CSCI 490 Capstone Pitch Talk

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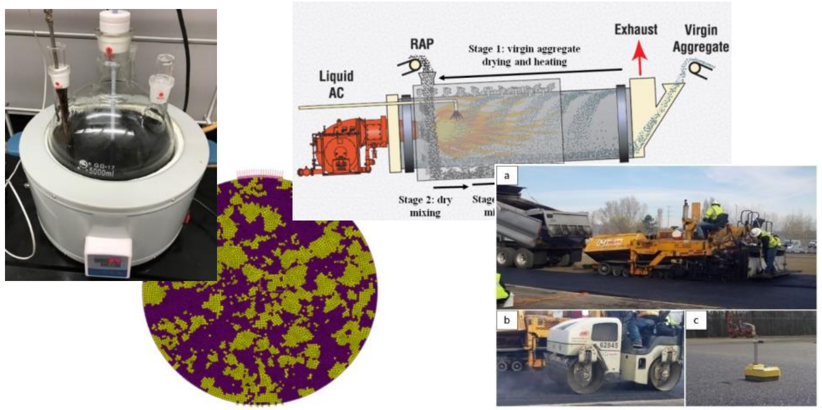
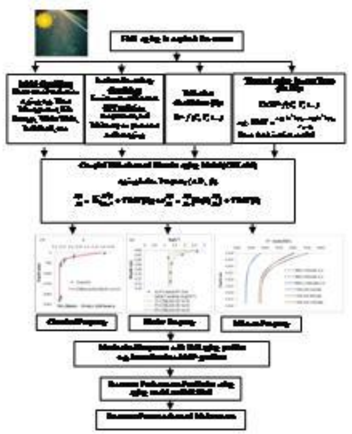
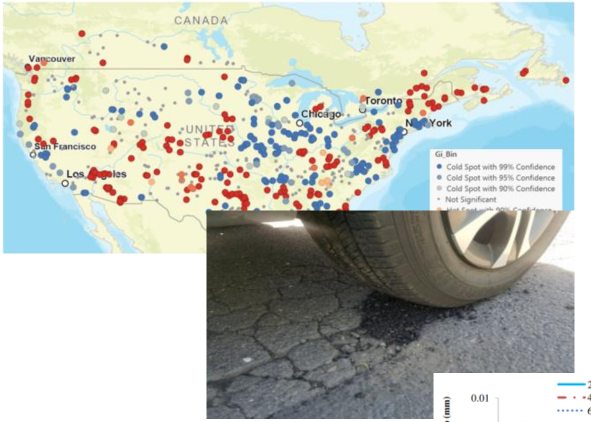
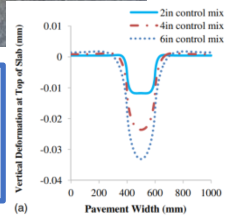
Research Goal: Sustainable and Resilient Pavement Infrastructure



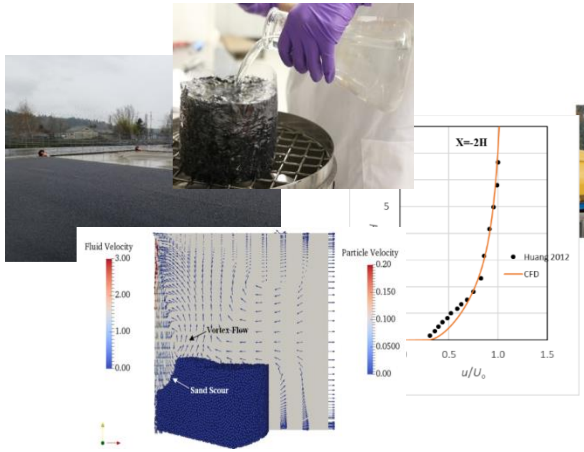






Materials R&D → Production → In-Service Performance Evaluation → Preservation and Maintenance → Rehabilitation and Recycling → Materials R&D

Journals: 27
Conf.: 10
Presentation: 36



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Project 1: GUI for Pavement Temperature and Aging Analysis for Pavement Design

- Temperature is one of the critical environmental factors causing pavement distresses

- Rutting
  - Plastic Flow
  - Softer mixture
  - High-temp. (Summer)

- Bottom-up fatigue cracking (Alligator Cracking)
  - Thin pavement
  - Brittle mixture
  - Intermediate temp. (Spring & Fall)

- Transverse (thermal) cracking
  - Interval between 8-10m
  - Stiffer mixture
  - Low temp. (winter)

Model Development

- Follow the work done by Han et al. 2011 and Alavi et al. 2013 with modifications
  - To introduce and calibrate a seasonal variable ($\Delta\varepsilon = \varepsilon_a - \varepsilon$); and
  - Revise the thermal diffusivity between layers
- Governing PDE for heat transfer:

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(\alpha \frac{\partial T}{\partial z}\right)$$

Modeling Pavement Temperature for Use in Binder Oxidation Models and Pavement Performance Prediction

Rongbin Han[1]; Xin Jin[2]; and Charles J. Glover, Ph.D., P.E.[3]

Prediction of Asphalt Pavement Temperature Profile with Finite Control Volume Method

Mohammad Z. Alavi, Mohammad R. Pouranian, and Elie Y. Hajj

Model Development

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  - To introduce and calibrate a seasonal variable ($\Delta\varepsilon = \varepsilon_a - \varepsilon$); and
  - Revise the thermal diffusivity between layers

$$\alpha_n = \frac{2\alpha_N \alpha_P}{\alpha_N + \alpha_P}$$

Prediction of Asphalt Pavement Temperature Profile with Finite Control Volume Method

Mohammad Z. Alavi, Mohammad R. Pouranian, and Elie Y. Hajj

- Governing PDE: $$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(\alpha \frac{\partial T}{\partial z}\right)$$
- Integrate PDE over time and control volume

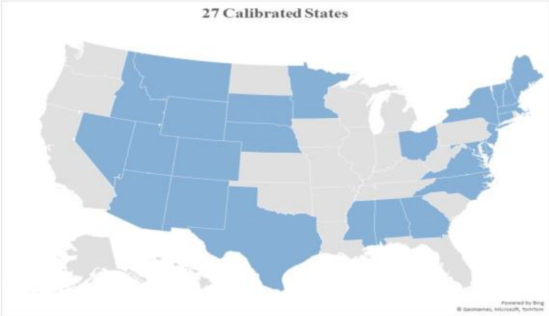
$$\int_n^s \int_t^{t+\Delta t} \frac{\partial T}{\partial t} dt dz = \int_t^{t+\Delta t} \int_n^s \alpha \frac{\partial}{\partial z}\left(\frac{\partial T}{\partial z}\right) dz dt$$

- Discretized equation with a fully implicit scheme

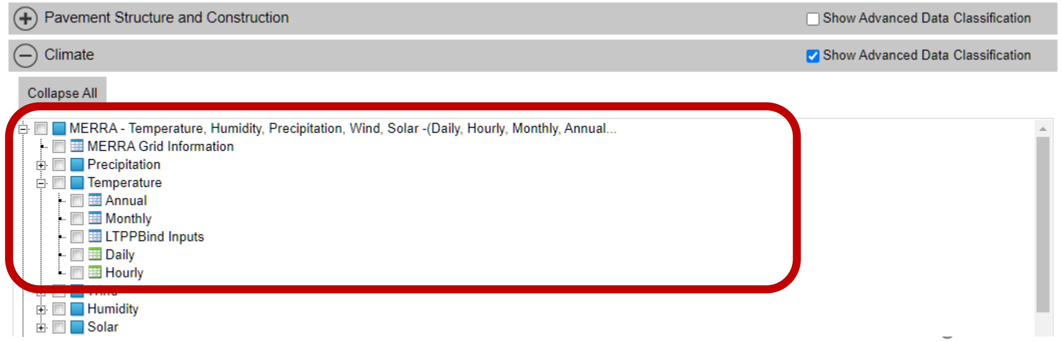
$$T_P^1 \left(\frac{\Delta z}{\Delta t} + \frac{\alpha}{dz} + \frac{\alpha}{dz}\right) = \frac{\alpha}{dz} T_S^1 + \frac{\alpha}{dz} T_N^1 + T_P^0 \frac{\Delta z}{\Delta t}$$

- The discretized equation is solved using the TriDiagonal-Matrix Algorithm (TDMA)

Data Collection

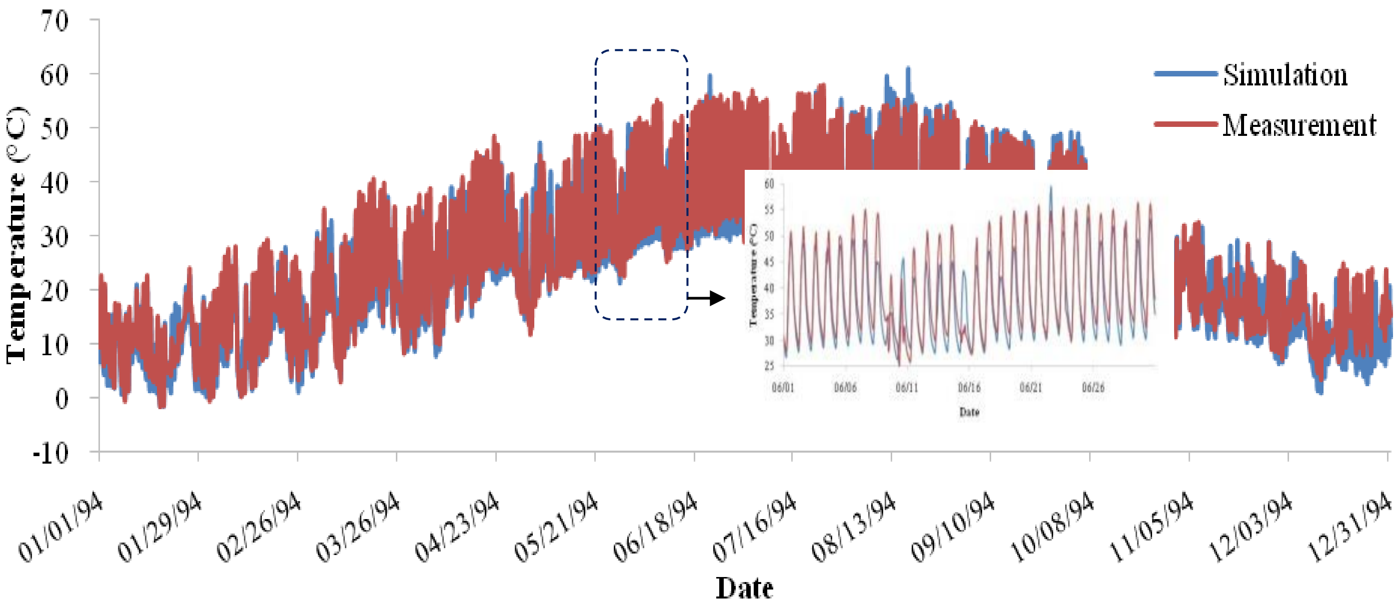


- Hourly pavement temperatures from the Seasonal Monitoring Program (SMP) in the Long Term Pavement Performance (LTPP) database.
  - A total of **49 asphalt pavement sections** located in **27 states** in the U.S
  - One LTPP section in each state was used to **calibrate** Δε_1 and Δε_6
  - If more than one LTPP section was monitored in a state, the rest of the pavement sections were used for **validation**
- Hourly climatic data from the LTPP InfoPave
  - MERRA-2: Modern-Era Retrospective Analysis for Research and Applications
  - Air Temperature, Wind Speed, and Solar



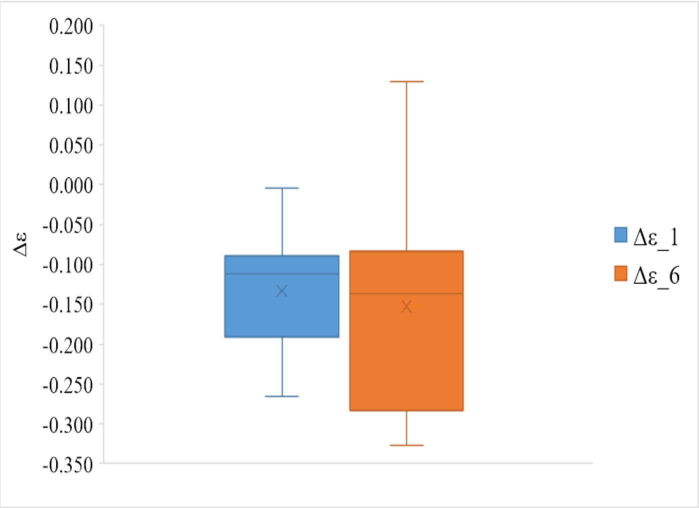
Results

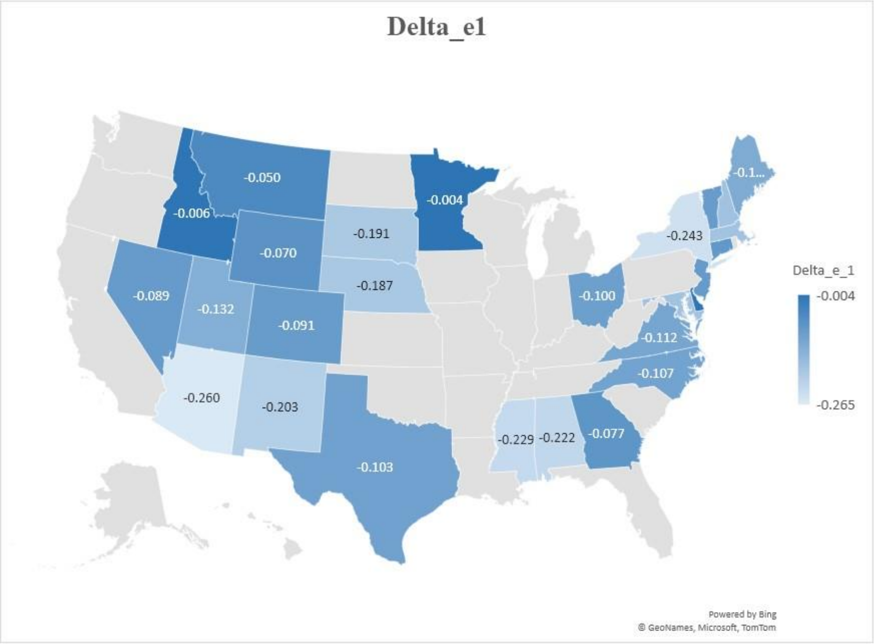
- LTPP Section 48-1068 in Texas
  - Calibrated Δε_1 = -0.103 and Δε_6 = 0.004
  - This work: MAE= 2.263°C (@25mm), 1.913°C (@128mm), and 1.722°C (@232mm)
  - Han et al. 2011: MAE = 2.4°C, 2.0°C, and 2.2°C at 25mm, 128mm, and 232mm, resp.
  - Omairey et al. 2022: MAE = 4.01°C @ 25mm

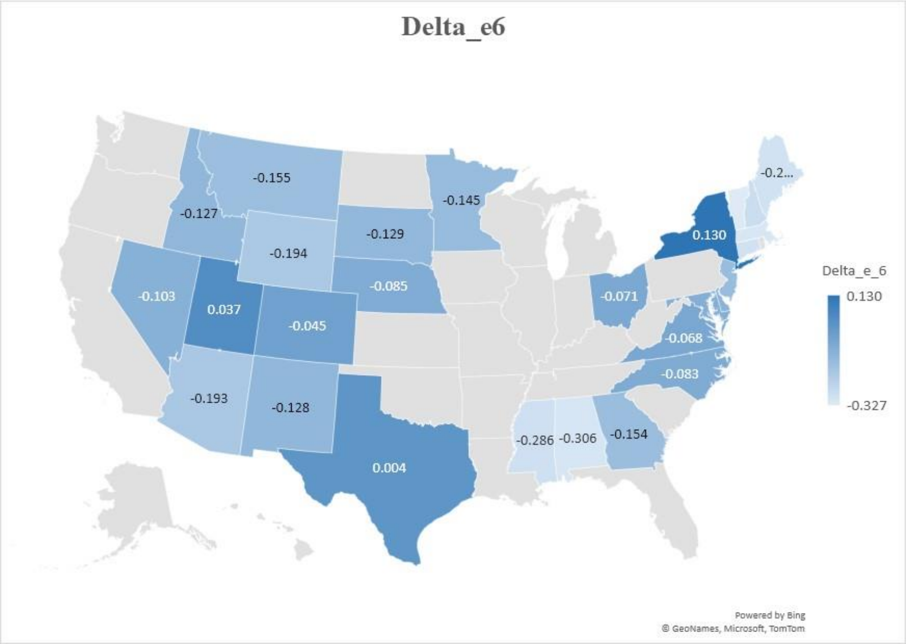


Results

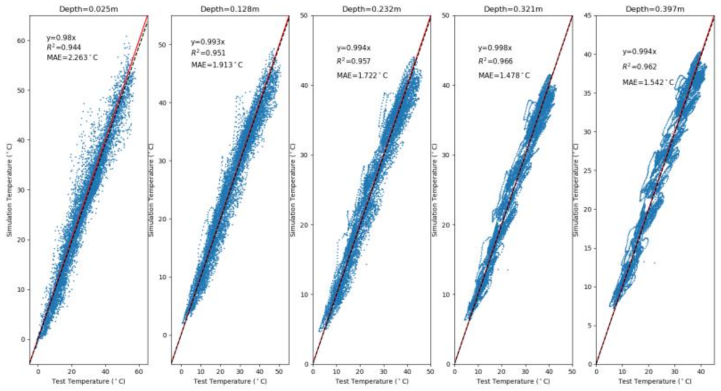
- Calibrated $\Delta\varepsilon_1$ and $\Delta\varepsilon_6$ for 27 states
  - $\Delta\varepsilon_1$: -0.265 to -0.004
  - $\Delta\varepsilon_6$: -0.327 to 0.130
    - New York ($\Delta\varepsilon_6$ = 0.130), Texas ($\Delta\varepsilon_6$ = 0.004), Utah ($\Delta\varepsilon_6$ = 0.037)

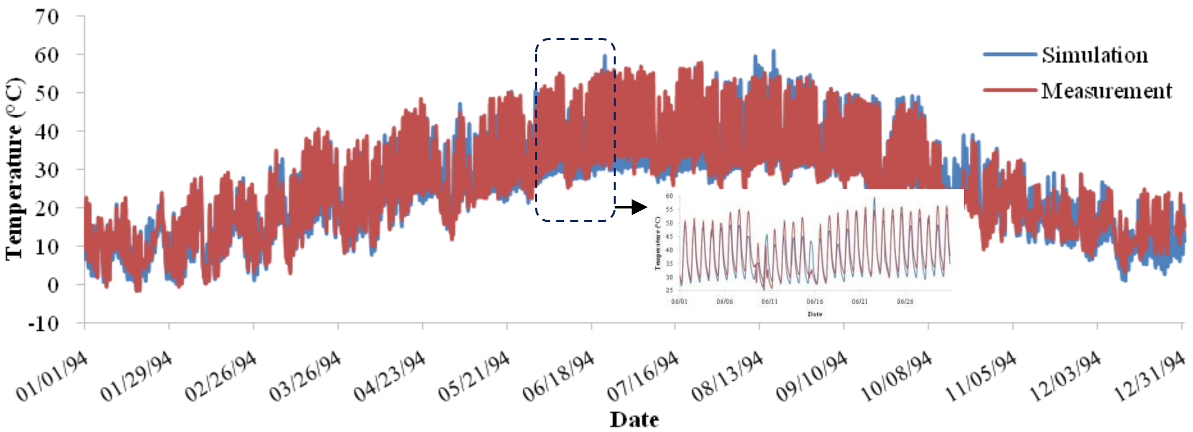






- Existing software
  - Developed by UNR and only be compatible with Windows XP system
- Work has been done in my team
  - Python-based Program for Pavement Temperature Analysis Using Finite Volume Method
  - Calibrate seasonal parameters for 27 States
- Potential Users and Customers
  - State/County/City Transportation Agencies for Pavement Design
  - Researchers/Engineers design the flexible pavement
- Needs
  - Improve computational efficiency
  - GUI to import environmental files and export/plot results





TEMPY-Code

```
### This code is used to calculate temperature field of asphalt pavement ###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import openpyxl as xl
import math
import numpy
import matplotlib.pyplot as plt
#from scipy import stats
from sklearn.linear_model import LinearRegression
import pandas as pd
from datetime import datetime

Section_ID = '31'
Thermo_depth = [0.012, 0.024, 0.052, 0.064, 0.076, 0.088, 0.101, 0.152, 0.305, 0.457] # reserve for 10 thermocouples

# Define Pavement Thickness, unit meters; # 48-1068: 0.278; 0.152; 0.203;
thickness_AC = 0.102
thickness_Base = 0.076
thickness_subbase = 0.305
thickness_subgrade = 3 - thickness_AC - thickness_Base - thickness_subbase  # Total thickness = 3 meters

file_path = r"C:\wrdapp\Tempy\MnROAD"
row_correction = 0  # shift peak of test to match the peak of simulation, default = 0

# delt_e = e_a - e_AC, difference between absorption and emission of pavement surface, negative value, seasonal adjustment
delta_e_1 = .10598863558982 #-0.15  # winter time value in Jan and Dec # default = -0.15
delta_e_6 = .02147073036731 #-0.12  # summer time value in June and July # default = -0.05

post_process = 'False' # run postprocess or not, True or False
Ucode = 'True' # this is used to run the sensitivity analysis for delta_e_1 and delta_e_6

# constants used in the simulation, e.g. density (rho) of pavement
rho_AC = 2450  # density kg/m3; value from Omairey et al. 2021, this can be found from LTPP
rho_base = 2350
rho_subbase = 2350
rho_subgrade = 2200
rho_water = 1000
```

Project 2: Pothole Volume Detection using 3D Camera

- **Potholes**
  - **Bumping** driving with **safety concerns**
  - AAA reported $26.5 Billion for vehicle repairs due to potholes
  - My team has developed waste cooking oil based cold mix for pothole patching
- One of the issues is “Crews don’t know how much patching material to throw”
  - Pothole Volume is unknown

- Commercial software
  - GPC Highway Measure App
  - https://gpcsl.com/highways-highway-measure/
  - https://www.mobileworxs.com/solutions/3d-pothole-measurement/
  - Not accurate
- Previous Capstone Project done by Dalton Bailey (Fall 22)
  - Intel-Realsense 3D camera;
  - XX.ply files

Github

- https://github.com/Yalton/CSCI_Capstone
- QuadP
  - Software designed to scan potholes and calculate volume
  - Software will automatically establish reference plane and calculate volume of all spaces beneath plane
  - Using the calculated volume and density provided by user mass of required material can be calculated
  - Software is entirely written in python using as few libraries as possible
- Need to improve integration method for volume calculation!!!

Database

- 31 potholes
- Actual volume measured based on sand fill method