeze-thaw cycles at all the depths in six test cell locations