Engineered Water Repellent Soils: Moisture Control in Pavement Systems

Micheal Abiodun Uduebor
Ph.D. Candidate, Civil, and Environmental Engineering
UNC Charlotte | muduebor@uncc.edu

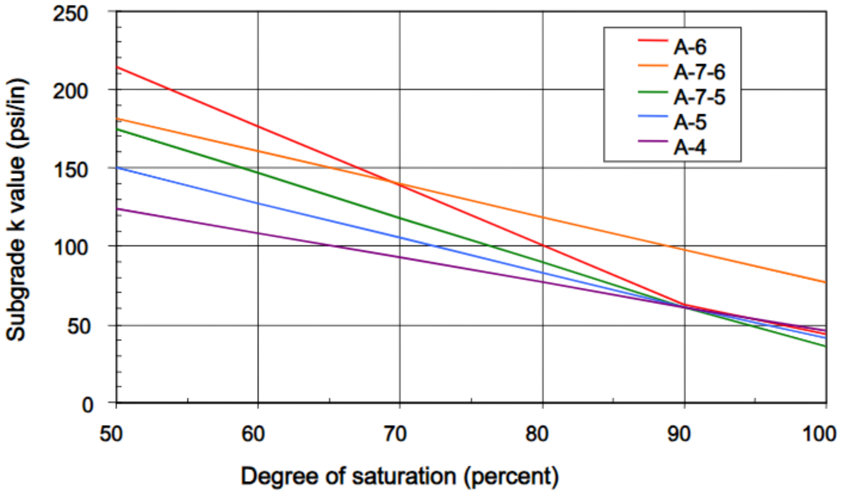
Introduction

Moisture-related pavement distress and damage

- **Moisture-related distresses** account for approximately **50% to 90%** of all pavement distresses, depending on the pavement type and environmental conditions. (NCHRP, Report 840)

https://www.nap.edu/catalog/25537/simplified-procedures-for-design-of-hot-mix-aspalt-overlays-nchrp-report-840

Introduction



Effect of Degree of Saturation on Subgrade K Value

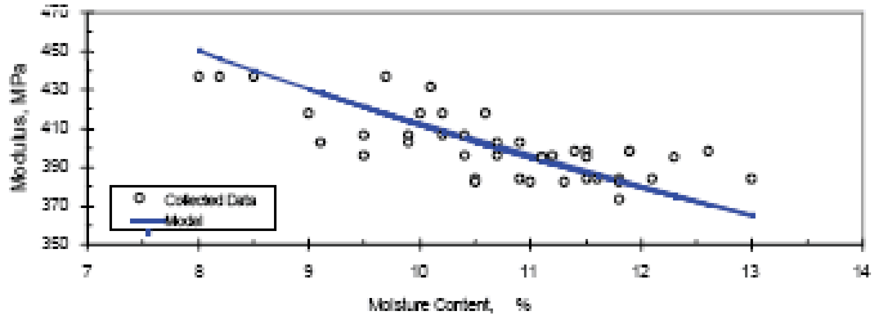


Figure 11. Backcalculated modulus vs. moisture content for fine sandy clay soil, site 13-1005

Effect Of Seasonal Moisture Variation On Subgrade Resilient Modulus (Salem, 2005)

- **Excessive moisture** in unbound pavement materials (subgrade) results in **loss of strength** and large **irrecoverable deformations** under applied stress

Introduction

Airport Taxiway – Charlotte Douglas International Airport, NC

Moisture-related pavement distress and damage

- This results in pavement **deterioration** and **damage** (weakened subgrade and subbase, pumping, etc.) especially in pavements that are subject to **large and impact loadings.**

Introduction

Total spending on maintenance and rehabilitation in the United States was **$67.9billion** in 2020 representing approximately **16.2%** of total spending on highways and roads (FHWA, 2020)

https://www.fhwa.dot.gov/policyinformation/statistics/2020/

Introduction

Road construction and maintenance activities contribute **5-25%** of the total **CO_2 emissions** from the transport sector (EU-C, 2019)

https://ec.Europa.eu/transport/facts-fundings/statistics/pocketbook-2019_en

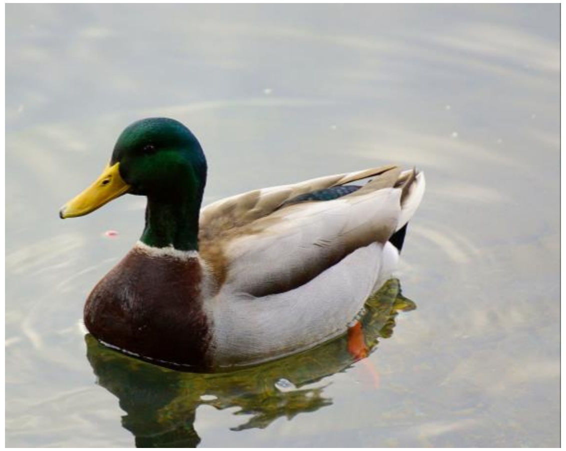
Introduction

Remedial techniques for moisture control in pavement soils

- Different methods for improving pavement subgrade include
  - Geosynthetics (geomembrane or wick)
  - Replacing in-situ material
  - Chemical stabilization

- **Limitations** include specialized know-how, significant haulage distance, high cost, heavy machinery requirement, labor intensity, reduced efficiency over time, and leaching effect

Engineered Water Repellency (EWR)



Water Repellency in Nature

Water Repellency in Everyday Use

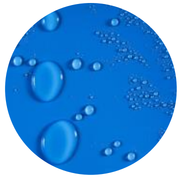
Water permeates the untreated soil in the left beaker, while water in the right beaker stays on top of the OS treated soil.

Images: Dr. John Daniels Lab

Engineered Water Repellency (EWR)

Organosilane Selection Considerations

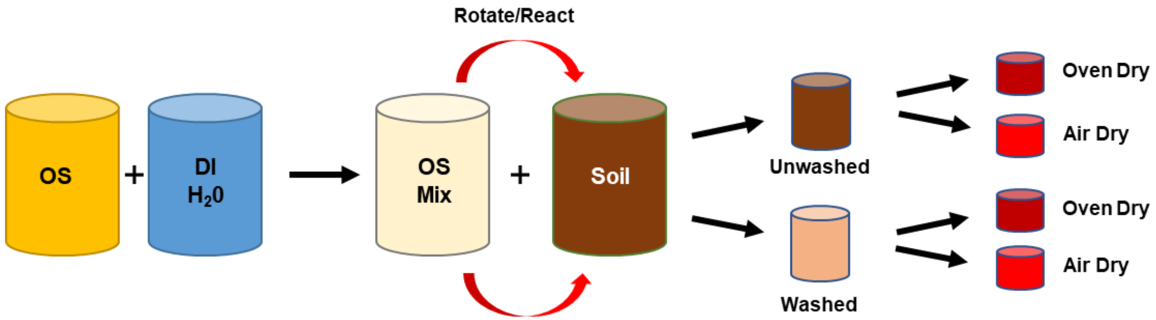
Environmental safety

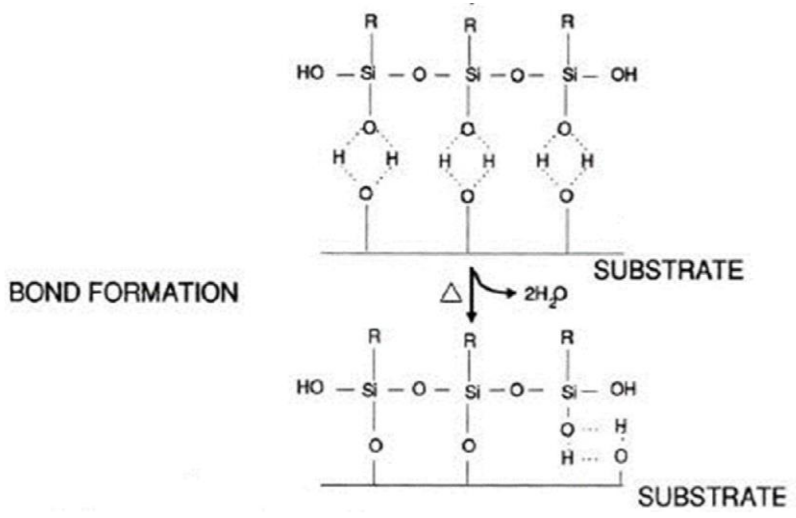


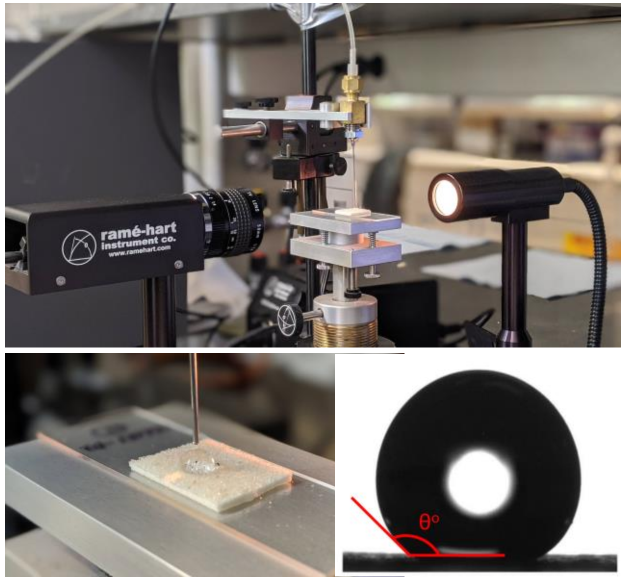
Effectiveness

Cost

Other considerations





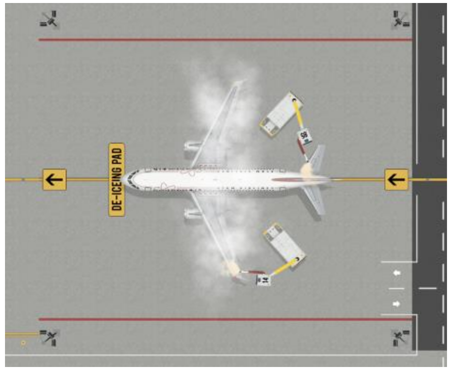


Contact Angle test for hydrophobicity assessment

- By engineering water repellency in soils, **moisture conditions** can be kept **uniform and controlled**, saving construction and maintenance costs

Airport Deicing Pad/Taxi Lanes – Charlotte, NC

CLT CHARLOTTE DOUGLAS INTERNATIONAL AIRPORT

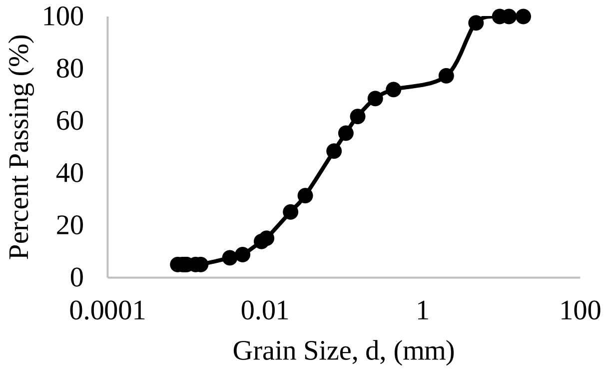


Deicing Operations in an airport

Site for Deicing pad & Taxi Lane – Charlotte Douglas International Airport, NC

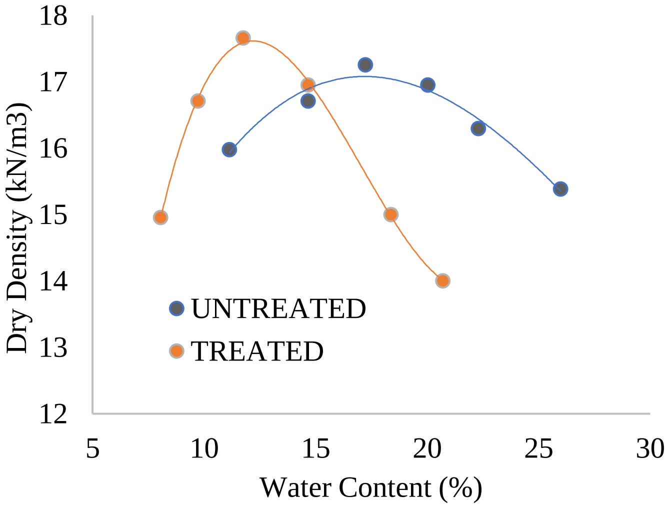
- No. 7 in the U.S. and the world for air traffic – ACI 2022 Rankings
- Second-largest hub for American Airlines
- Constructing a **de-icing pad** and **taxi lanes** to reduce airplane delays

Test Methodology

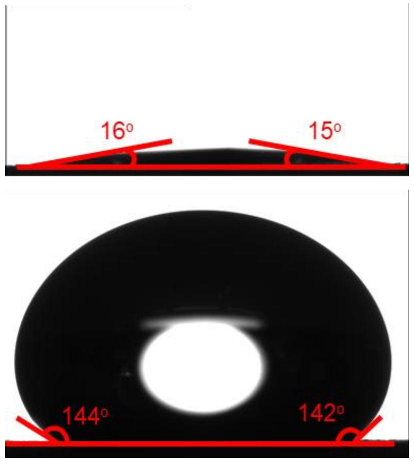


Grain size distribution of Airport Soil

Water "beads" on the treated surface



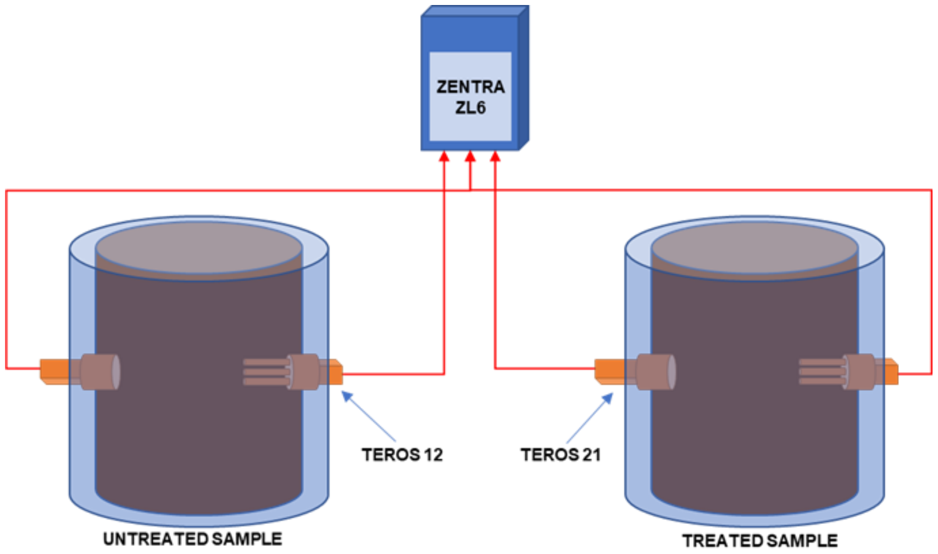
Compaction curves of untreated and treated soil



Contact angle of untreated and treated soil sample

- Subgrade soil was classified as Silty/Clayey Sands, SM/SC (USCS), and A-6(2) (AASHTO) and subject to large moisture contents due to high water table and capillary forces
- Soils were treated with compatible Organosilanes (1:40, OS:Soil)
- Water repellency was assessed using Contact Angle, Water Drop Penetration Time, and Breakthrough Head tests

Test Methodology



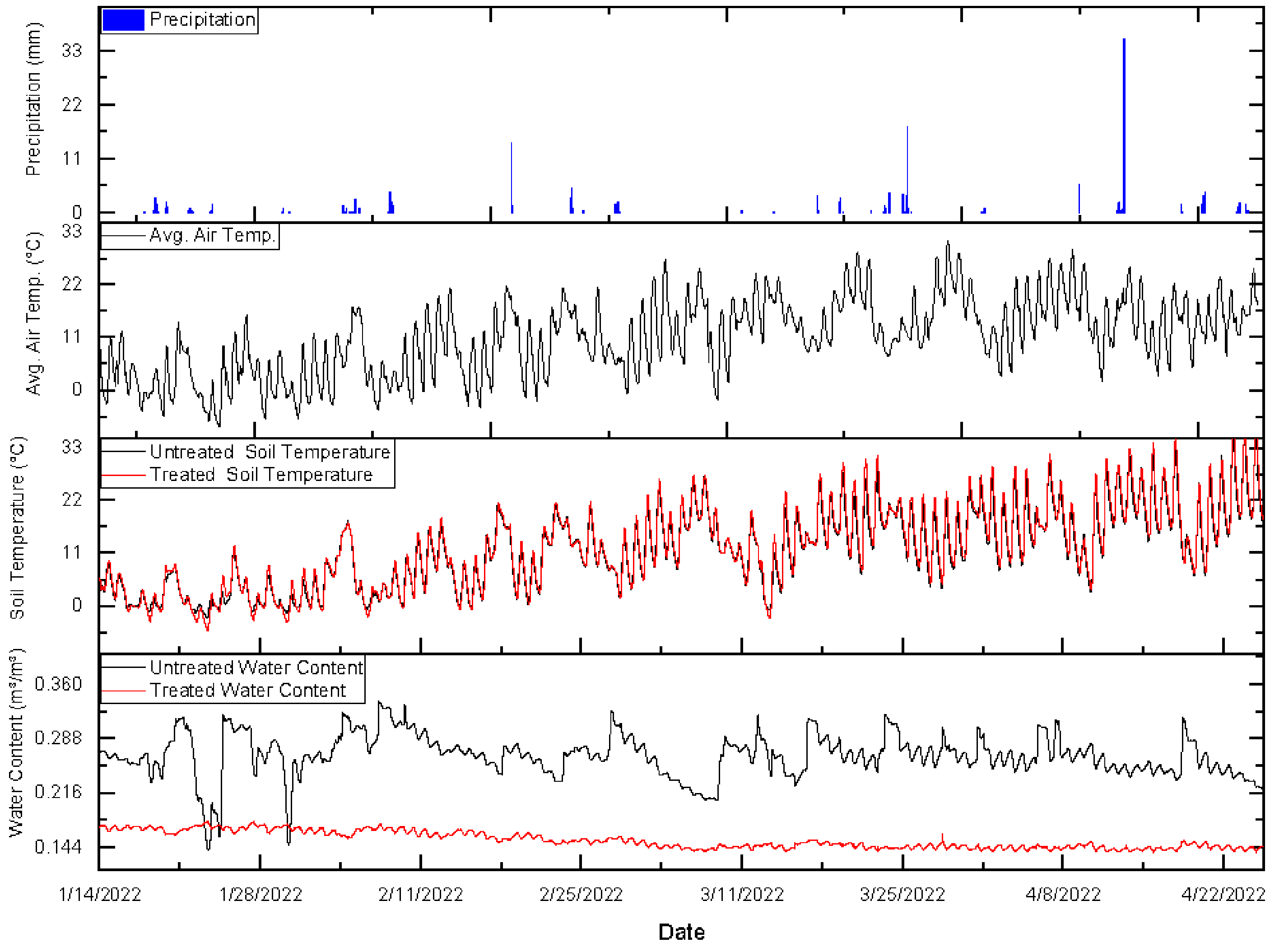
Schematic of the performance test setup

Teros 21, Teros 12 sensors and Zentra ZL6 Datalogger

- Test samples and sites were instrumented to monitor precipitation, air/soil temperature, moisture change (Teros 12), matric suction (Teros 21) and settlement (Shape Arrays) within both treated and untreated sections

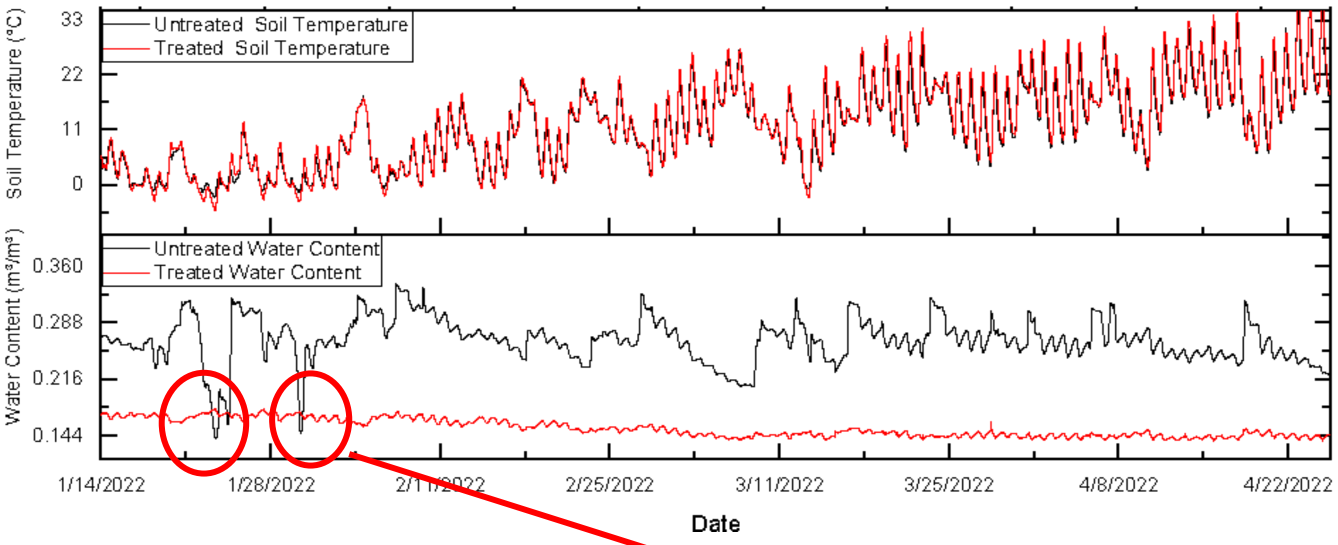
- The setup was exposed to field conditions over a period of three months (January – April 2022) with readings logged on the Zentra L6

Airport Deicing Pad – Charlotte, NC



- EWR was effective in limiting the infiltration and migration of water into the soil matrix when compared with the untreated soil.
- Improved strength and subgrade modulus due to retained unsaturated condition
- Moisture condition is maintained at a constant, preventing large volume changes due to shrink-swell

Airport Deicing Pad – Charlotte, NC



No heave due to frost action

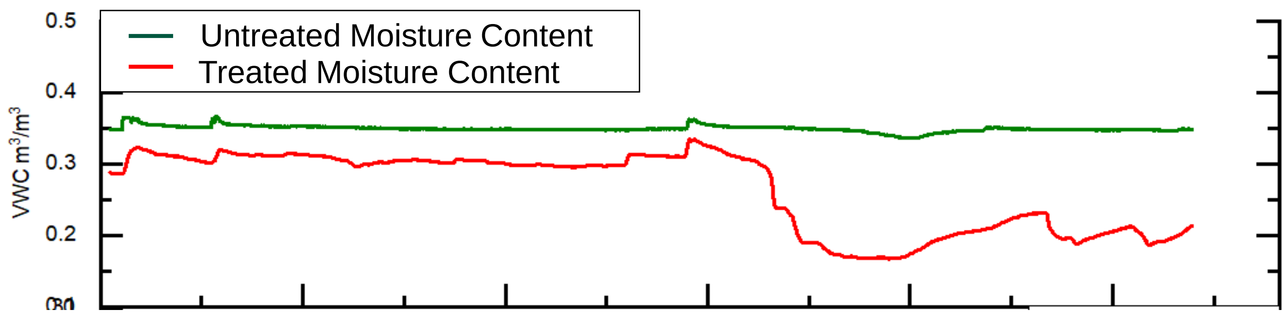
Measured heaving of ~6mm

- There were two winter storm events (Jan 20-23, 29-30) during the period, which provided a good opportunity for observing the performance of the samples under sub-freezing conditions.'
- EWR treatment inhibited capillary action mitigating frost heaving, a seasonal cause of pavement failure in cold regions

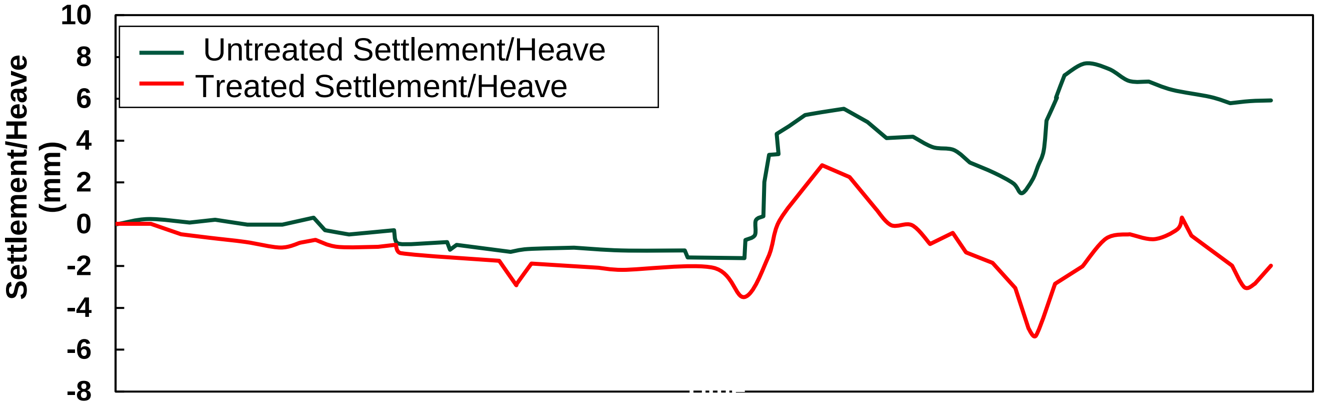
Low Volume Road – Keokuk, Iowa

Water “beads” on treated surface

Low Volume Road – Keokuk, Iowa



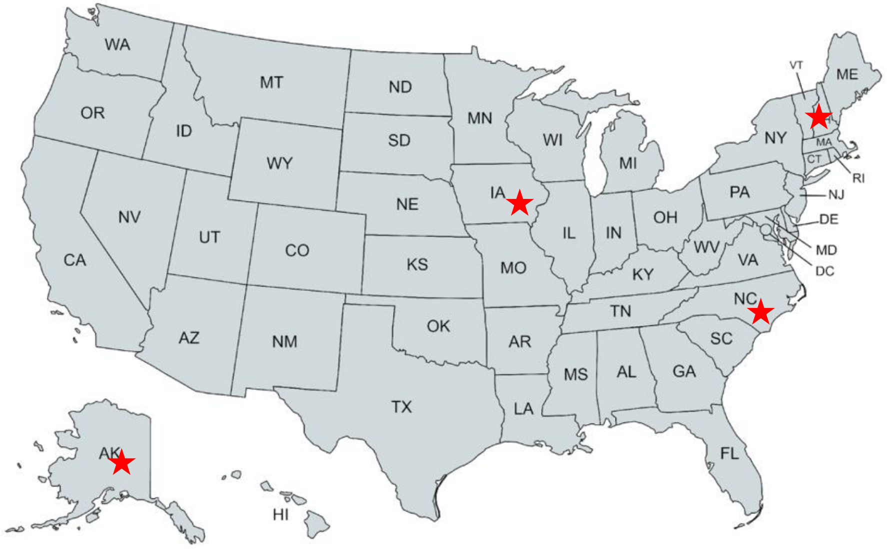
Treated soil has lower water content and gets drier over time



Treated soil has lower frost action (heave) during winter months

- EWR was effective in limiting the infiltration and migration of water into the soil matrix when compared with the untreated soil.
- EWR treatment also inhibited capillary action mitigating frost heaving, a seasonal cause of pavement failure in cold regions

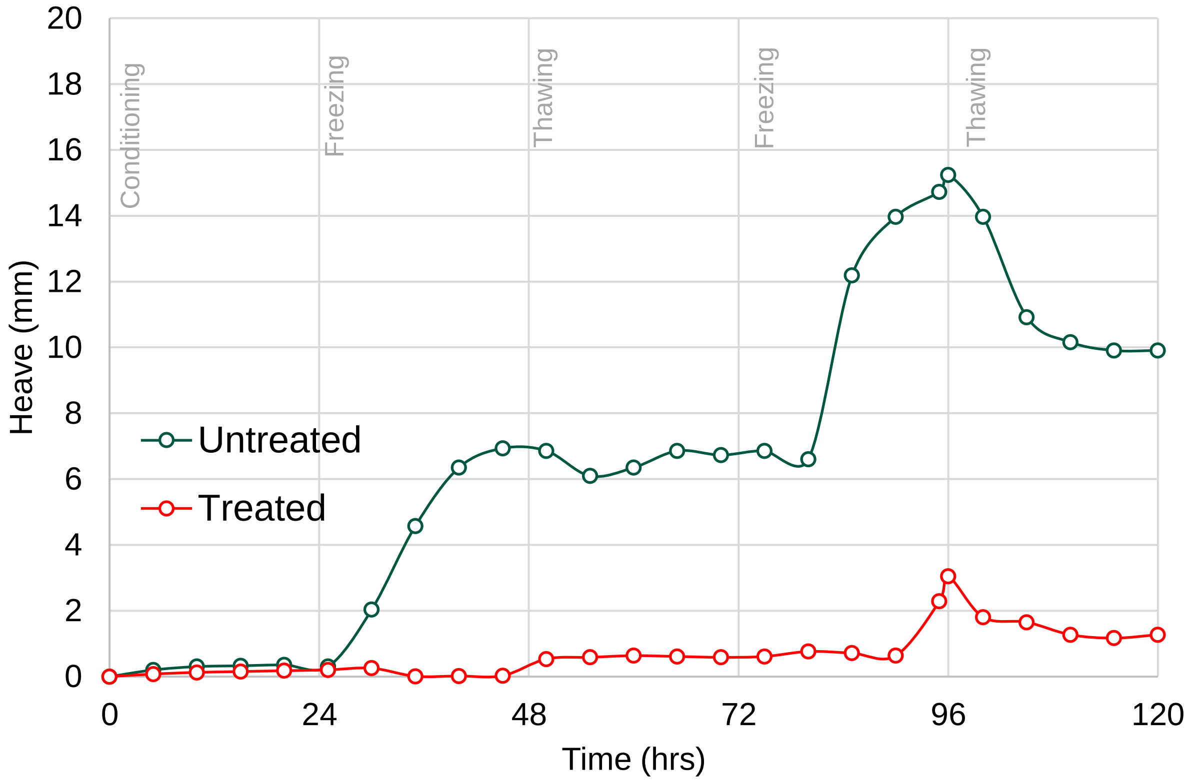
Other Test Sites – Frost Heave Mitigation



★ **Material Collection Sites**

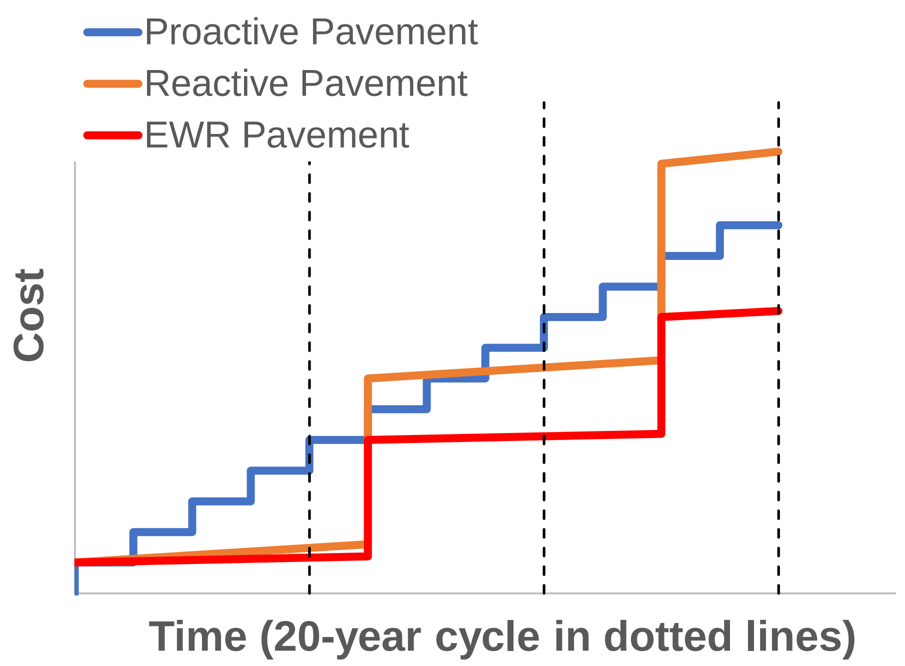
Fairbanks, Alaska
Pottawattamie, Iowa
Asheville, North Carolina
Boone, North Carolina
Hanover, New Hampshire

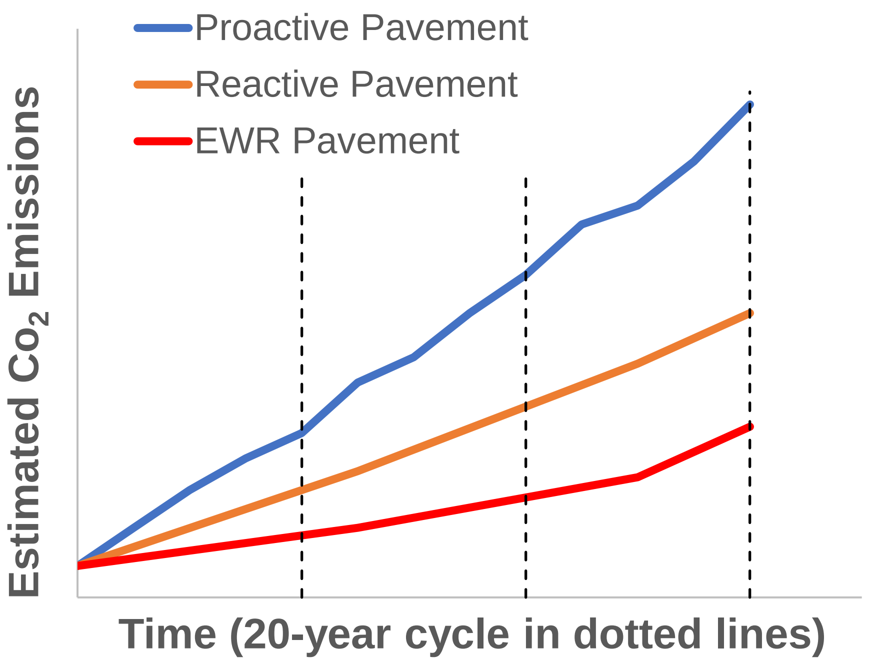
FROST HEAVE TESTS



EWR treatment is effective in mitigating frost action

CO_2 Emission & Maintenance Cost Reduction with EWR



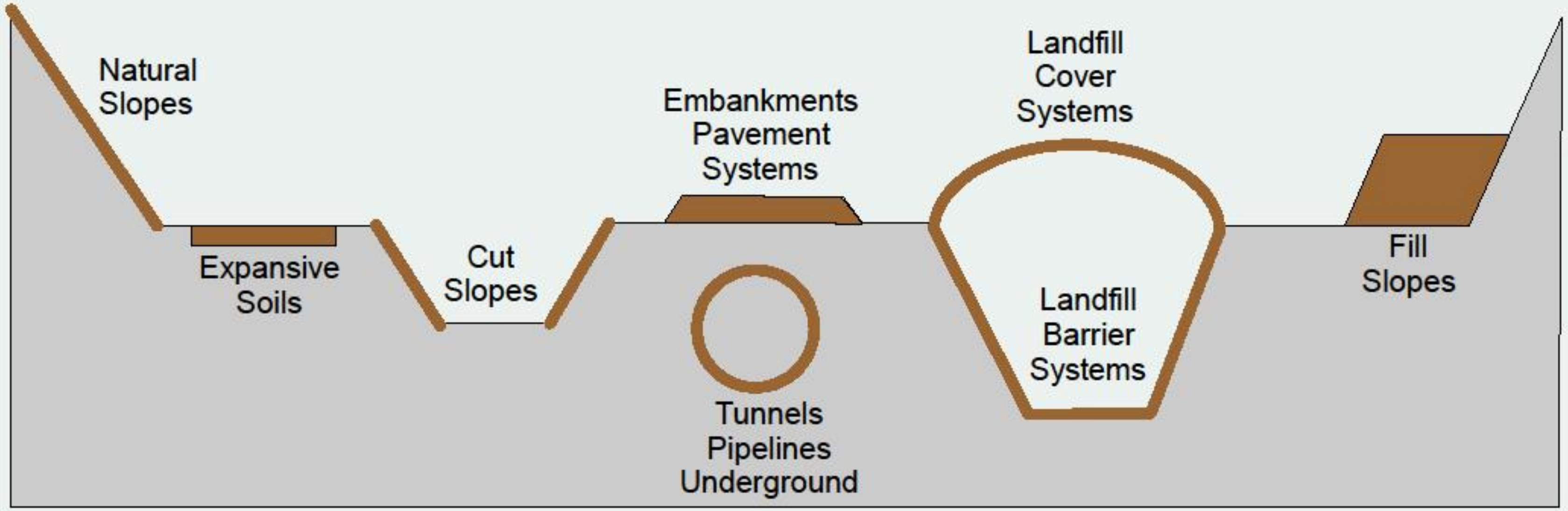


- Treated pavement soils result in a **23.3% to 36.1%** reduction in construction and maintenance costs when compared to proactive and reactive options respectively.
- There is a **65.4% to 40%** reduction in CO_2 emission from treated roads when compared to proactive and reactive options respectively

Pavement Test Track (Low Volume- Bound)

Engineered Water Repellency (EWR)

- Water repellent soils have potential for application in a wide range of civil engineering applications. There are two major advantages of water repellent soils over conventional materials: 1) inhibiting water permeation while remaining gas permeable, 2) the level of water repellency can be manipulated under various situations.



Conclusions

- Better pavement performance due to EWR treatment
- EWR is a viable solution for managing moisture conditions in pavement soils.
- EWR is an environmentally responsible solution for engineers and designers requiring innovative technologies for pavement design, particularly in cold regions.
- Reduction in maintenance and extended life span of pavement results in lower CO_2 emissions

Thank you!

More Information @ www.danielslab.org

The Daniels Lab (L-R): Mike, Dr. Saulick, Adams, Prof. Daniels, Emmanuel & Mackenzie

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