NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Advancing Unpaved Roads and Airfields Through Graduate Research

September 29, 2025

2:00PM – 3:30 PM

Learning Objectives

At the end of this webinar, you will be able to:

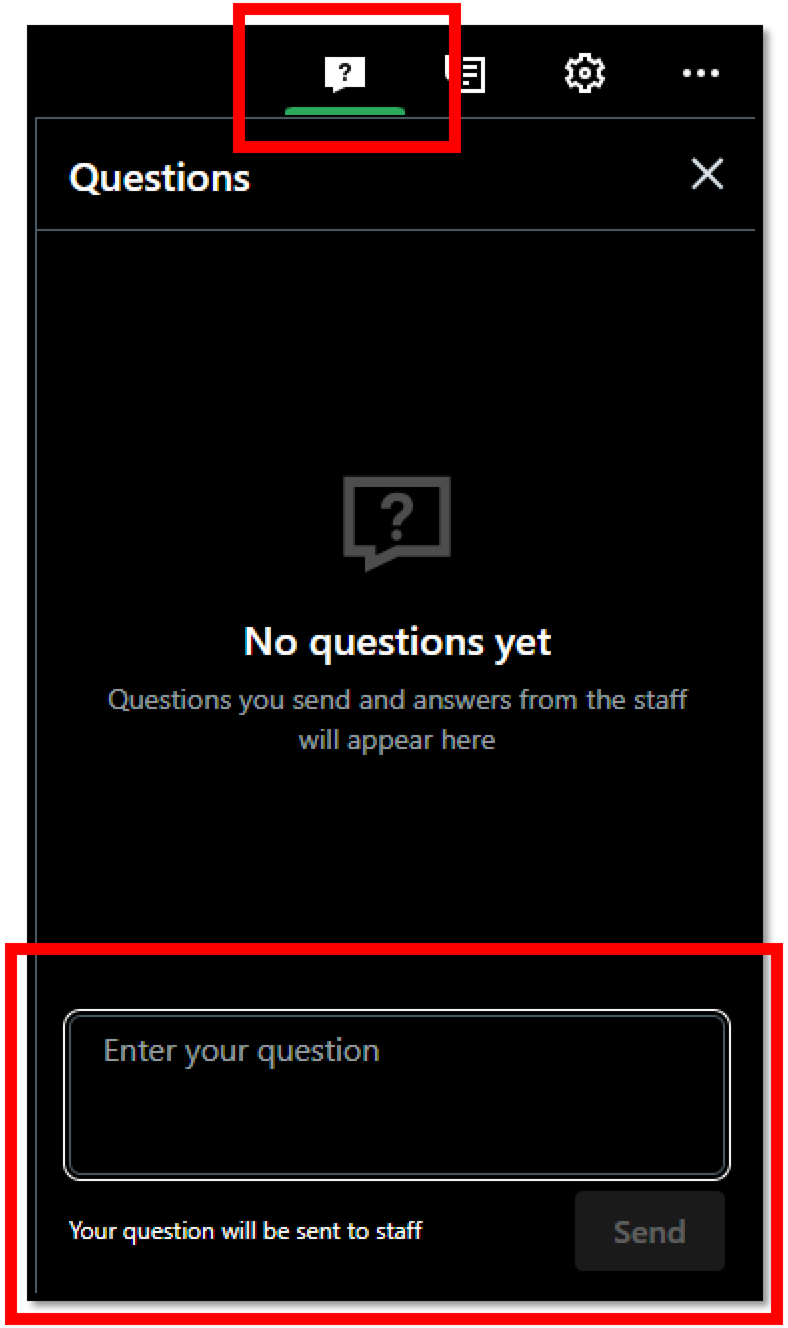
(1) Incorporate risk assessment principles into the structural analysis of unpaved roads

(2) Use geosynthetic products to improve the bearing capacity of unpaved roads

(3) Improve the structural performance of unpaved roads via chemical stabilization

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

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NATIONAL ACADEMIES *Sciences Engineering Medicine*

Design of unpaved roads based on risk assessment

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Director, Assistant Professor
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Ville de Québec
FPInnovations
CEN
Hydro Québec
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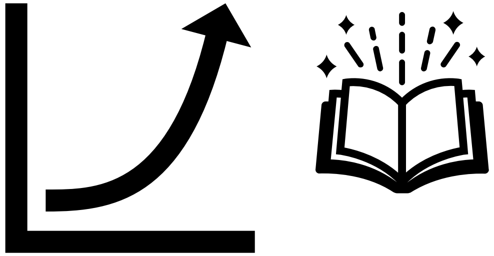
E4M Centre de recherche sur la géologie et l'ingénierie des ressources minérales
Sentinelle Nord
Chaire de recherche Sentinelle Nord sur les infrastructures nordiques

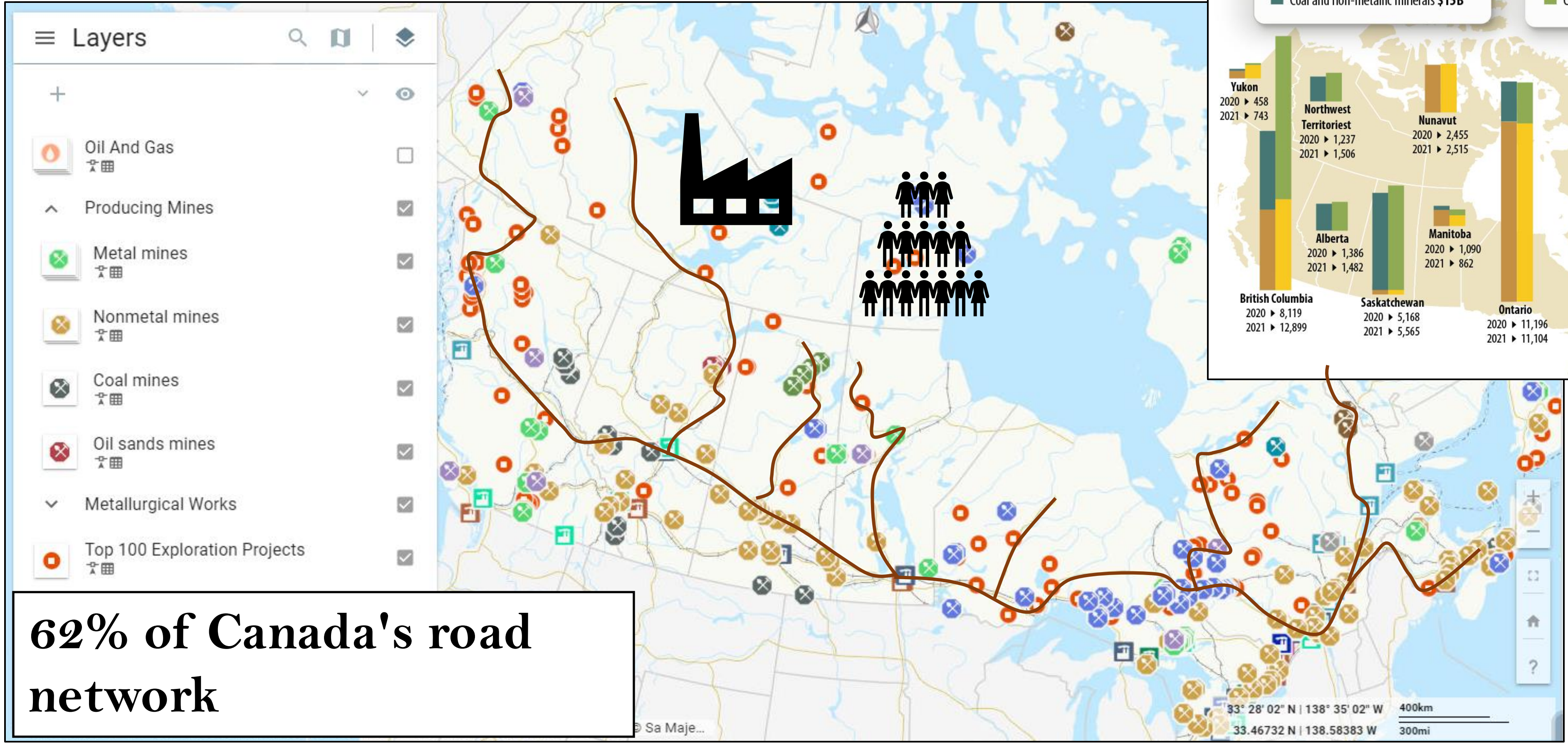
Introduction

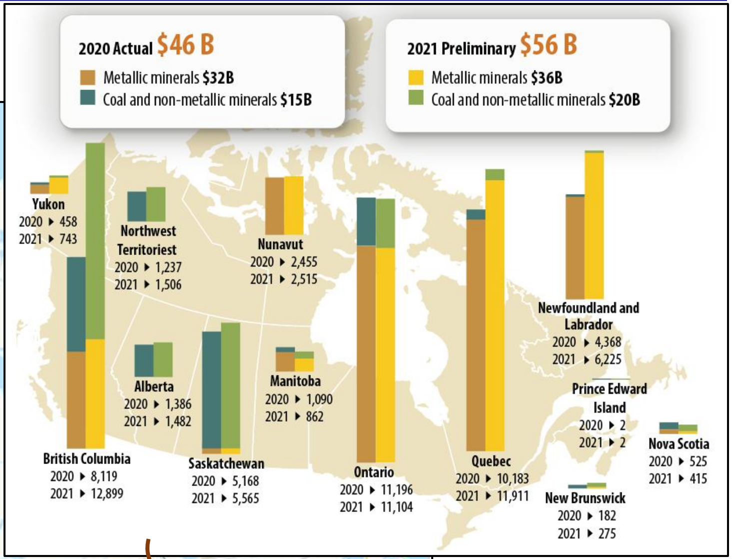
Source: iStock. https://www.istockphoto.com/photos/winter-road



Source: Backcountry Canada Travel. https://backcountrycanadatravel.com/getting-around-canada/adventure-canada/

Economic importance

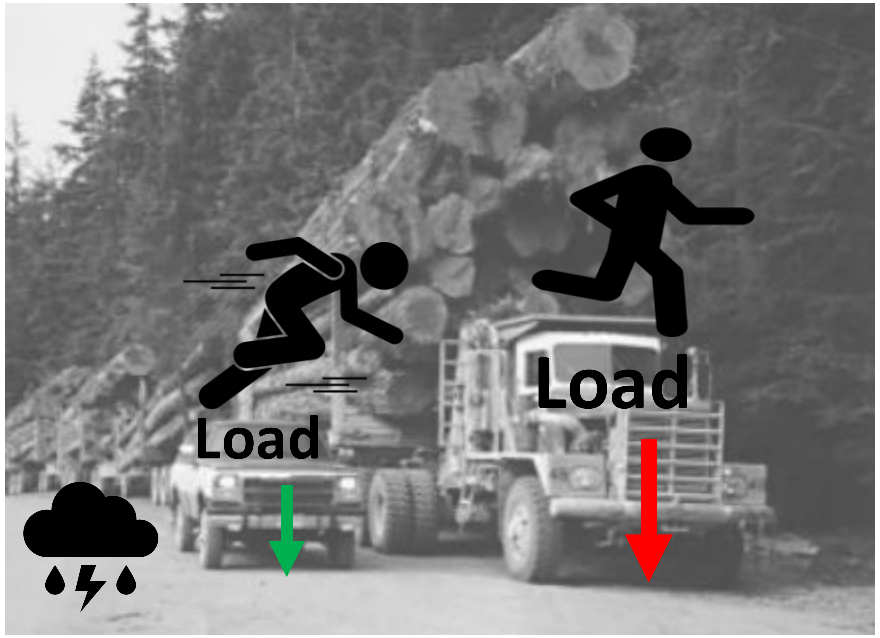




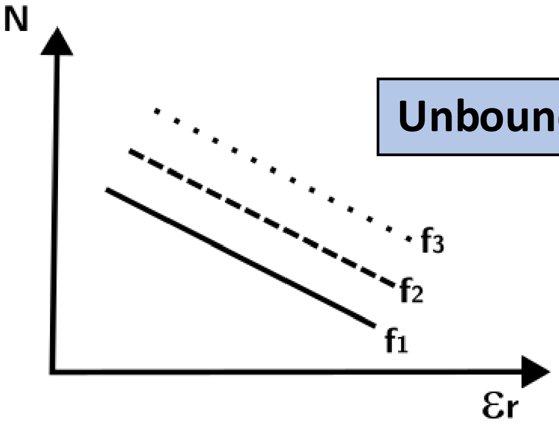
62% of Canada's road network

Mining Map(Government of Canada, 2021)

Load characteristics



Source: Pinterest (n.d).
https://co.pinterest.com/gregadkinson/log-haulers/



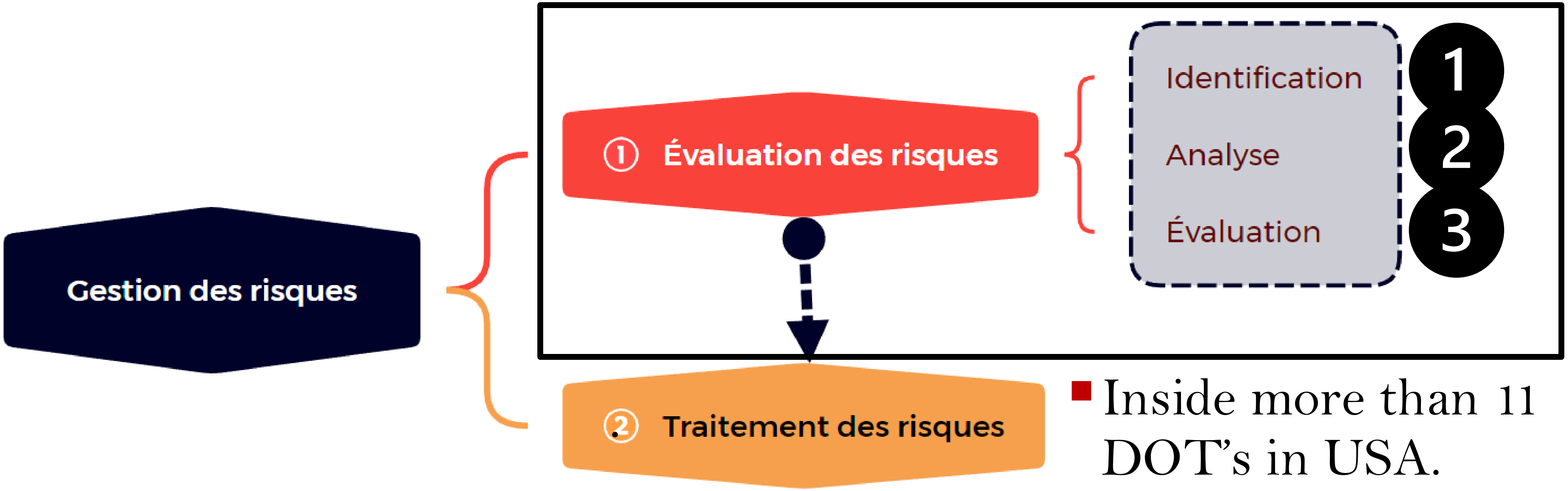
Asphalt mixes

Unbounded materials?

- Soil type
- Distance
- Alternative routes

Risk Management

Risk management is the method of dealing with potential hazards that threaten.



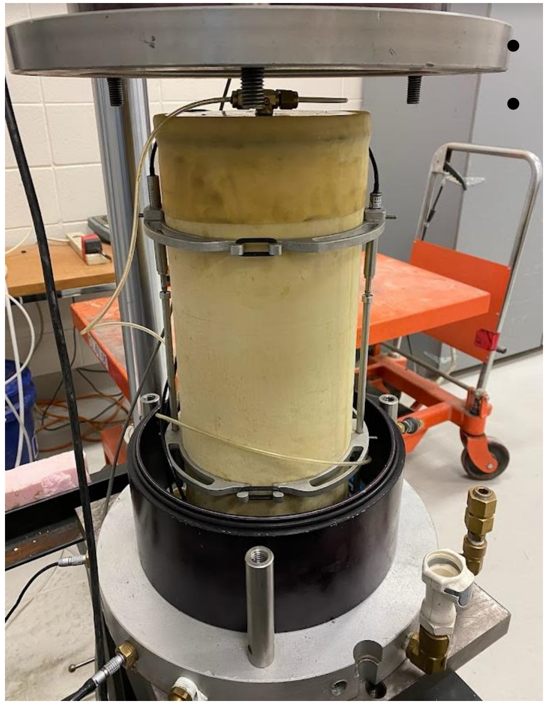
- Inside more than 11 DOT's in USA.
- Torabi et. al (2019)
- Chamorro, A. et al (2020)

Lack of analysis during design

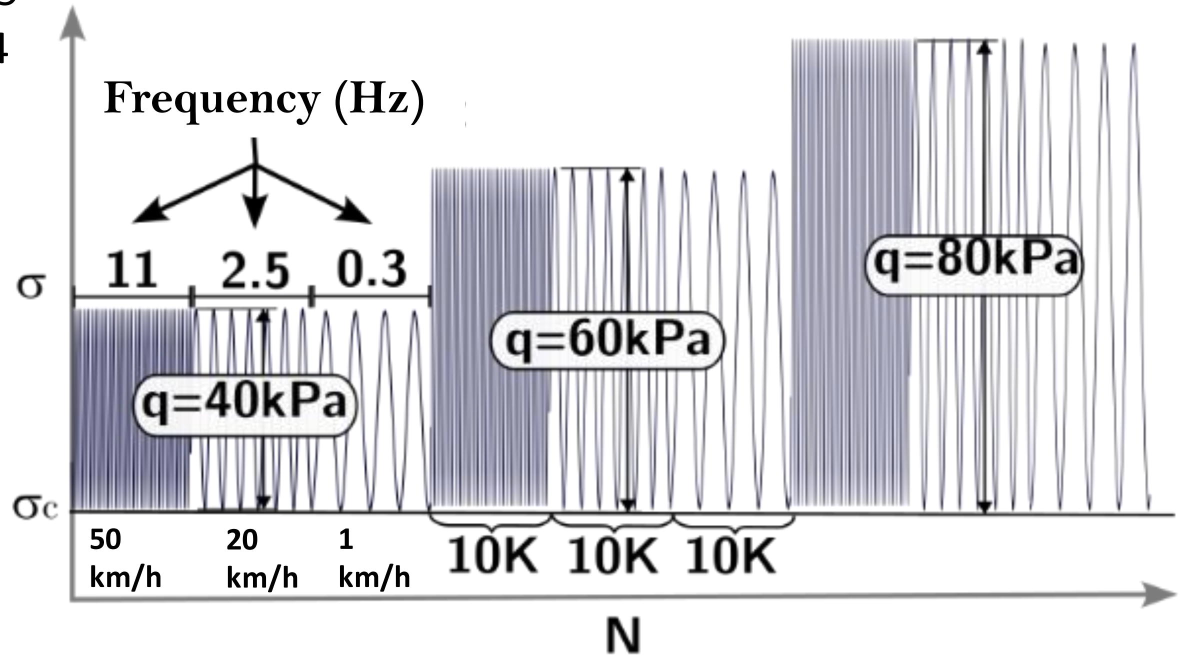
Objectives

- Propose a transfer function for unpaved roads based on the speed of load application.
- Implement a risk assessment method integrated into the design of unpaved roads.
- Generate a basic design tool by integrating risk assessment for unpaved roads.

Loading Protocol (MRLT)



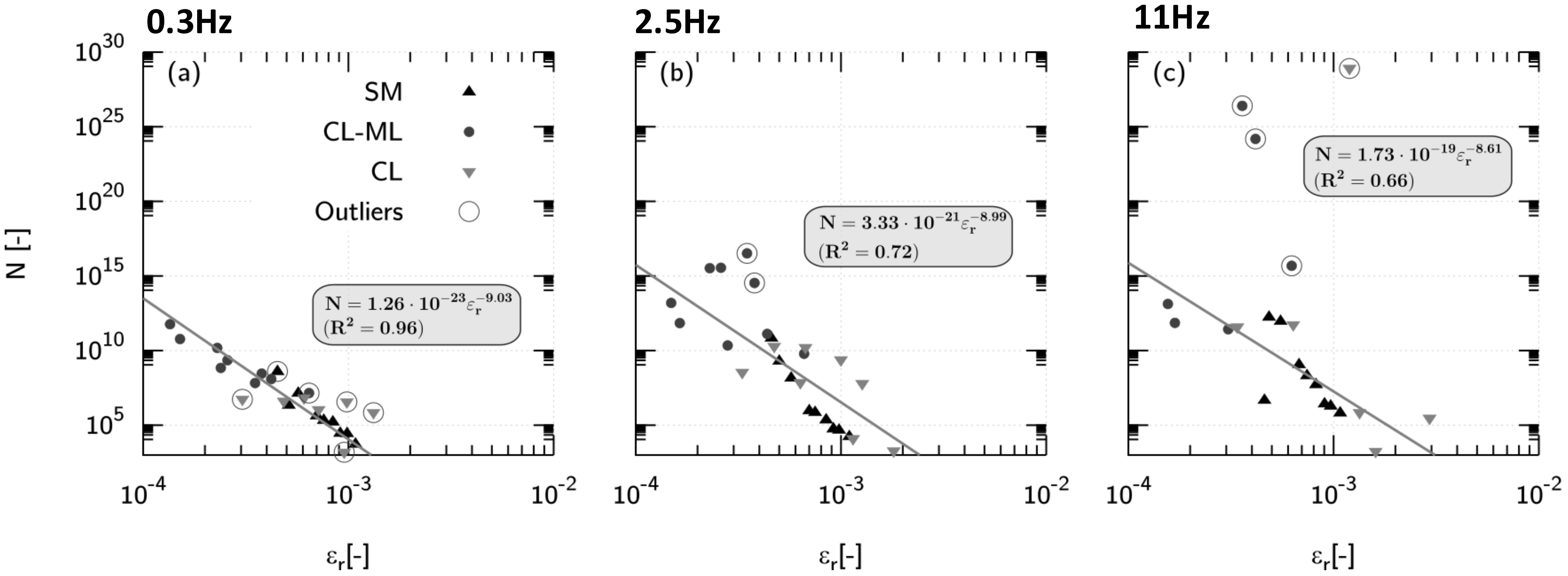
- AASTHO T-307-99
- EN 13286-7:2004



- 3 different soil types: SM, CL-ML, CL (80mm< 32%-72%-100%)
- Each with 3 different water contents (w_{opt}, w+, w-)

Damage Law - Laboratory

$\varepsilon_{1,p}$=2500 με



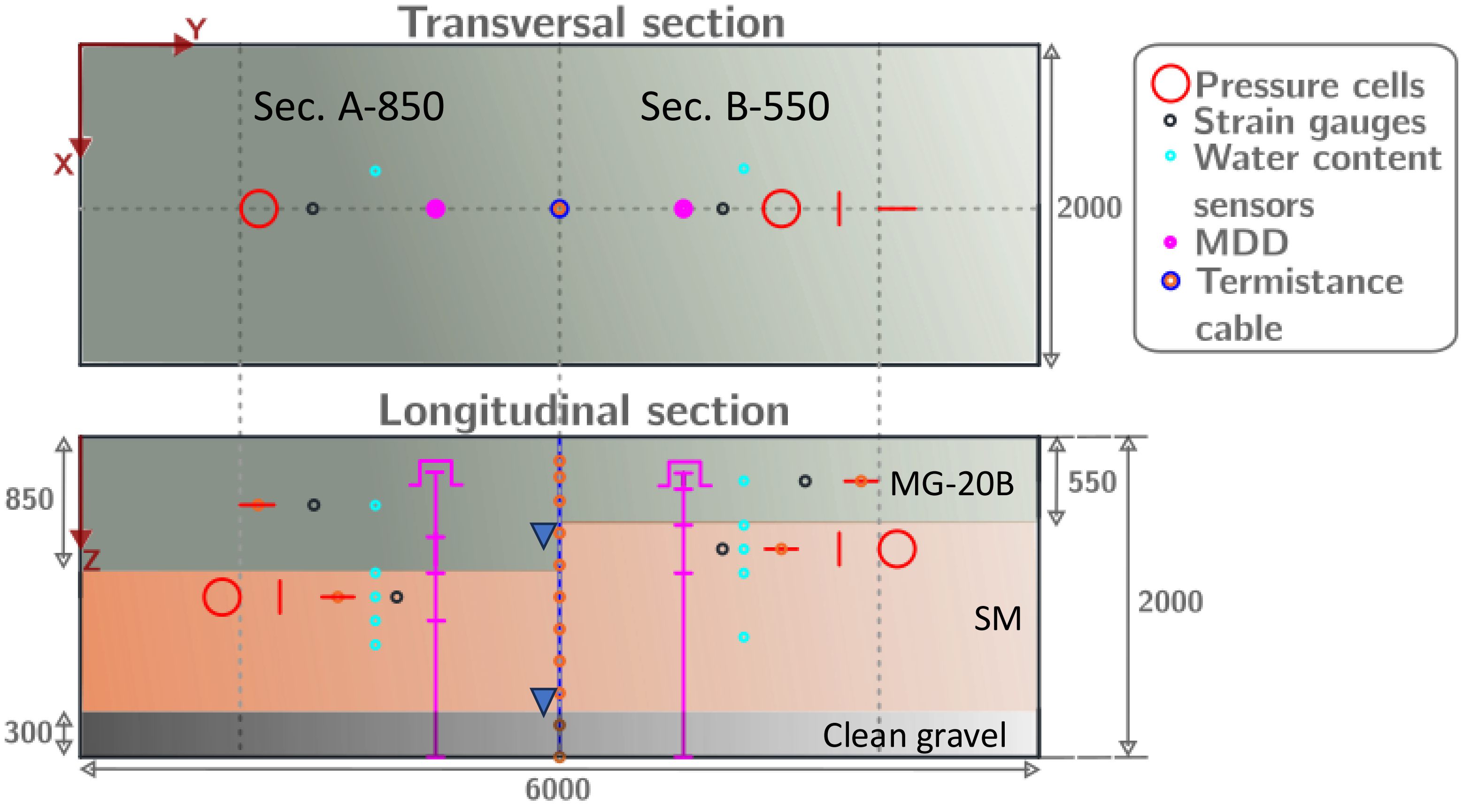
$$N = A\varepsilon_r^{B}$$

Heavy Vehicle Simulator

Heavy Vehicle Simulator (HVS)

- Speed 9 km/h
- 3 loads: 4000, 5000 and 6000 kg.
- 2 Groundwater Positions
- Positioned in the center

Instrumentation

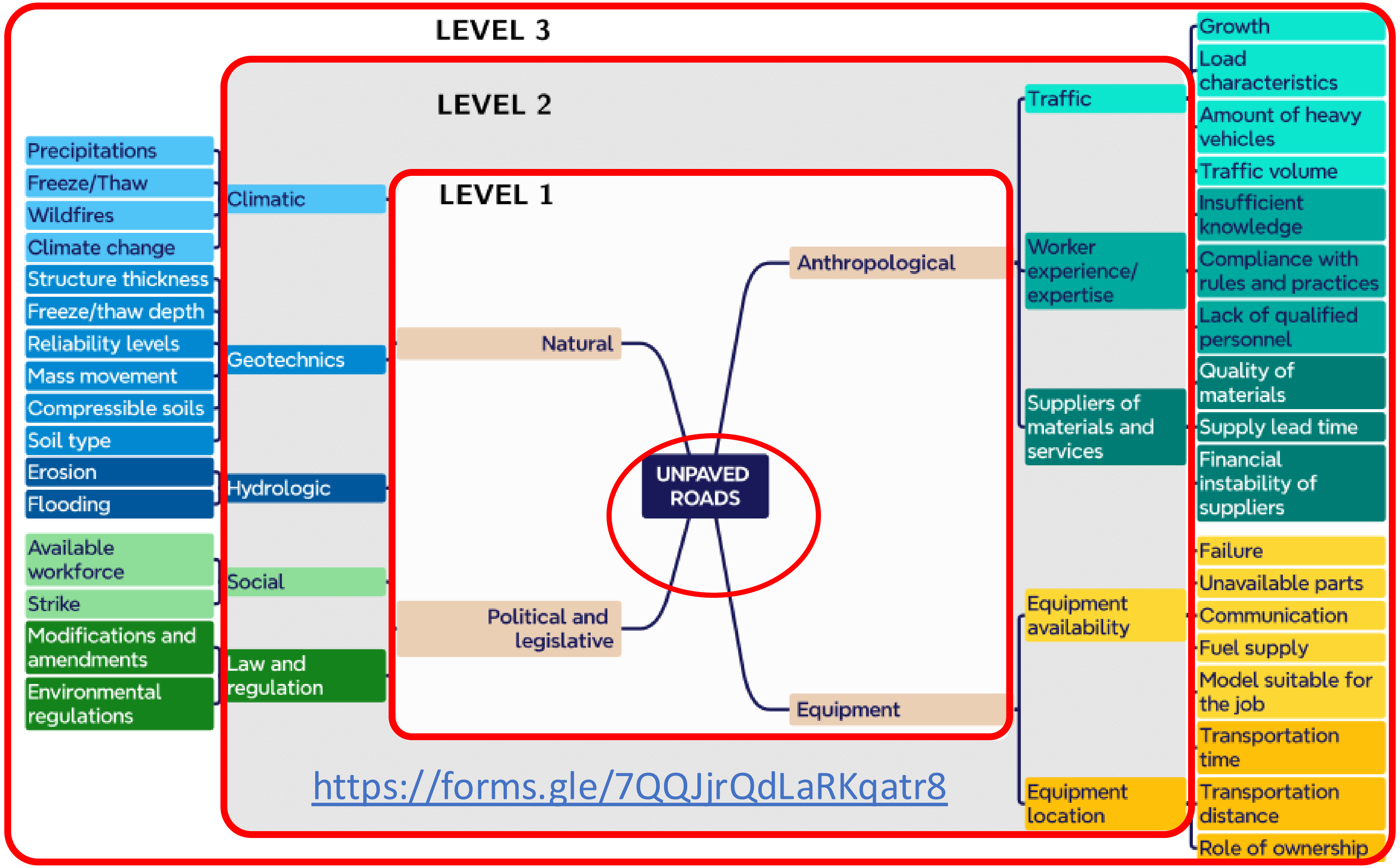


Instrumentation diagram

Risk Assessment: Identification

Risk assessment: Identification

- Hierarchical holistic method
- Bibliography and Brainstorming



Risk Assessment: Analysis

Risk assessment approach

Generalities of Business Impact Analysis:

- Cost and recovery time
- Links to other risks
- Risk detectability
- Risk growth over time

Impact factor

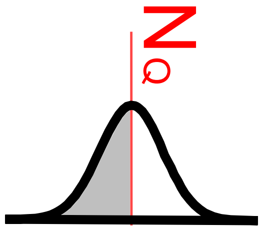
Vulnerability

- Human
- Financial
- Operational facilities
- Maintenance/Operation Machinery

Risk Score (RS)=Likelihood *x* Consequences

Qualitative

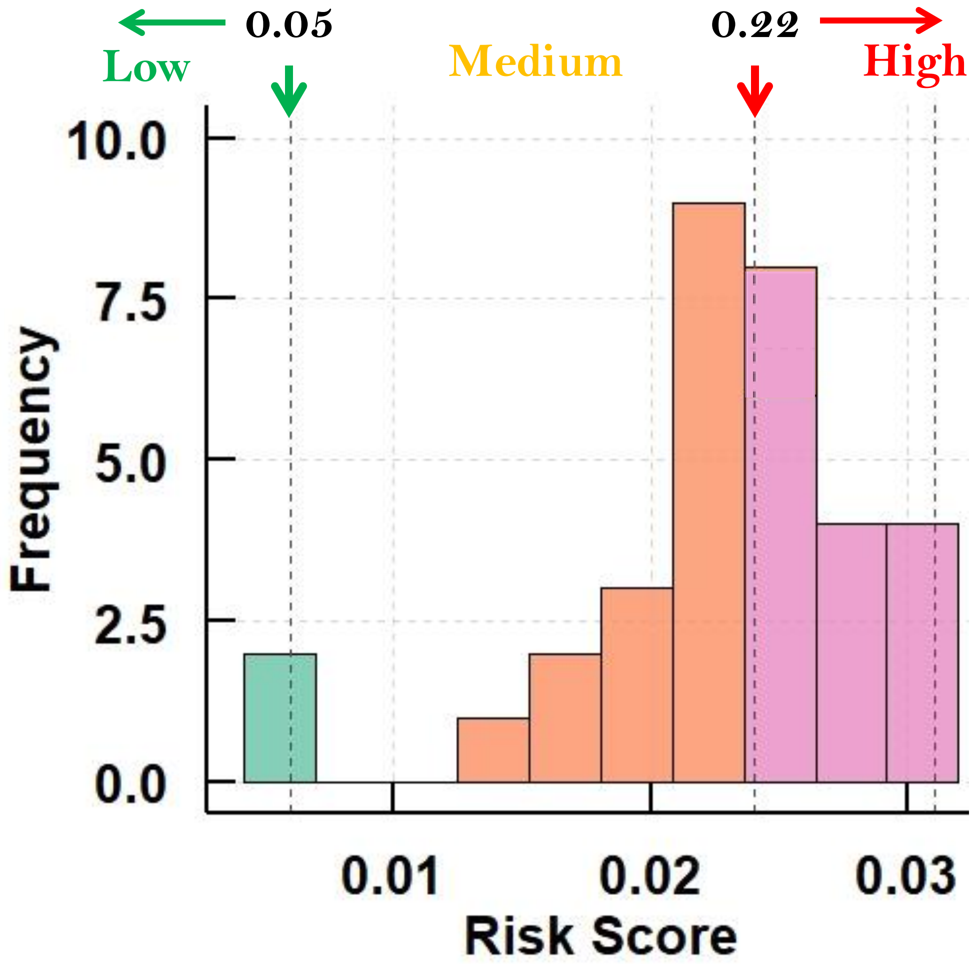
Quantitative



Risk Assessment: Evaluation

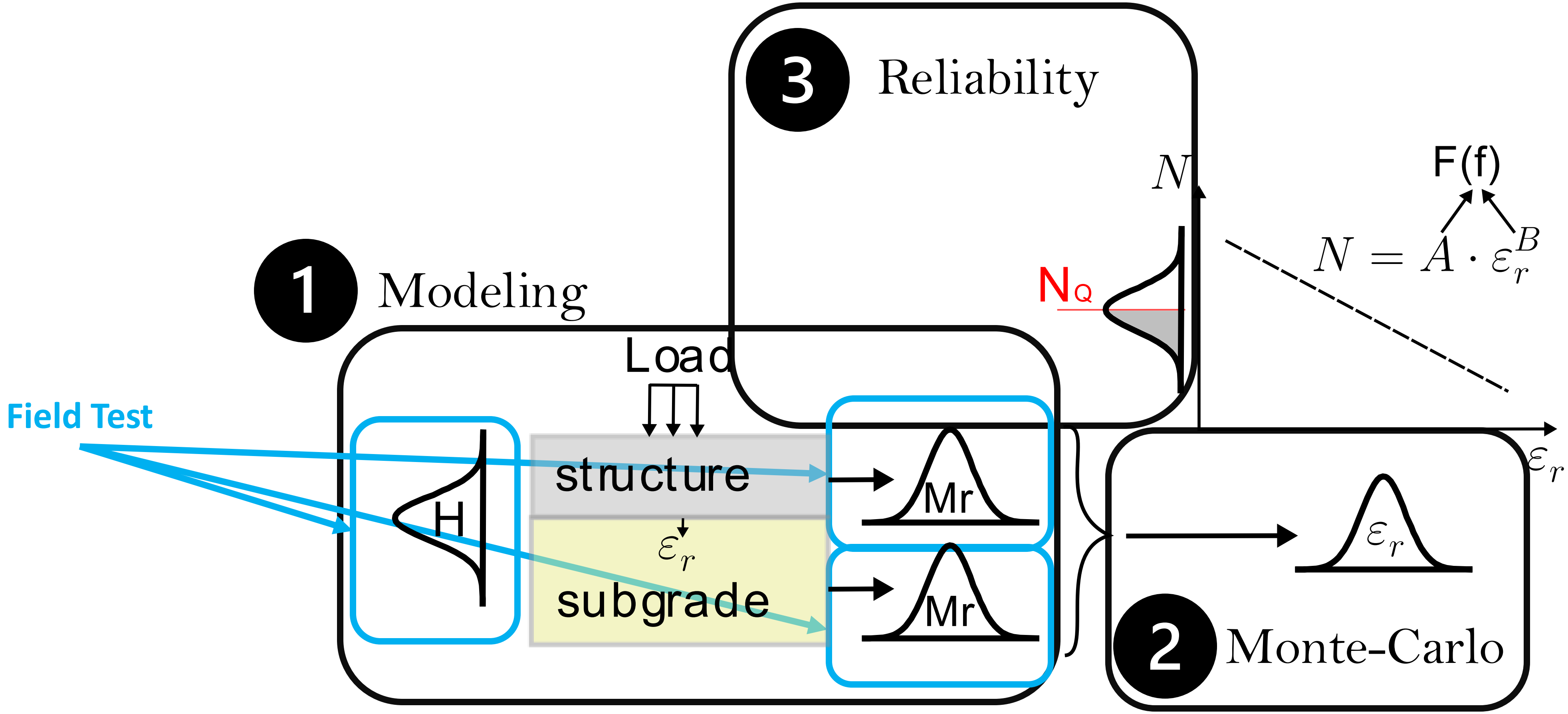
Risk assessment

- Comparison against established risk criteria.
- Classification by natural breaks (Jenks).



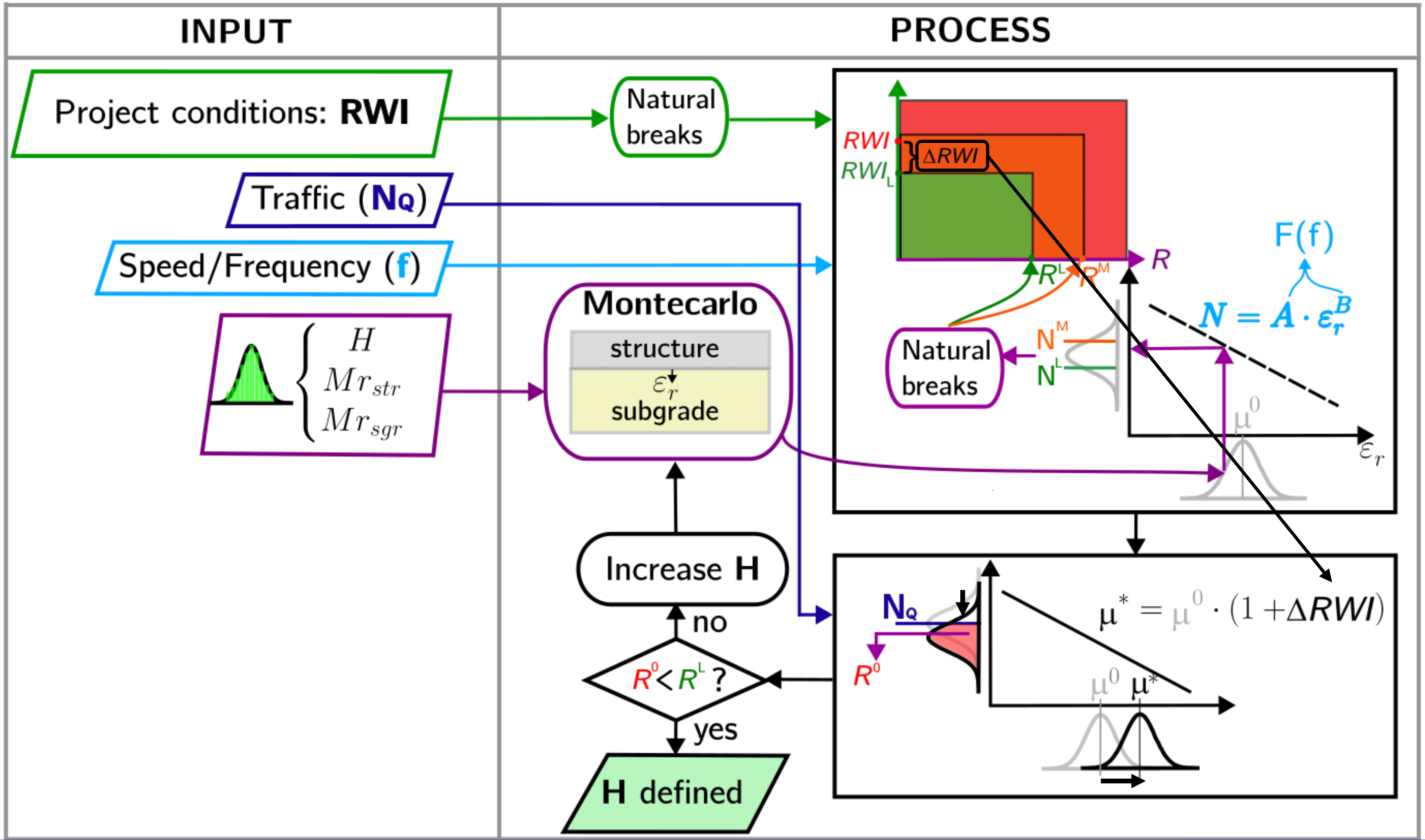
Reliability analysis

Short description



Design Method

Outline algorithm



Conclusions

- Load frequency affects the transfer curve for rutting in soils.
- Pavement design can account for a broad spectrum of risks.
- Risk Assessment methods applied in industry and cross-disciplinary algorithms strengthen pavement analysis.
- BIA effectively captures project conditions and scenarios during the design stage.

Thank you so much

Performance Evaluation of Unpaved Roads Stabilized with Composite Geosynthetic made of Recycled Plastic Geogrid and Nonwoven Geotextile

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Program for Sustainable Pavement Engineering and Research (PROSPER)
Iowa State University (ISU)

TRB Webinar: Advancing Unpaved Roads and Airfields through Graduate Research

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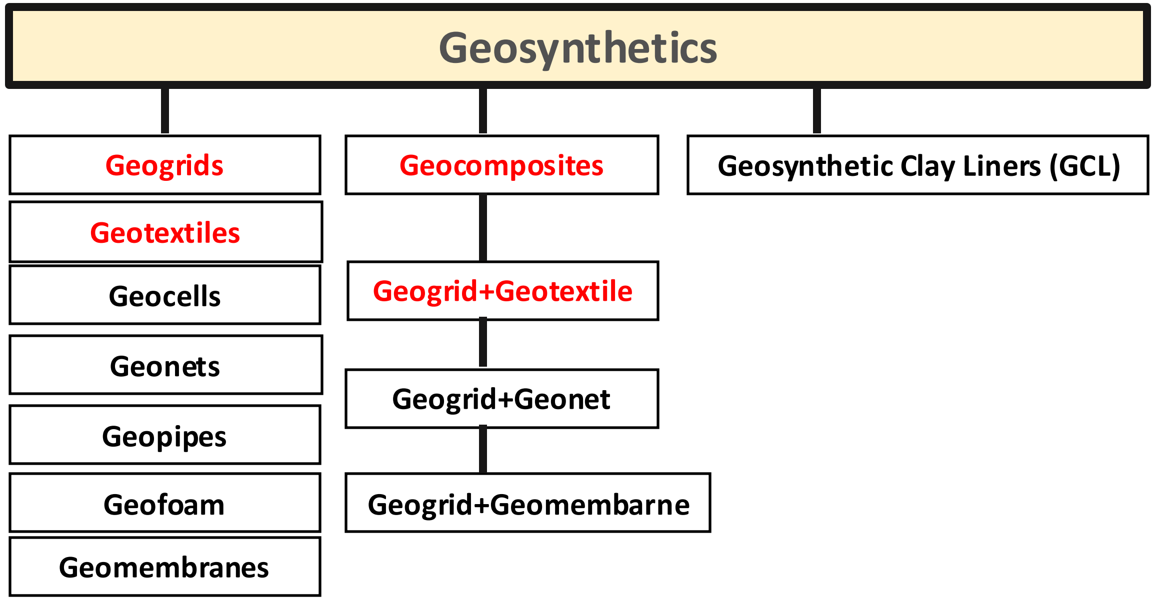
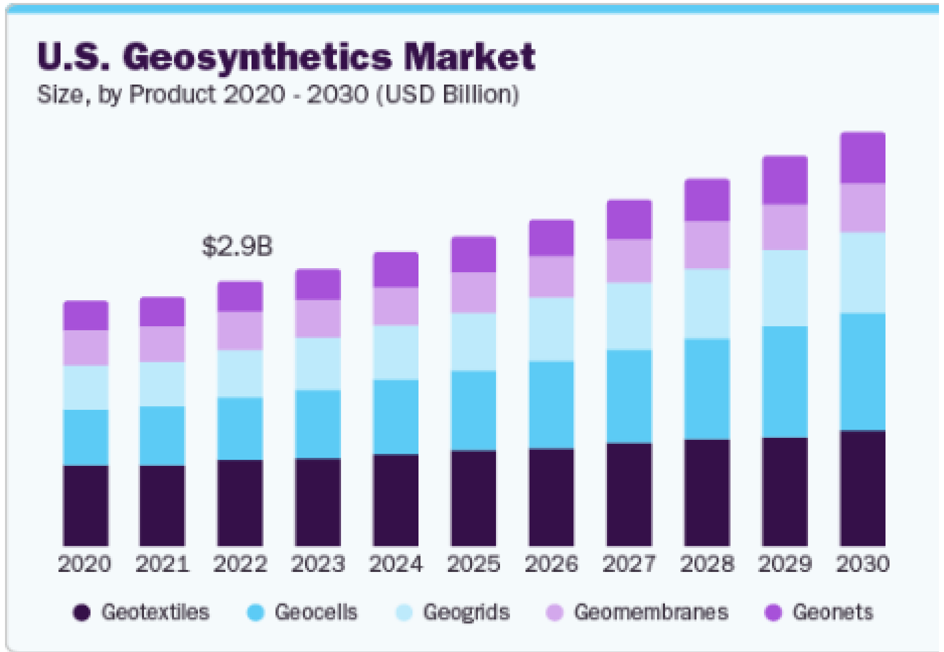
Contents

Introduction

- **Geosynthetics**
  - One of the most revolutionary engineered product groups within civil engineering
  - Manufactured from polymers or hydrocarbon chains
  - Offering high-performance, cost-effective and long-term solutions
  - Allowing infrastructures to be constructed ***more economically, more sustainably and with greater resilience***, compared to alternative solutions.





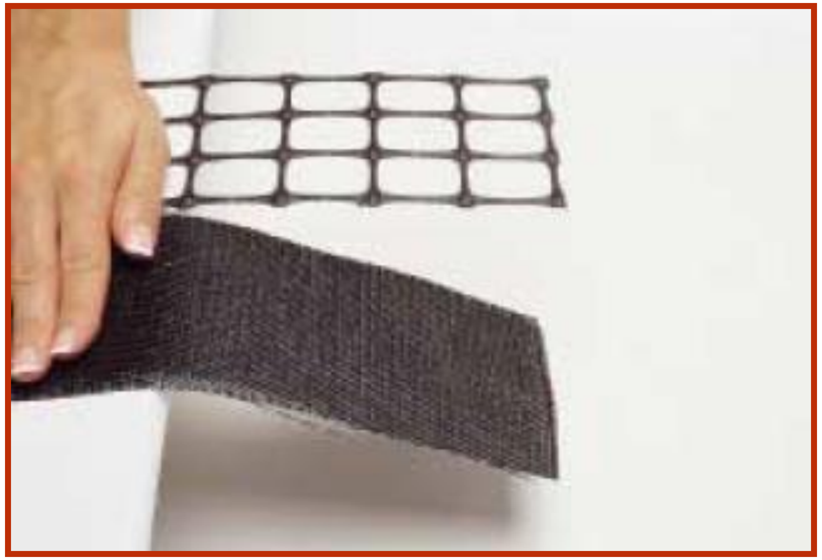
Source: https://www.grandviewresearch.com/

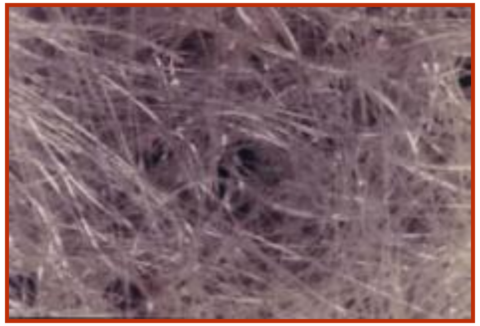
Introduction

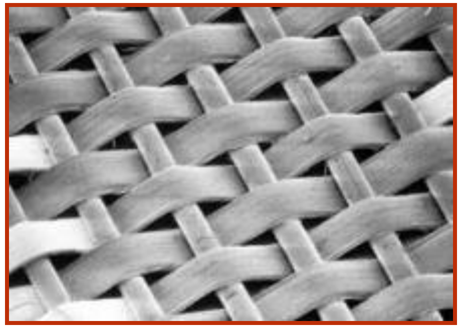
- Geosynthetics

Geogrid

Geotextile

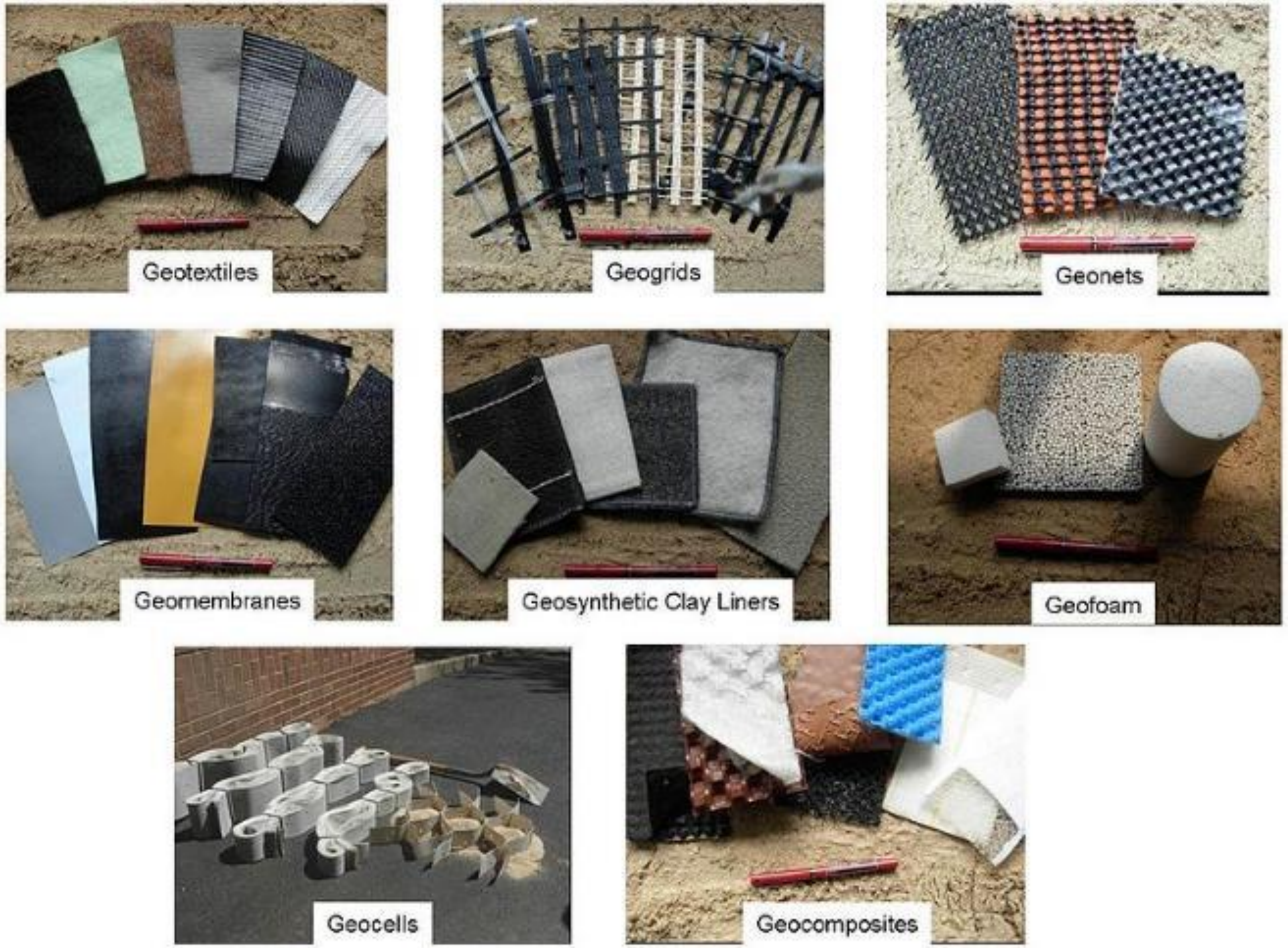






Nonwoven

Woven



Adapted from Tutumluer (2025)

Introduction

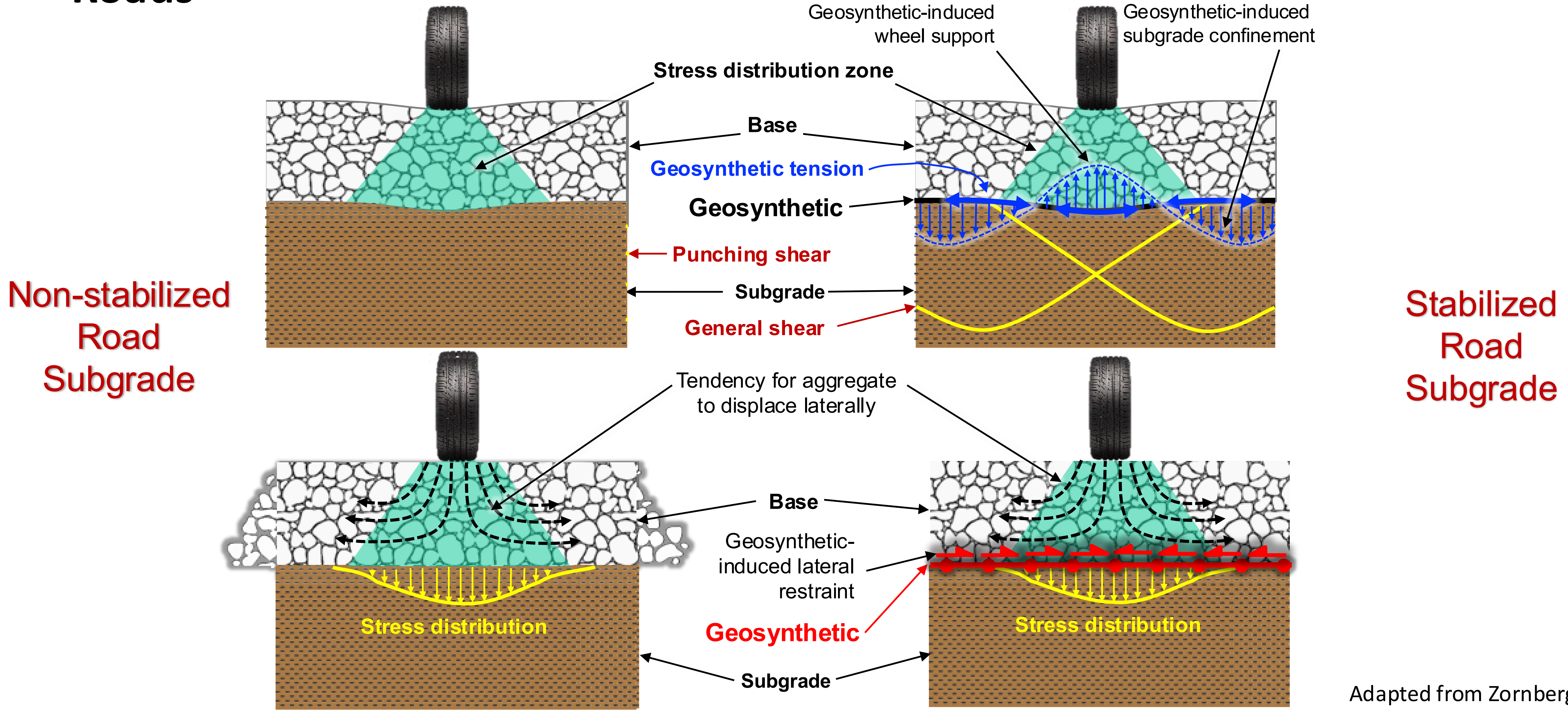
- **Geosynthetics in Civil Engineering Applications**

Application	Objective(s)	Mechanism(s)	Geosynthetic Function(s)		Benefits in Roadway Performance
			Primary	Secondary	
Mitigation of reflective cracking in structural asphalt overlays	Retard or eliminate reflective cracking into structural asphalt overlays triggered by pre-existing cracks in old surface layer	Develop tension to enhance stress redistribution within asphalt overlays in the vicinity of pre-existing cracks	Reinforcement (or Separation)	and/or Barrier	Maintain integrity of the structural asphalt overlay by retarding development of reflective cracks into asphalt overlays and, in turn, reduce/eliminate degradation mechanisms caused (or accelerated) by water intrusion through reflective cracks
Stabilization of unbound aggregate layers	Provide initial increase, and minimize time-dependent decrease, in the modulus of unbound aggregate layers	Develop lateral restraint through tension and shear transfer to minimize the tendency of unbound aggregates to displace laterally	Stabilization / Stiffening		Decrease time-dependent rutting by (a) providing an increased modulus of unbound aggregates at the time of construction, and (b) minimizing degradation of the modulus of unbound aggregates over time
Reduction of layer intermixing	Avoid contamination of unbound aggregate layers with fine-grained subgrade soil particles	Minimize (a) loss of aggregate particles into underlying soft subgrade, and (b) migration of fine-grained soil particles into overlying unbound aggregate layers	Separation	Filtration	Maintain the as-designed structural capacity by minimizing/eliminating (a) time and serviceability related decrease in base/ballast or subbase/subballast layer thickness, and (b) reduction in the quality of aggregate materials
Reduction of moisture in structural layers	Provide in-plane drainage to minimize access and accumulation of moisture within structural layers	Provide (a) gravity-driven drainage (for saturated soil conditions), and (b) enhanced drainage due to capillarity (for unsaturated soil conditions)	Drainage	Filtration Separation	Avoid or minimize (a) generation of positive pore water pressures (due to traffic loading in near-saturated layers), and (b) moisture content increase in unsaturated layers (to maintain adequate modulus and shear strength over time)
Stabilization of soft subgrades	Increase the bearing capacity of soft subgrade soils	Develop (a) vertical restraint beyond the wheel path, and (b) some membrane-induced tension under the wheel path	Reinforcement	Stiffening Separation Filtration	Decrease time-dependent rutting by (a) minimizing vertical and shear stresses in the subgrade under the wheel path, and (b) redistributing shear and normal stresses beyond the wheel path
Mitigation of distress induced by shrink/swell subgrades	Retard or eliminate environmental longitudinal cracks along roadways due to the presence of expansive or frost-susceptible subgrade soils	Maintain integrity and uniformity of unbound aggregate layer to minimize stress concentration that triggers longitudinal cracks	Stiffening (and/or Drainage) (or Barrier)		Maintain integrity of asphalt surface course and, in turn, reduce/eliminate degradation mechanisms, such as environmental longitudinal cracks along roadways, which are triggered by water content fluctuations and frost action in the subgrade

Adapted from Zornberg & Tutumluer: ACIGS Roadshow, Geosynthetics Design for Roadways and Railways, 26-30 June 2023

Introduction

- **Geosynthetic Functions for subgrade and base stabilization in Granular Roads**



Adapted from Zornberg (2017)

Introduction

- **Recycled Plastic**
  - **Plastic pollution is one of the great environmental challenges in the world**
    - **Plastic waste is hazard to the environment**
    - **Plastic may contain substances to improve performance and/or reduce costs**

Source: https://www.greenpeace.org/

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Environment ▸ Climate crisis Wildlife Energy **Pollution** Green light

Plastics

Microplastics cause damage to human cells, study shows

Harm included cell death and occurred at levels of plastic eaten by people via their food

Damian Carrington
Environment editor
@dpcarrington
Wed 8 Dec 2021 09.09 EST

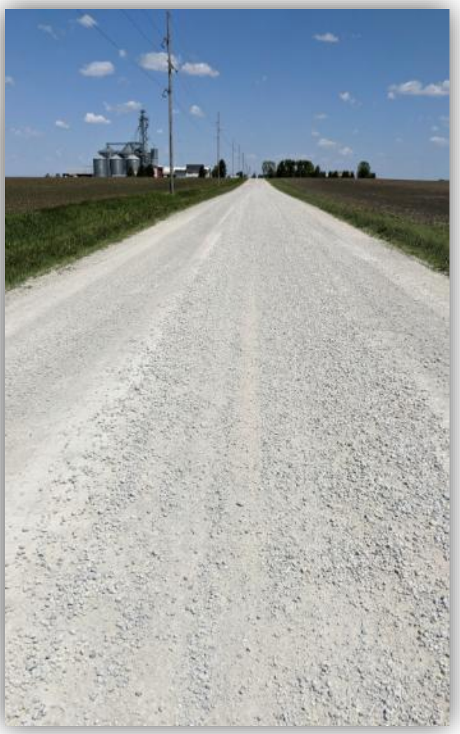
Plastic waste in Rize, Turkey. Photograph: Anadolu Agency/Getty Images

Microplastics cause damage to human cells in the laboratory at the levels known to be eaten by people via their food, a study has found.

Introduction

- **Cold-region Transportation Infrastructure**
  - Iowa has over 70,000 miles of granular (unpaved) county roads
  - Backbone of Iowa's agricultural and manufacturing economy that help feed the world
  - Very low daily traffic with frequently heavy vehicle (i.e., farm equipment) movements
  - Iowa's county road departments spend over $145 million annually for maintenance costs






Introduction

- **Cold-region Transportation Infrastructure**
  - Iowa granular roads commonly face surface distresses such as washboarding, rutting, potholes, and loose aggregate, along with moisture-related issues like frost heave and boils driven by poor drainage and freeze–thaw cycles.
  - Many examples of reported freeze-thaw related damage problems on many Iowa granular roads in recent years

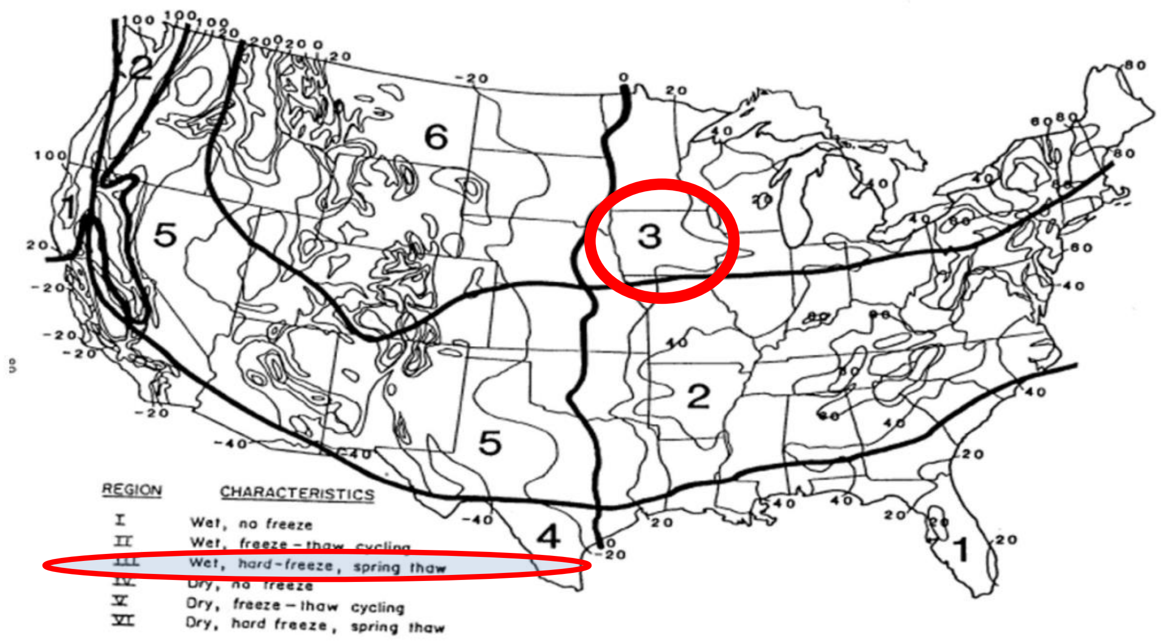
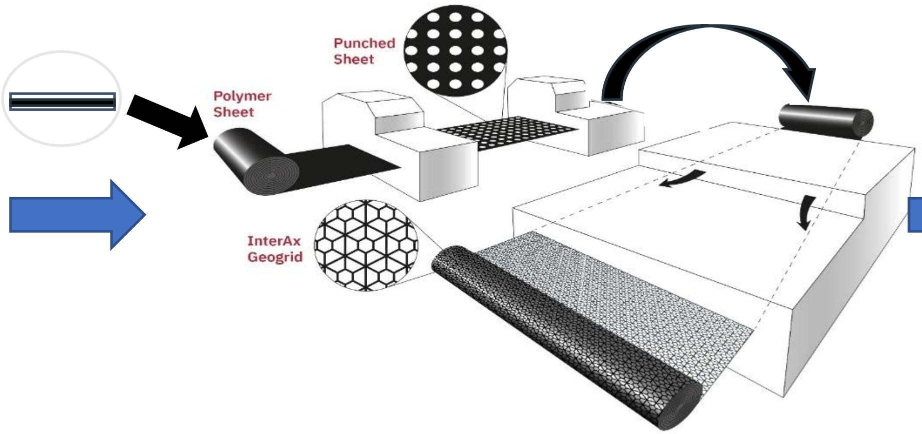


Photo of courtesy: Brian Keierleber

Introduction

- **Objectives**
  - **New and less expensive means are desired**
    - **To strengthen the bases of Iowa's granular roads**
    - **To reduce the effects of the freeze thaw cycles**
    - **To reduce maintenance costs and increase serviceability to the traveling public**
    - **Innovative and sustainable application of recycled plastic for unpaved roads stabilization**

Plastic Waste



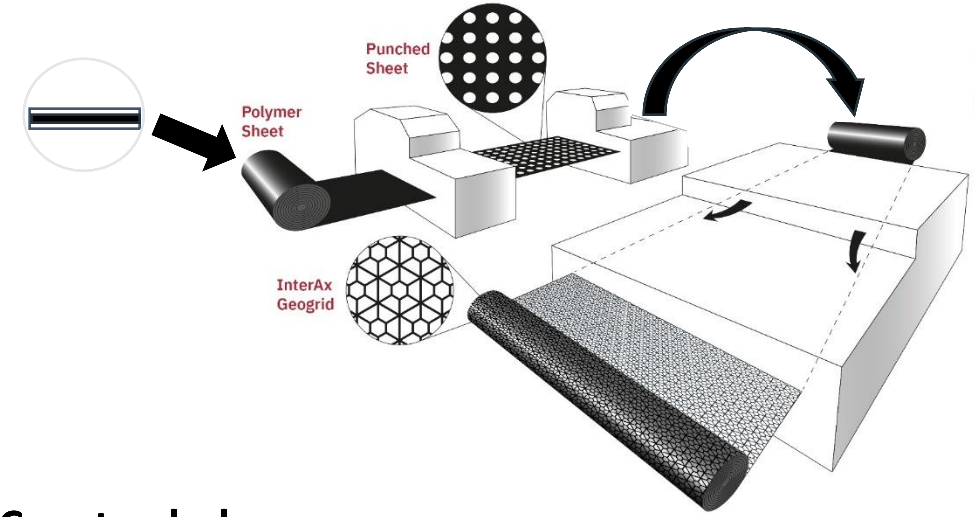
Recycled Plastic Geosynthetic

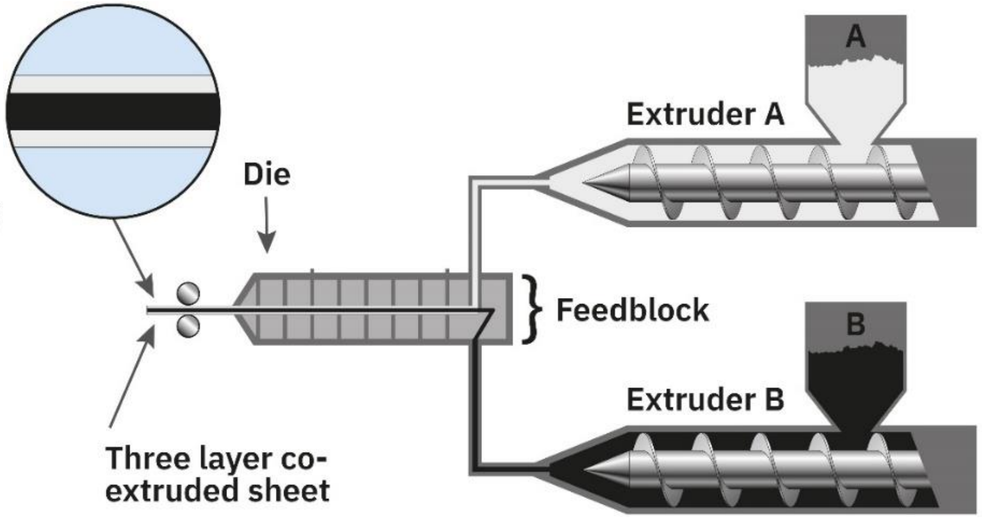
Turning Plastic Waste to Sustainable Construction Materials

Contents

Recycled Plastic Composite Geosynthetic

- Newly developed Composite Geosynthetic called DEV-IA1 (A geogrid made from *100% recycled plastic (Polypropylene (PP))* and a nonwoven geotextile) **developed for the first time for Iowa** and
- Conventional Composite Geosynthetic called DEV-IA2 (A geogrid made from *virgin plastic (PP)* and a nonwoven geotextile)





Source: Slides provided by geosynthetic manufacturer

Coextruded process

- One extruder barrel contains the “white” polymer for the caps and the other contains “black” polymer for the core.
- The three layers are extruded simultaneously so there is no “joining” of the three layers – they form a single sheet

Recycled Plastic Composite Geosynthetic

- **Functions**
  - –Stabilization
  - –Separation
  - –Drainage
  - –Confinement
  - –Filtration

Virgin Plastic Composite Geosynthetic

Source: Slides provided by geosynthetic manufacturer

100% Recycled Plastic Geogrid

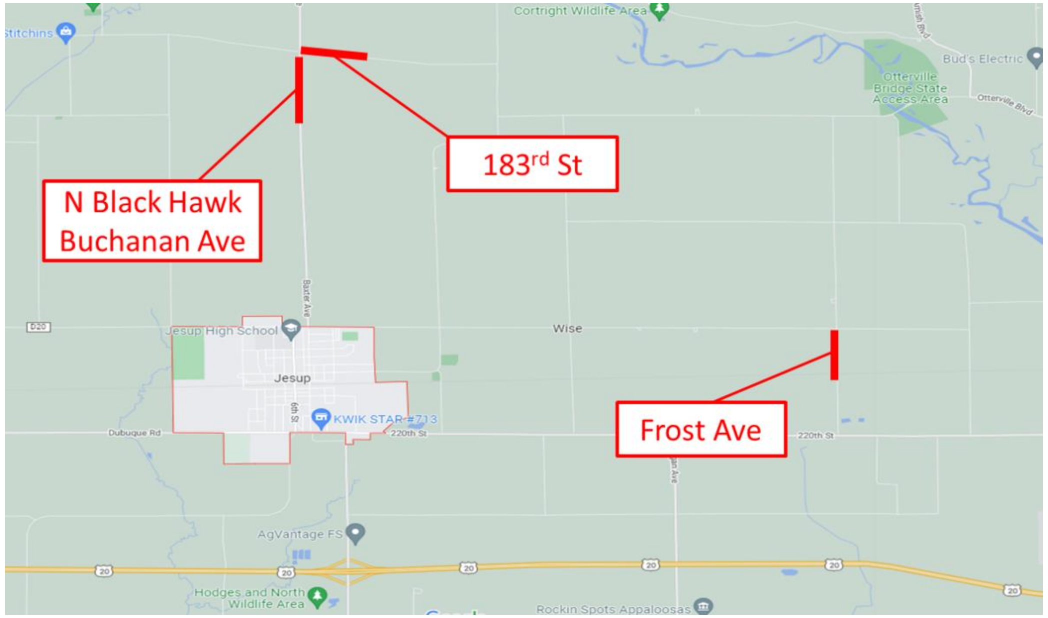
Nonwoven Geotextile

Recycled Plastic Composite Geosynthetic

Contents

Laboratory and Field Study

- **Laboratory Testing on Soil and Aggregates**
  - Three candidate sites in Buchanan County, IA were selected for field demonstration
  - All three sites are granular roads



Laboratory and Field Study

- **Laboratory Testing on Soil and Aggregates**
  - Collected subgrade soils and surface aggregates from three candidate sites for laboratory investigations

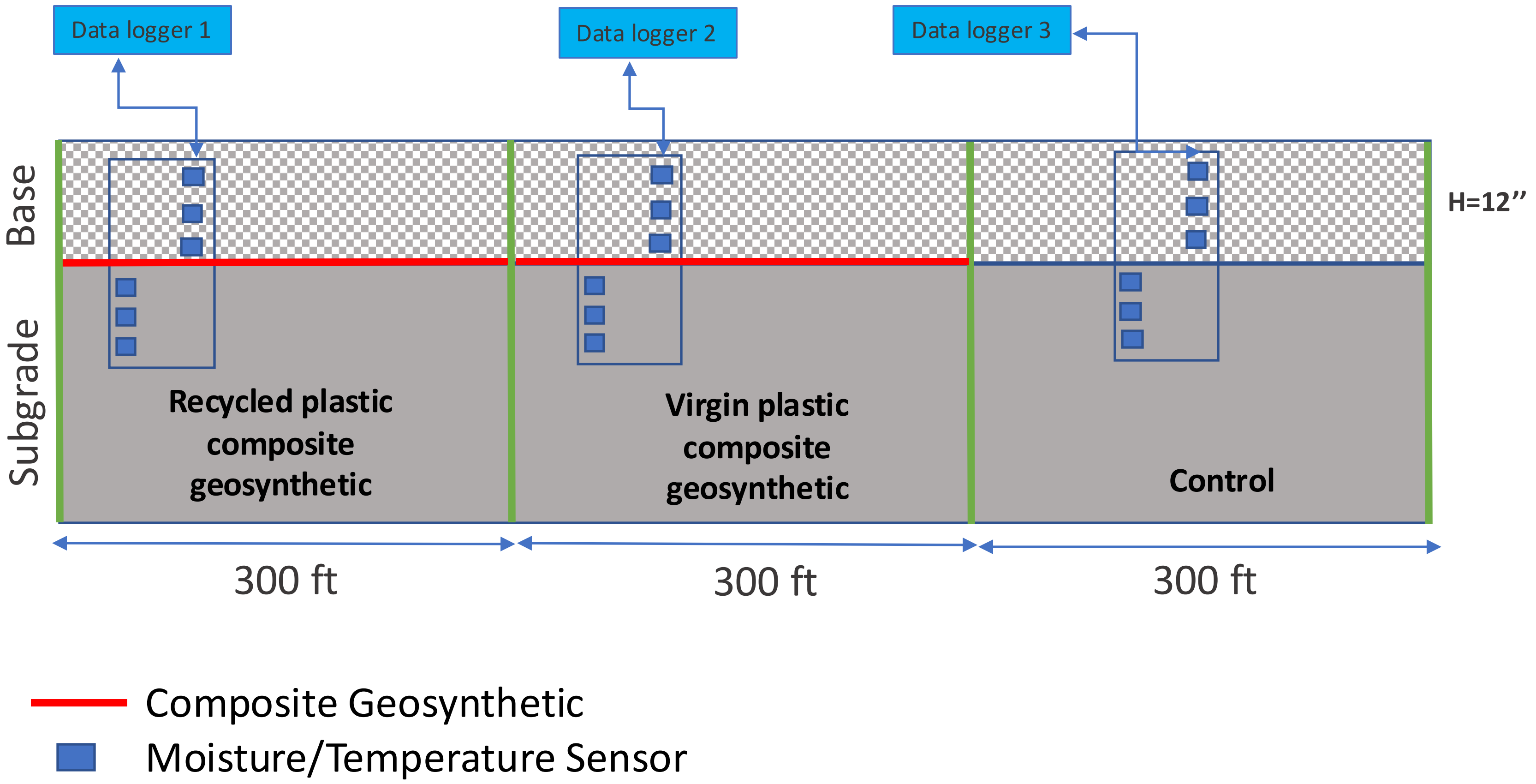
Laboratory and Field Study

- **Laboratory Testing on Soil and Aggregates**
  - Sieve Analysis
  - Atterberg Limits
  - Standard Proctor Compaction
  - Laboratory CBR Test

Property	Base Aggregate			Subgrade Soil		
	N Black Hawk Buchanan Ave	**183rd St**	**Frost Ave**	**N Black Hawk Buchanan Ave**	**183rd St**	**Frost Ave**
AASHTO Classification					**A-6**	
Liquid Limit				**31.8**		**29.0**
Plastic Limit				**20.9**		**11.0**
Plasticity Index				**10.9**		**18.0**
CBR (%)					**2-3**	
OMC (%)	**9.0**	**8.8**	**4.8**	**14.85**		**11.3**
MDD (PCF)	**128.0**	**132.8**	**129.0**	**105.67**		**102.8**

Laboratory and Field Study

- Field Construction and Sensor Instrumentation
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic



An advanced soil **moisture, temperature, and electrical conductivity (EC) sensor** designed for high-precision, long-term field monitoring.

Laboratory and Field Study

- Field Construction and Sensor Instrumentation
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic

Laboratory and Field Study

- Field Construction and Sensor Instrumentation
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic


Dig trench for sensor installation in subgrade

Laboratory and Field Study

- Field Construction and Sensor Instrumentation
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic

Laboratory and Field Study

- Field Construction and Sensor Instrumentation
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic

Laboratory and Field Study

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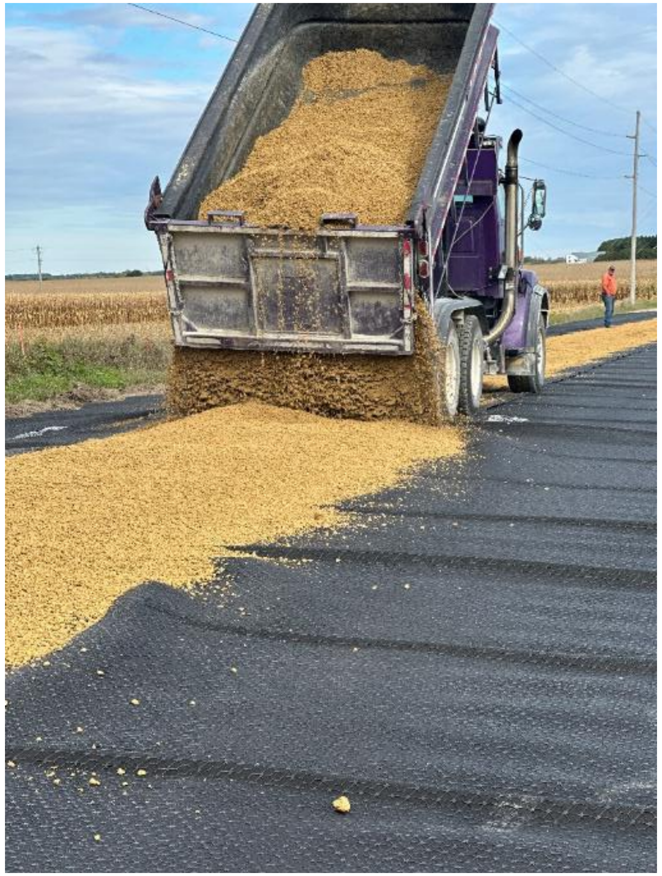


Laboratory and Field Study

- Field Construction and Sensor Instrumentation
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic

Contents

Performance Monitoring

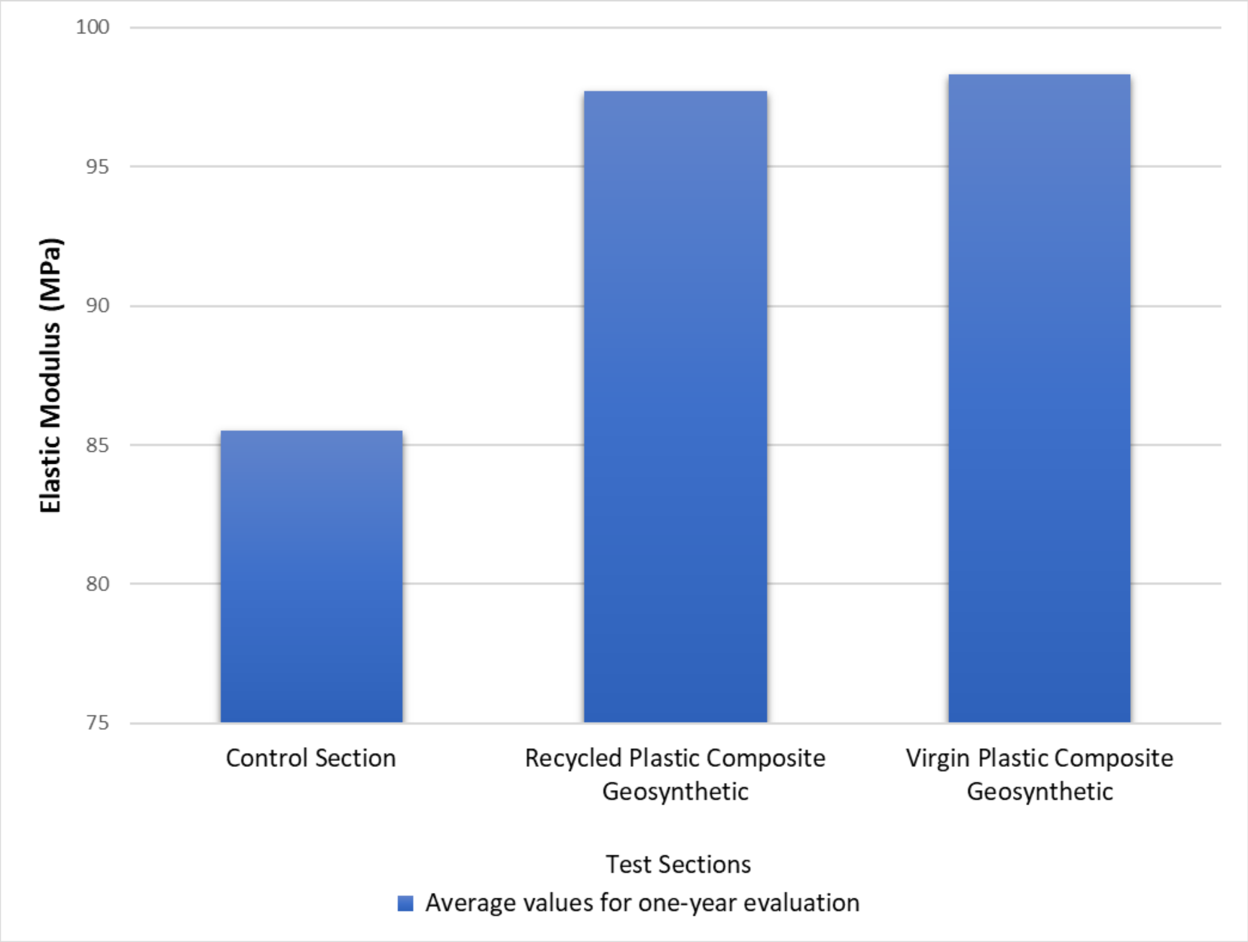
- Field Tests, visual inspections and in-situ testing






Performance Monitoring

- LWD Test
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic

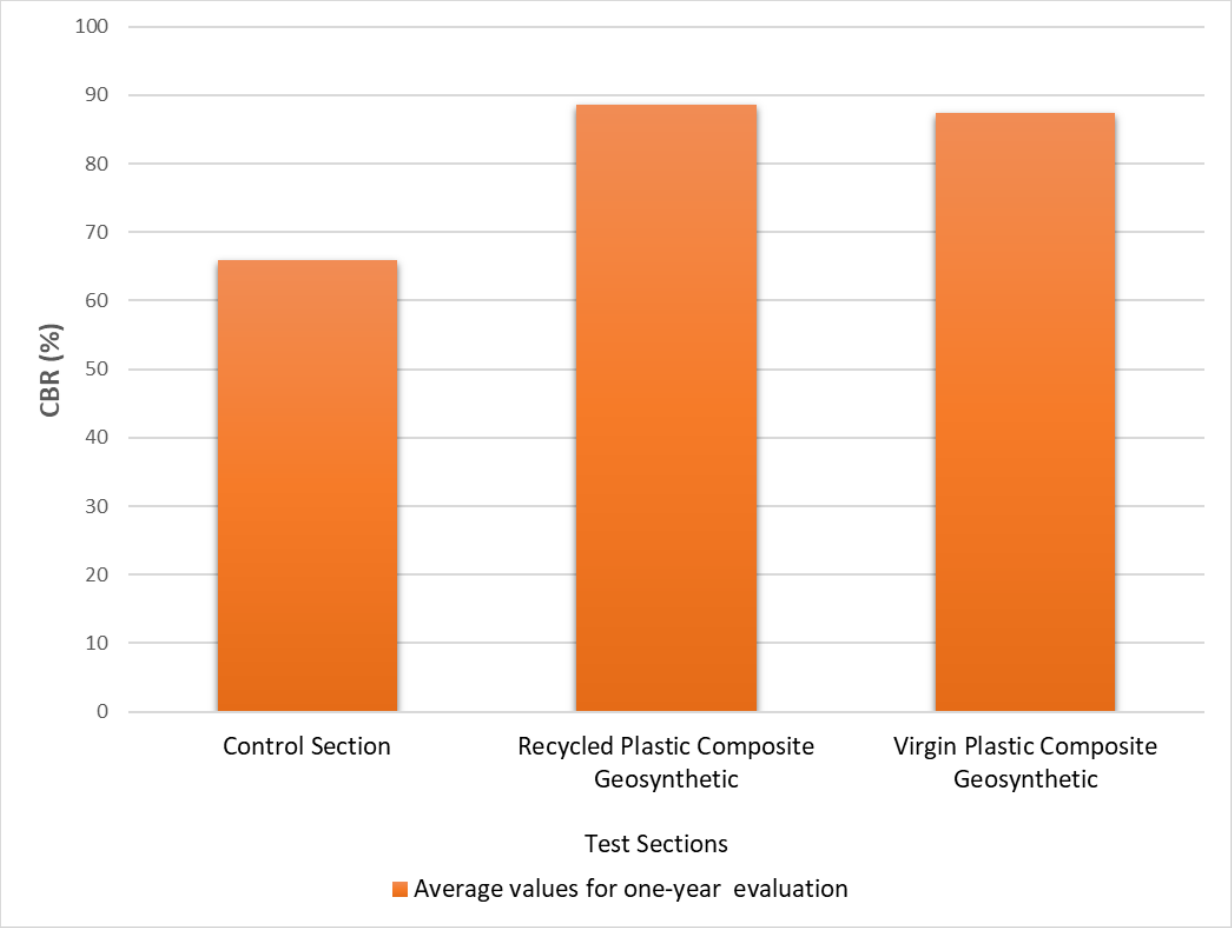


About 15% increase in comparison to the control section

Hasheminezhad et al. (2025)

Performance Monitoring

- Field CBR Test
  - Recycled Plastic Composite Geosynthetic vs. Virgin Plastic Composite Geosynthetic

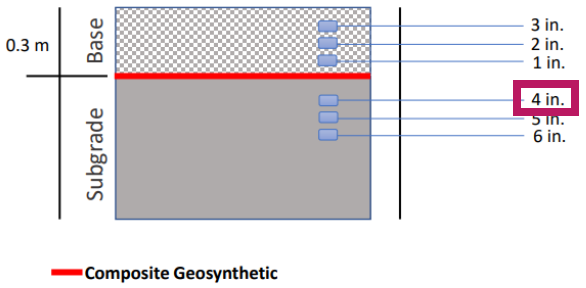


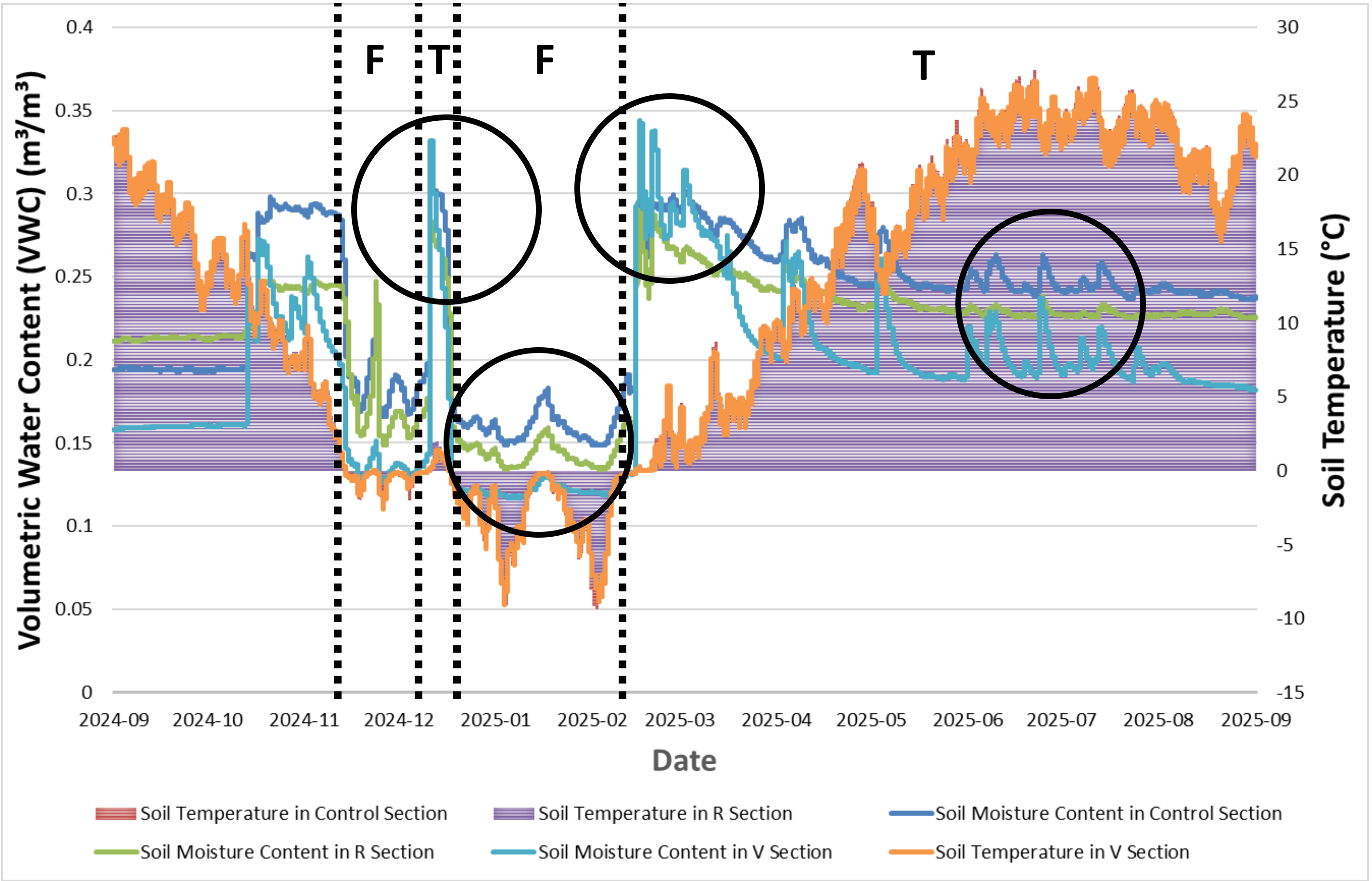
Hasheminezhad et al. (2025)

About 35% in comparison to the control section

Performance Monitoring

- Recycled and Virgin Plastic Composite Geosynthetics vs. Control - *Subgrade*





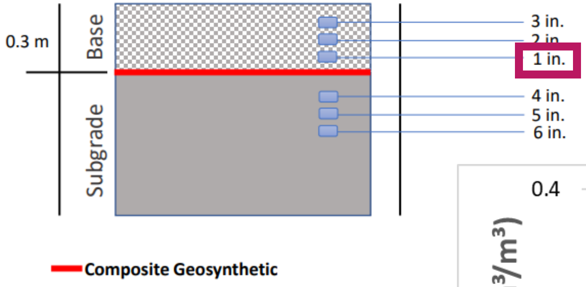
Subgrade beneath the composite geosynthetic

Freeze (F) and Thaw (T) period

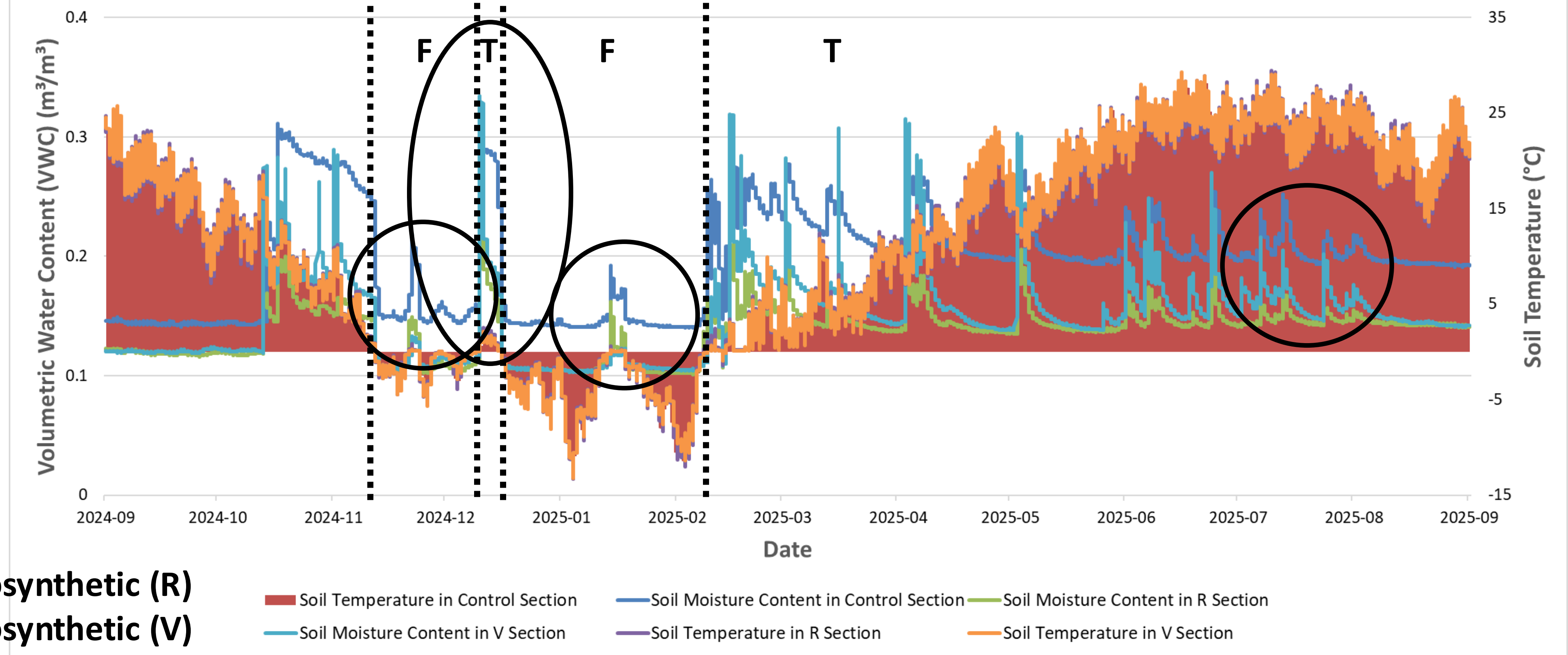
Recycled Composite Geosynthetic (R) and Recycled Composite Geosynthetic (V)

Performance Monitoring

- Recycled and Virgin Plastic Composite Geosynthetics vs. Control - *Base*



Aggregate base on top of the composite geosynthetic



Freeze (F) period
Thaw (T) period
Recycled Composite Geosynthetic (R)
Recycled Composite Geosynthetic (V)

Performance Monitoring

- Recycled and Virgin Plastic Composite Geosynthetics vs. Control

Control

Severe frost boils and heaves

Field observations in April 2025

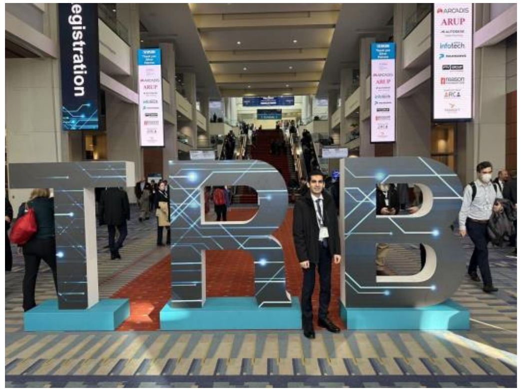
Contents

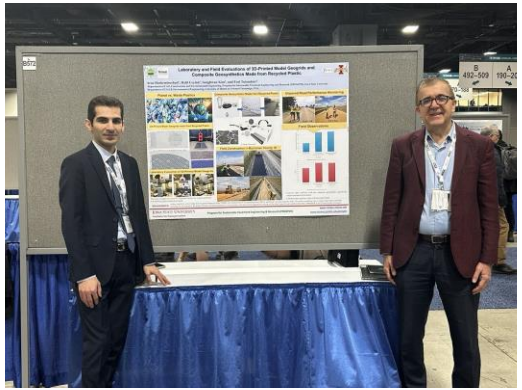
Conclusion

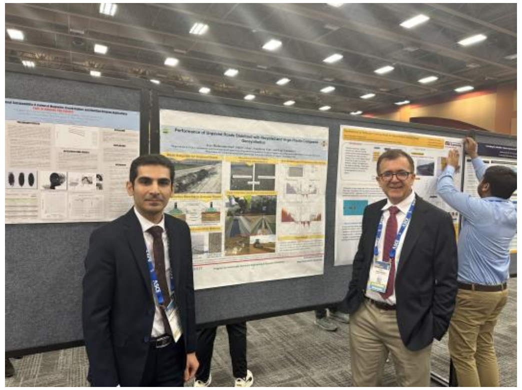
- By repurposing plastic waste into valuable construction materials such as geosynthetics, we can address both the environmental challenges and the resource demands of modern infrastructure development.
- The results indicate that recycled plastic composite geosynthetic shows promise in soil stabilization by increasing bearing capacity, strength, and stiffness, while reducing rutting, deformation, and granular base thickness.
- The results show that recycled plastic composite geosynthetic effectively reduced soil moisture contents to improve the bearing capacities of unpaved roads and furthermore significantly reduced rutting and other damage caused by traffic and weathering.
- These findings also suggest that the recycled plastic composite geosynthetic offer comparable performance benefits to that of virgin plastic for enhancing unpaved road performance, pending further validation through continuous monitoring and long-term evaluation.
- The findings highlight the potential of recycled plastic-based geosynthetics to reduce greenhouse gas emissions, promote material circularity, and enhance resiliency of transportation infrastructure systems under extreme climatic conditions.

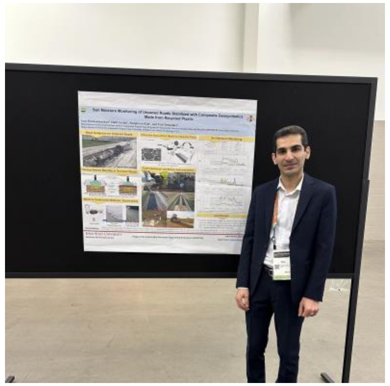
Publications and Presentations

- Hasheminezhad, A., Ceylan, H., Kim, S., & Tutumluer, E. (2025). Evaluation of 3D-printed model geogrids and composite geosynthetics made from recycled plastics: Bridging laboratory insights with field performance. Construction and Building Materials, 465, 140258.
- Hasheminezhad, A., Ceylan, H., Kim, S., & Tutumluer, E. (2025). Moisture and Temperature Monitoring of Unpaved Roads Stabilized with Recycled and Virgin Plastic Composite Geosynthetics. In Airfield and Highway Pavements 2025 (pp. 275-285).
- Hasheminezhad, A., Ceylan, H., Kim, S., & Tutumluer, E. (2025). Performance Evaluation of Unpaved Roads Stabilized with Composite Geosynthetic Made of Recycled Plastic Geogrid and Nonwoven Geotextile. In Geotechnical Frontiers 2025 (pp. 354-364).
- Hasheminezhad, A., Ceylan, H., Kim, S., Tutumluer, E. (2025). Laboratory and Field Evaluations of 3D-Printed Model Geogrids and Composite Geosynthetics Made from Recycled Plastic, 104th Transportation Research Board (TRB) Annual Meeting, Washington, DC, January 5–9.









Achievements and Awards

IOWA STATE RESEARCH
DISCOVERIES and DEVELOPMENTS

IOWA STATE UNIVERSITY
Institute for Transportation

En Route
NEWS FROM THE INSTITUTE FOR TRANSPORTATION
July 14, 2025

PROSPER research strengthens Iowa's rural transportation infrastructure

Iowa is home to more than 71,000 miles of granular county roads. Though these unpaved roads typically carry low traffic volumes, they are essential to local communities and routinely bear heavy loads from farm equipment, construction vehicles, and service trucks.

Araz Hasheminezhad, an Iowa State University civil engineering graduate student with the Institute for Transportation's Program for Sustainable Pavement Engineering and Research (PROSPER), is addressing the challenge of maintaining these roads by three-dimension (3D) printing geogrids. Their web-like geosynthetic structures are made from recycled plastic to improve granular road performance and longevity. More

Geogrids for gravel roads strengthen Iowa's rural transportation infrastructure

Graduate student Araz Hasheminezhad is 3D printing geosynthetics to strengthen granular roads

Author: Anna Keplinger

ASEE FIRST BELL
Today's engineering and technology news prepared exclusively for the engineering and technology community

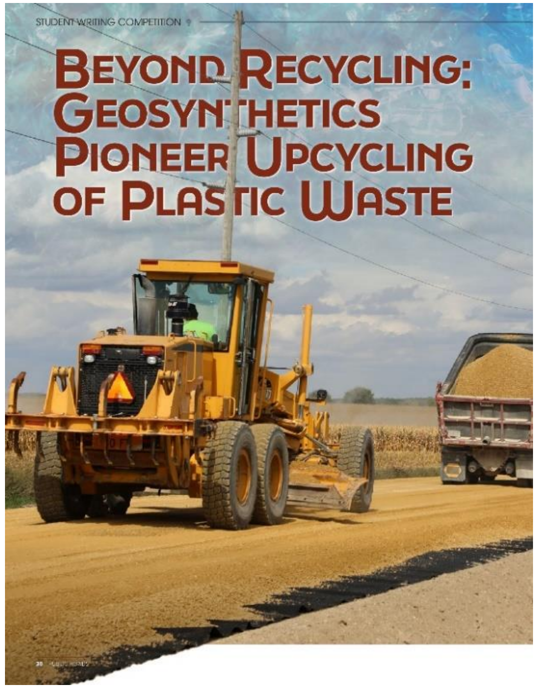
Good morning | July 15, 2025

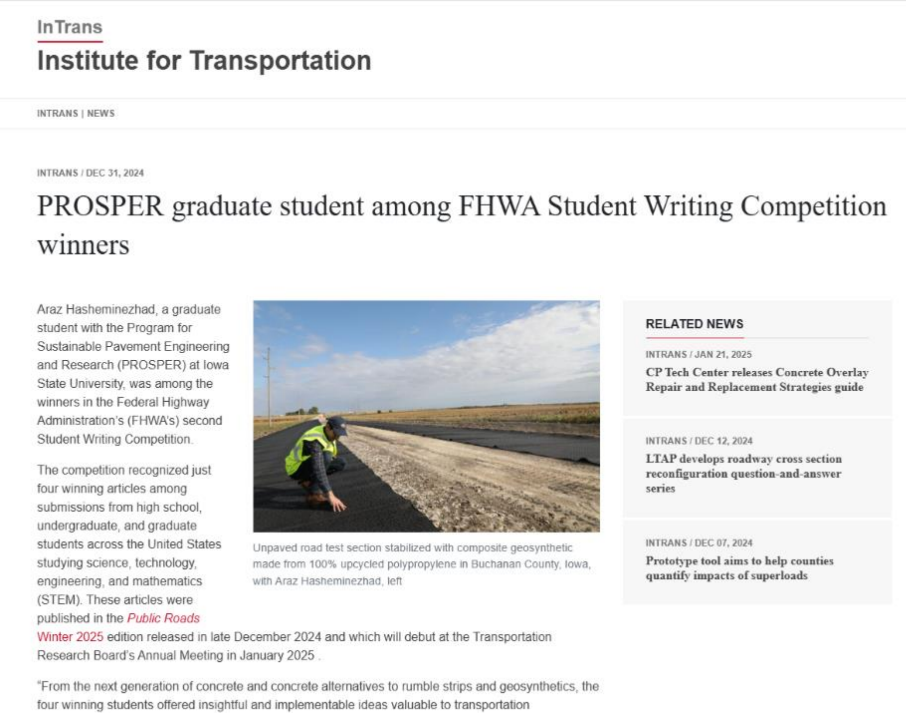
LEADING THE NEWS

Survey Reveals Adults' Misconceptions About College Costs
Higher Ed Dive (7/14, McLean) reports that a Strada survey found that a large majority of US adults "say the cost of attaining a college degree is more expensive than it actually is – a perception that may cause some to forgo education beyond high school." Conducted in November 2024, the survey revealed that 77 percent of adults perceive college as unaffordable, with 65 percent agreeing it is prohibitively expensive. Many respondents significantly overestimated costs; for instance, one in five believe community college costs "more than $20,000 annually," while the actual average is "about $6,000 annually, the report said, citing College Board

Awards and Achievements (Cont'd)

- U.S. Department of Transportation Federal Highway Administration (FHWA) 2nd Annual Student Writing Competition Winner
  - *Article published in Public Roads magazine (Winter 2025 issue)*
  - ***Being selected as one of the first student writers featured in Public Roads, a prestigious publication that has existed for more than 100 years.)***
  - Showcased at the 104th Transportation Research Board (TRB)'s Annual Meeting, Washington, DC, January 2025




InTrans
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INTRANS | NEWS

INTRANS / DEC 31, 2024

PROSPER graduate student among FHWA Student Writing Competition winners

Araz Hasheminezhad, a graduate student with the Program for Sustainable Pavement Engineering and Research (PROSPER) at Iowa State University, was among the winners in the Federal Highway Administration's (FHWA's) second Student Writing Competition.

The competition recognized just four winning articles among submissions from high school, undergraduate, and graduate students across the United States studying science, technology, engineering, and mathematics (STEM). These articles were published in the Public Roads Winter 2025 edition released in late December 2024 and which will debut at the Transportation Research Board's Annual Meeting in January 2025.

"From the next generation of concrete and concrete alternatives to rumble strips and geosynthetics, the four winning students offered insightful and implementable ideas valuable to transportation

Unpaved road test section stabilized with composite geosynthetic made from 100% upcycled polypropylene in Buchanan County, Iowa, with Araz Hasheminezhad, left

RELATED NEWS

INTRANS / JAN 21, 2025
CP Tech Center releases Concrete Overlay Repair and Replacement Strategies guide

INTRANS / DEC 12, 2024
LTAP develops roadway cross section reconfiguration question-and-answer series

INTRANS / DEC 07, 2024
Prototype tool aims to help counties quantify impacts of superloads

Acknowledgement

- **Transportation Research Board (TRB)**
  - Victor M. Garcia, Ph.D., Laura Fay, Ericka Hall, and others for organizing this fantastic event and giving me the opportunity to share our research.

- **Project PI and Co-PIs:**
  - PI: Halil Ceylan, Ph.D., Dist.M.ASCE
  - Co-PIs: Sugnhwan Kim, Ph.D., P.E and Erol Tutumluer, Ph.D., Dist.M.ASCE

- **Collaborators:**
  - Brian Keierleber and his staff in Buchanan County, Iowa
  - Tensar
  - Project TAC members
  - PROSPER team members
  - UIUC team members

- **This research is supported by the Iowa Highway Research Board and the Iowa Department of Transportation under grant TR-799 "Base Stabilization of Iowa Granular Roads Using Recycled Plastics"**

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PROSPER

Iowa State University

Institute for Transportation

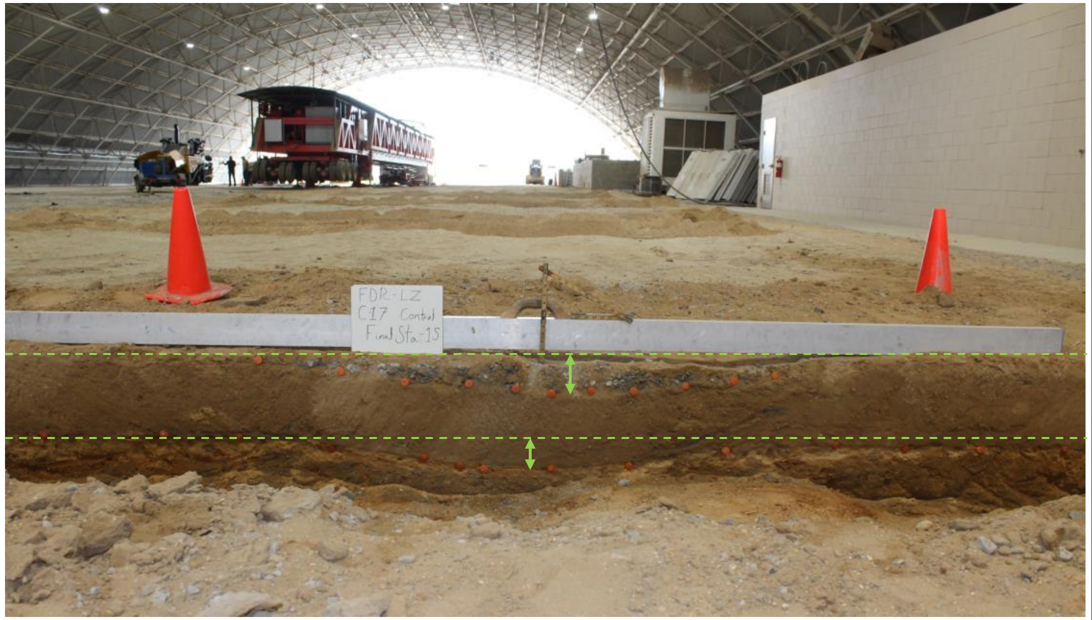
Extra Slides

- **Field CBR Test**
- The clegg impact soil tester (CIST) measures soil properties related to the California Bearing Ratio (CBR).
- This tool provides practical insights into soil strength and compaction, indirectly estimating CBR.
- It drops a 10 lb. hammer onto the soil surface, recording the clegg impact value (CIV) per ASTM D5874.
- Higher CIV values indicate stiffer, more compacted soils. The CIV can be empirically correlated to CBR using the Equation below:
- $CBR = 0.1691 \times (CIV)^{1.695}$

Full-scale Performance of Chemically Stabilized Unpaved Landing Zones for Military Aircraft Operations

- Brendon Quon
- Research Civil Engineer
- Brendon.D.Quon@erdc.dren.mil

- September 2025
- Advancing Unpaved Roads and Airfields Through Graduate Research



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BACKGROUND

- Semi-prepared Landing Zones (LZs)
  - Contingency aircraft operations
  - Difficult due to poor native soil/materials

- Traditional LZs comprised of unbound aggregates or compacted native subgrade
  - High-quality materials
  - Portland Cement Concrete (PCC)
  - Asphalt Concrete (AC)

- Full-Depth Reclamation (FDR) technique
  - Initially developed for rehabilitation of asphalt pavements
  - Pulverizing/reclaiming the “full” surface layer to stabilize and enhance its structural capacity
  - Chemical (Cement, Lime, Fly Ash)
  - Bituminous (Asphalt Emulsion)

OBJECTIVES

- Cargo aircraft may be required to operate on unpaved or aggregate-surface airfields
  - Generally designed for limited operations
  - May have relatively low-strength surface materials (≤ 20 CBR)
  - May experience significant rutting damage
- Techniques to extend operational capabilities are needed
  - Full-depth reclamation (FDR) may be one solution
  - Minimize required equipment
  - Unknown performance of in-situ material

- Determine performance of an unpaved LZ reconstructed with an FDR technique to support development of performance models

APPROACH

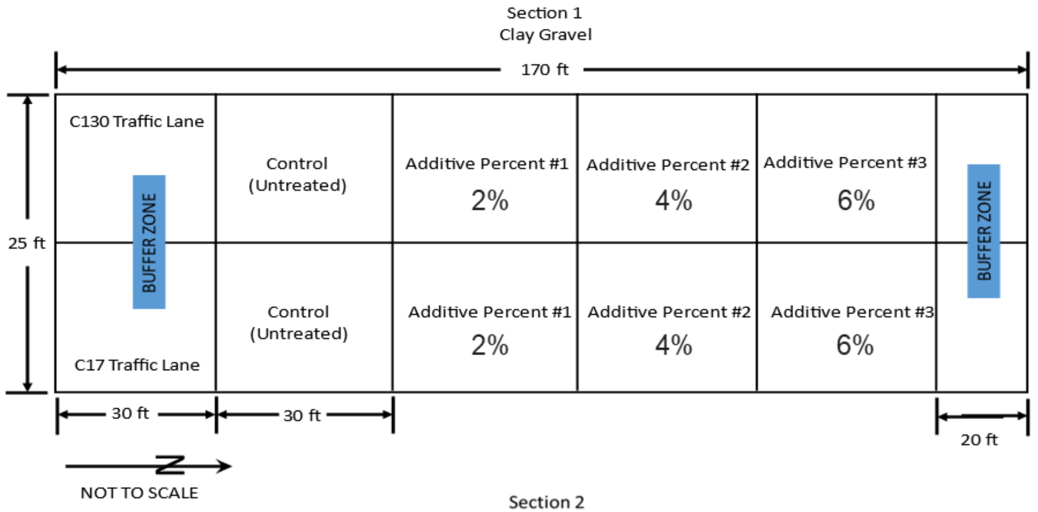
- Construct (2) test sections with commonly available granular materials stabilized with cement
  - "Clay Gravel" (SP-SC)
  - Silty Sand (SM)
  - Sand (Subgrade)

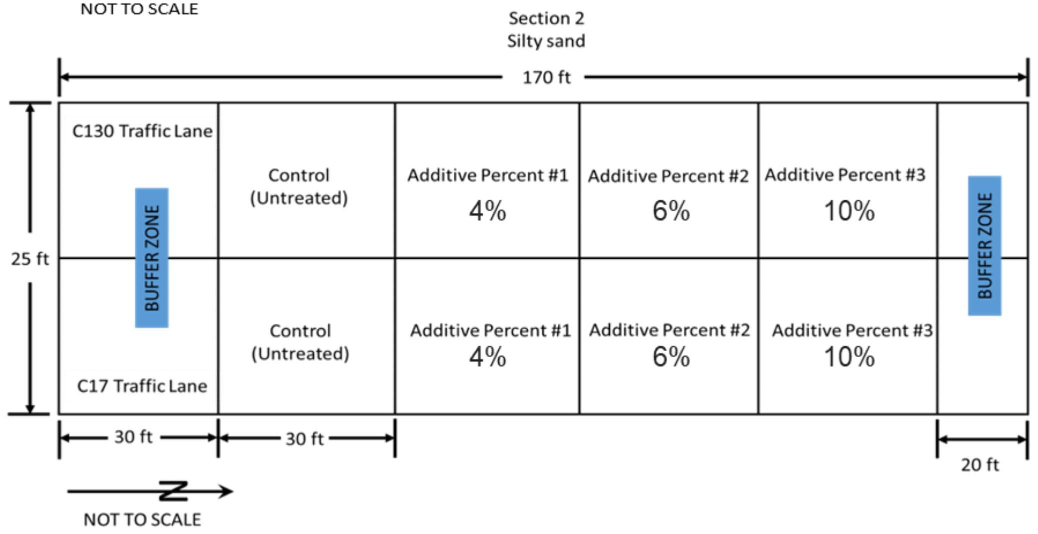
- (4) different test items for both test sections
  - (3) Increasing cement contents by weight
  - 2% to 10% cement addition
  - (1) Untreated Test Item

Loading Conditions for Auxiliary Airfields:

C-130:
Wheel load = 39,375 lb
Tire = 100 psi

C-17:
Wheel load = 38,500 lb
Tire = 142 psi





- Perform traffic operations using cargo military aircraft to determine the soil strength/stiffness characteristics between the two different surface materials

MATERIAL CHARACTERIZATION

Targeting Compressive Strength (psi)

- 350 psi (Low range Cement Additive)
- 700 psi (Mid range Cement Additive)
- 1200 psi (High range Cement Additive)

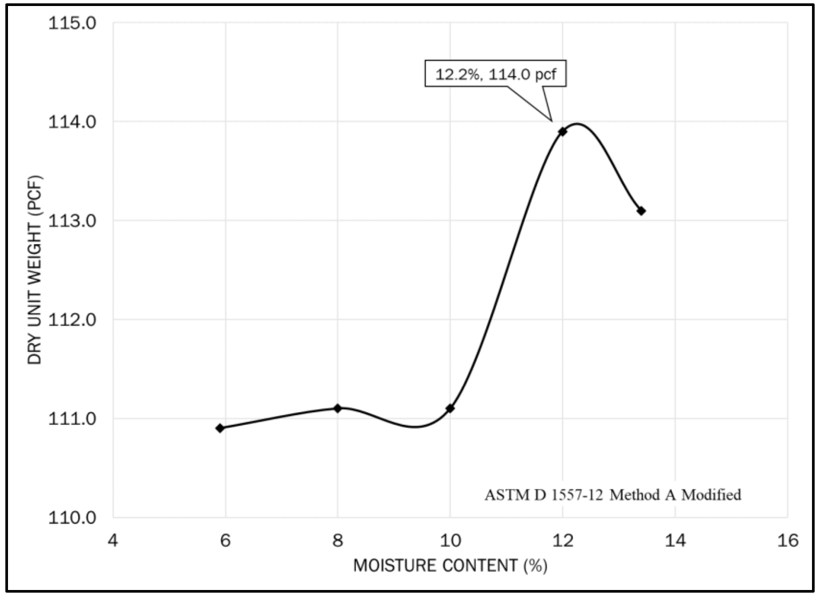
[SP-SC] Compressive Strength

- 361 psi
- 668 psi
- 1076 psi

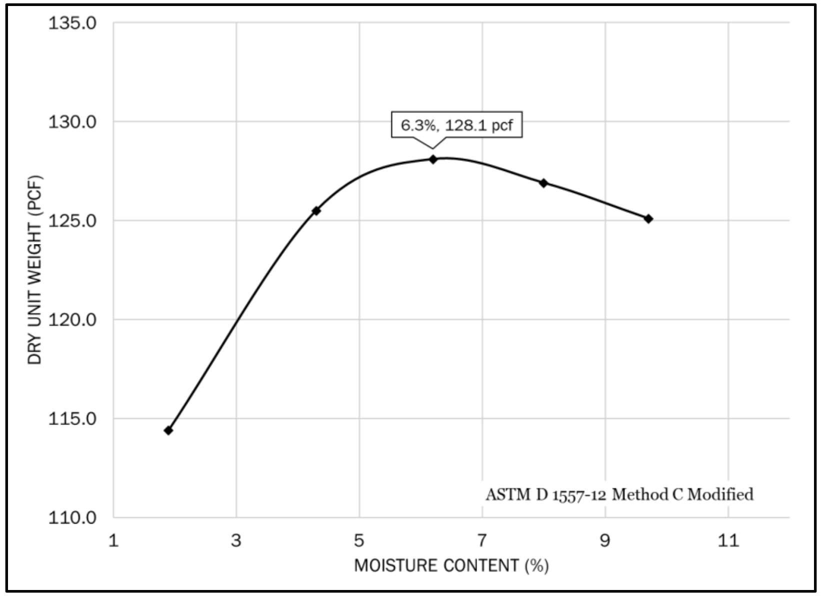
[SM] Compressive Strength

- 347 psi
- 722 psi
- 1358 psi

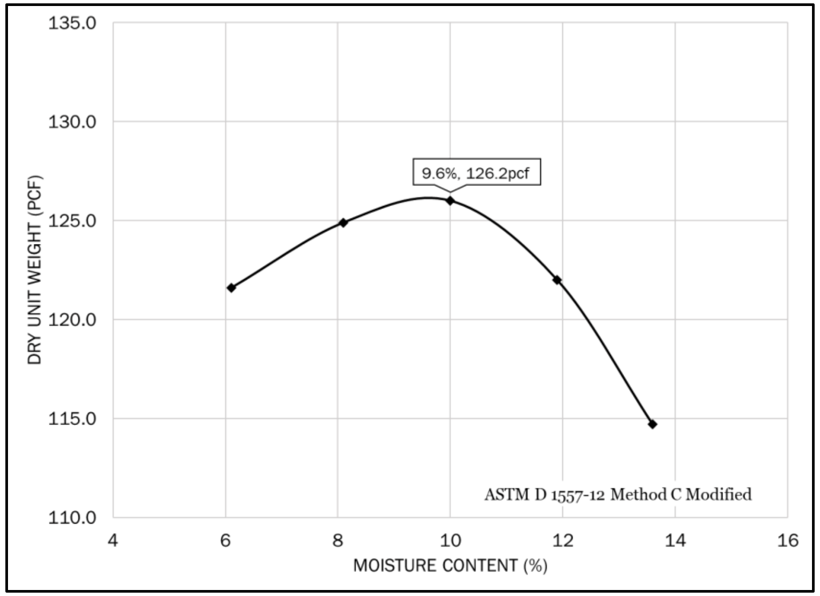
Subgrade (SP) Compaction Curve



Section 1 (SP-SC) Compaction Curve



Section 2 (SM) Compaction Curve



TEST SECTION CHARACTERIZATION

C-17 Traffic Lane

Clay Gravel Surface Course(128.1pcf @ 6.3%)				
Cement Content (%)	Test Item 1 (0%)	Test Item 2 (2%)	Test Item 3 (4%)	Test Item 4 (6%)
Dry Density (pcf)	123.0 ± 2.9	111.5 ± 3.2	109.7 ± 1.5	108.9 ± 3.3
Oven-Dried Moisture (%)	6.8	7.9	7.8	7.8
CBR (DCP)	21 ± 0.1	38 ± 3.8	57 ± 9.4	68 ± 7.4
Thickness (in.)	11.7 ± 0.2	11.3 ± 0.4	11.9 ± 0.1	11.6 ± 0.3
Silty Sand Surface Course(126.2pcf @ 9.6%)				
Dry Density (pcf)	121.5 ± 0.8	117.0 ± 5.4	122.8 ± 2.4	116.5 ± 5.8
Oven-Dried Moisture (%)	7.0	7.4	6.9	6.1
CBR (DCP)	19 ± 0.8	75 ± 5.1	88 ± 4.5	95 ± 4.0
Thickness (in.)	11.4 ± 0.3	11.7 ± 0.5	11.9 ± 0.2	12.3 ± 0.3

*OMC = Optimum Moisture Content, pcf = pounds per cubic foot, CBR = California Bearing Ratio, DCP = Dynamic Cone Penetrometer

C-130 Traffic Lane

Clay Gravel Surface Course(128.1pcf @ 6.3%)				
Cement Content (%)	Test Item 1 (0%)	Test Item 2 (4%)	Test Item 3 (6%)	Test Item 4 (10%)
Dry Density (pcf)	127.0 ± 1.8	111.5 ± 2.0	107.5 ± 2.2	105.1 ± 1.1
Oven-Dried Moisture (%)	7.1	7.1	9.4	9.0
CBR (DCP)	25 ± 2.4	37 ± 4.3	40 ± 3.7	51 ± 4.1
Thickness (in.)	11.7 ± 0.2	11.3 ± 0.3	11.4 ± 0.2	11.1 ± 0.3
Silty Sand Surface Course(126.2pcf @ 9.6%)				
Dry Density (pcf)	126.0 ± 1.7	116.2 ± 0.4	118.6 ± 3.9	120.6 ±0.8
Oven-Dried Moisture (%)	6.3	6.7	6.3	6.2
CBR (DCP)	25 ± 14	96 ± 15	99+	99+
Thickness (in.)	11.1 ± 0.2	11.4 ± 0.6	11.6 ± 0.4	12.6 ± 0.7

*OMC = Optimum Moisture Content, pcf = pounds per cubic foot, CBR = California Bearing Ratio, DCP = Dynamic Cone Penetrometer

CONSTRUCTION METHODS



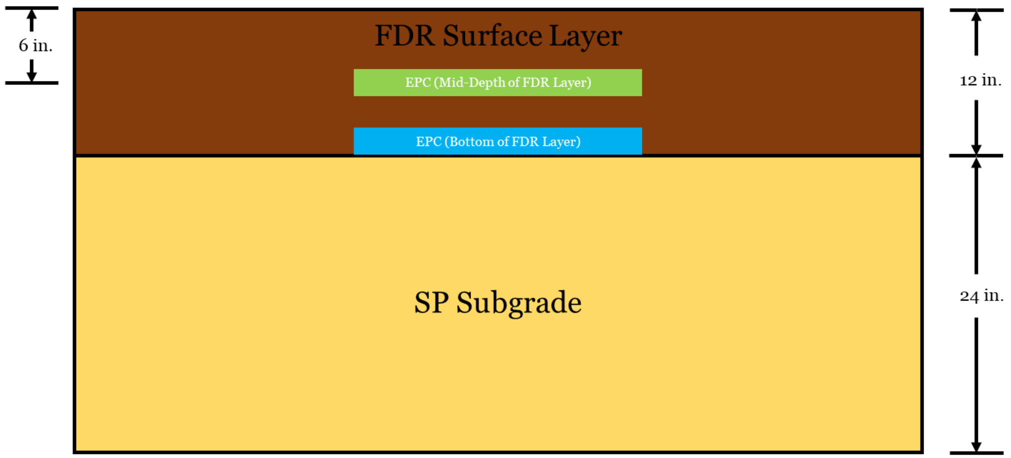



INSTRUMENTATION

Instrumentation

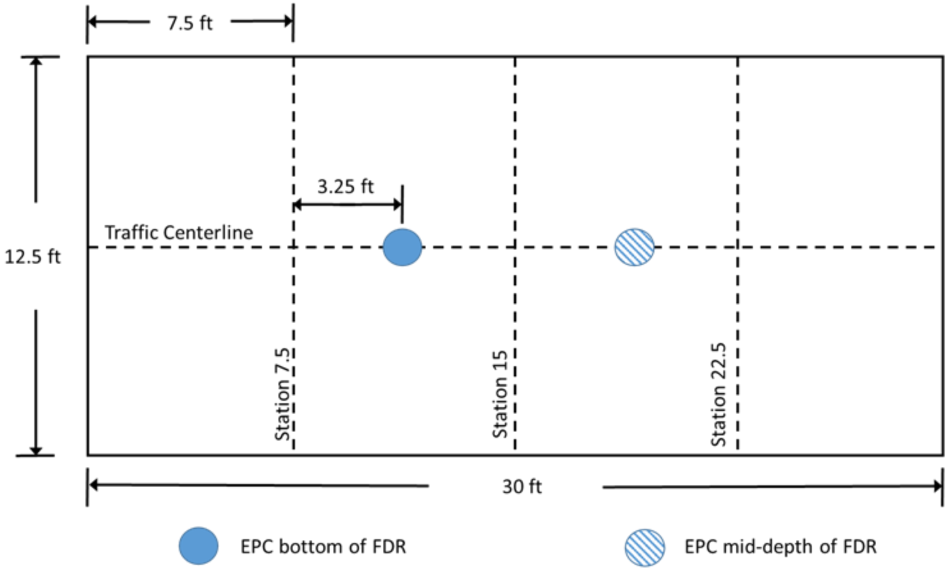
- Fully instrumented and monitored with non-destructive test methods at select traffic intervals
  - Falling Weight Deflectometer (FWD)
  - Light Weight Deflectometer (LWD)
  - Total Station Robotic Survey (Rutting/Deformation)

- Earth Pressure Cells (EPCs) used to analyze the stress distribution throughout the layers



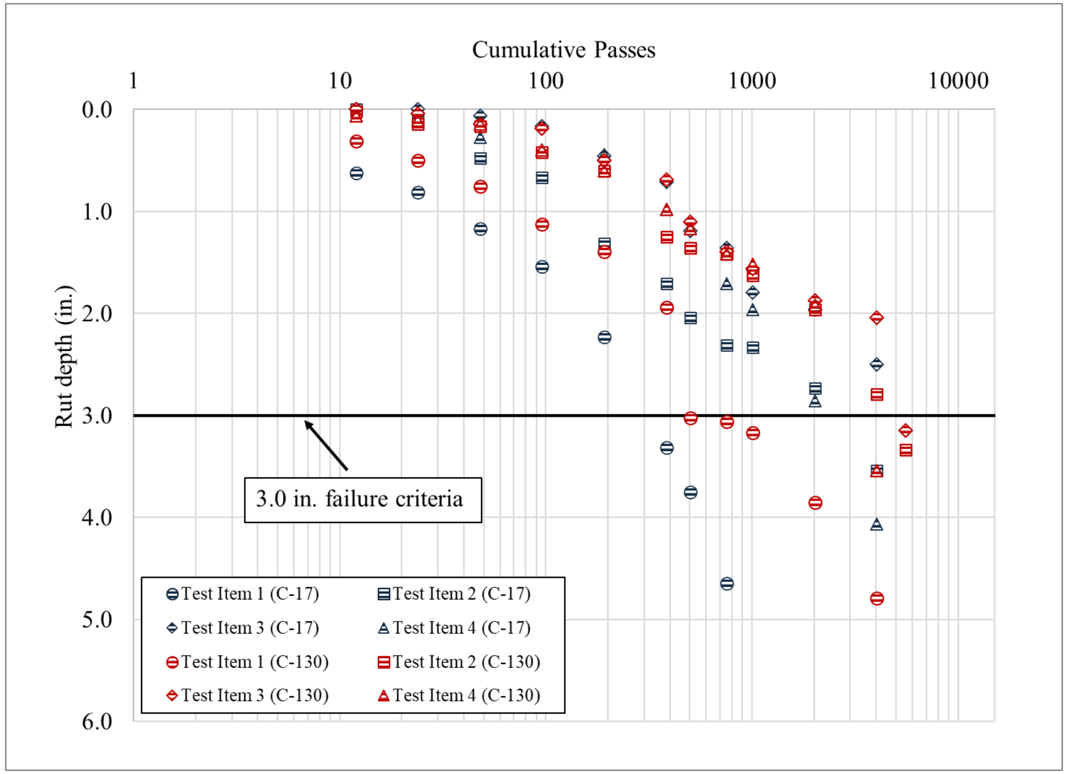
FDR = (SP-SC) or (SM)
SP = Poorly Graded Sand
EPC = Earth Pressure Cell

NOT TO SCALE

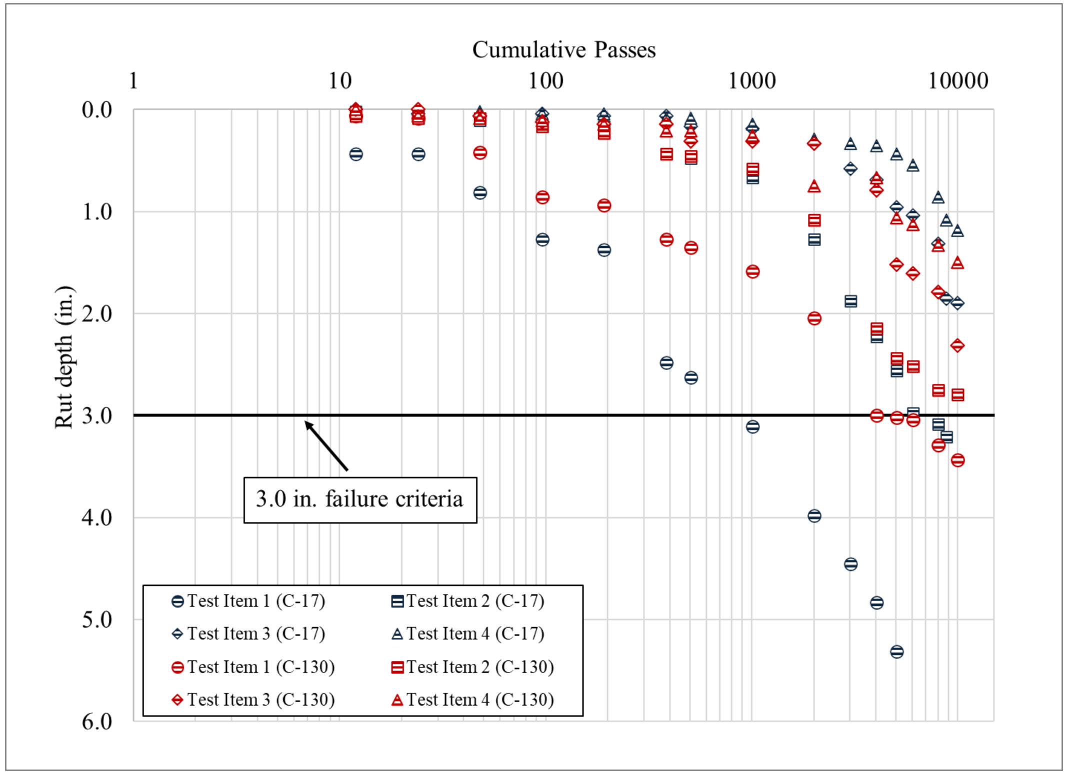


RUTTING/DEFORMATION

- Better performance from the (SM) material compared to the (SP-SC) material
- C-130 outperformed C-17 in both Test Sections
  - Lower tire inflation pressure in C-130
- Nearly 5,000+ more traffic passes achieved in the (SM) material with the highest cement contents



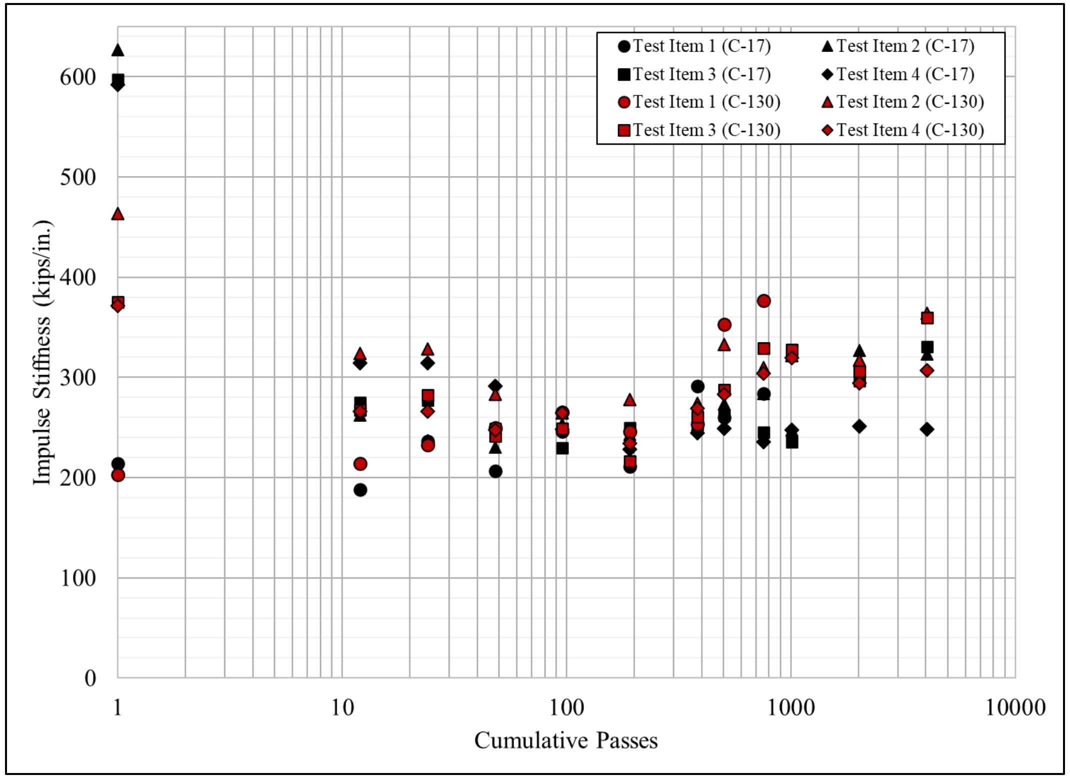
Test Section 1 (SP-SC)



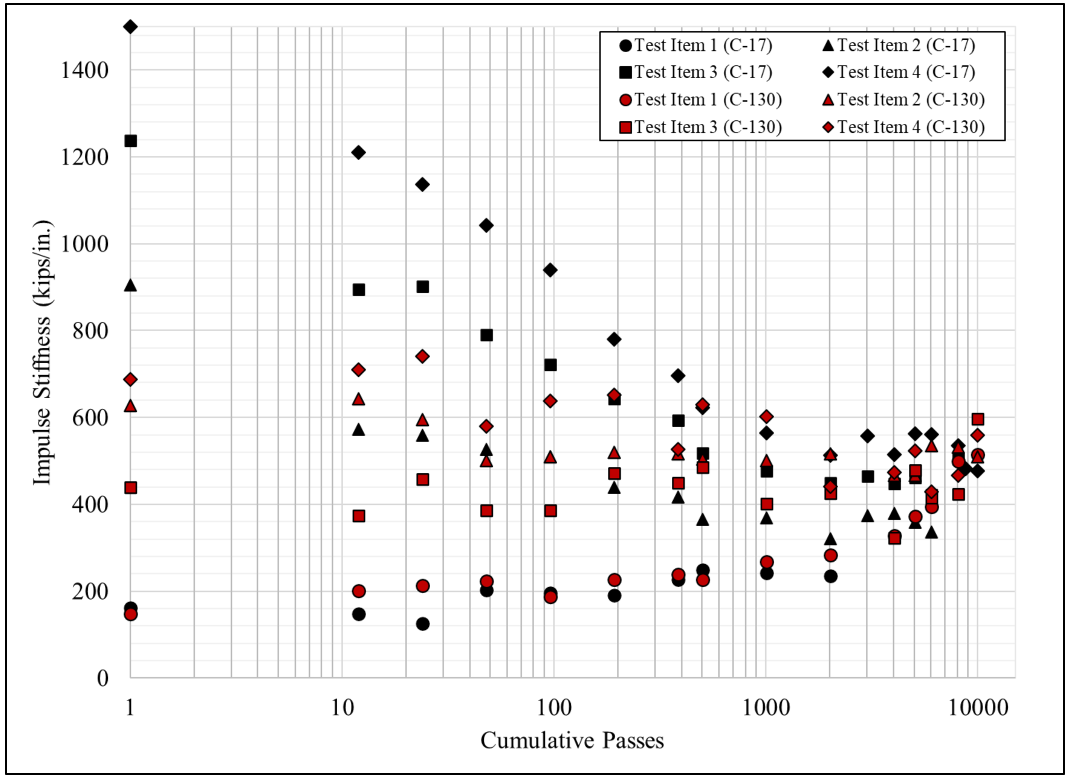
Test Section 2 (SM)

FWD IMPULSE STIFFNESS

- Little stiffness change in (SP-SC) material throughout traffic (200-350 kips/in.)
  - An initial decrease in stiffness was observed, but as traffic continued, the values remained relatively comparable (SP-SC)
- Higher initial stiffness values in the (SM) material
  - A downward trend in stiffness was observed as traffic passes increased until reaching a structural deterioration threshold where additional loading did not result in further decrease (SM)



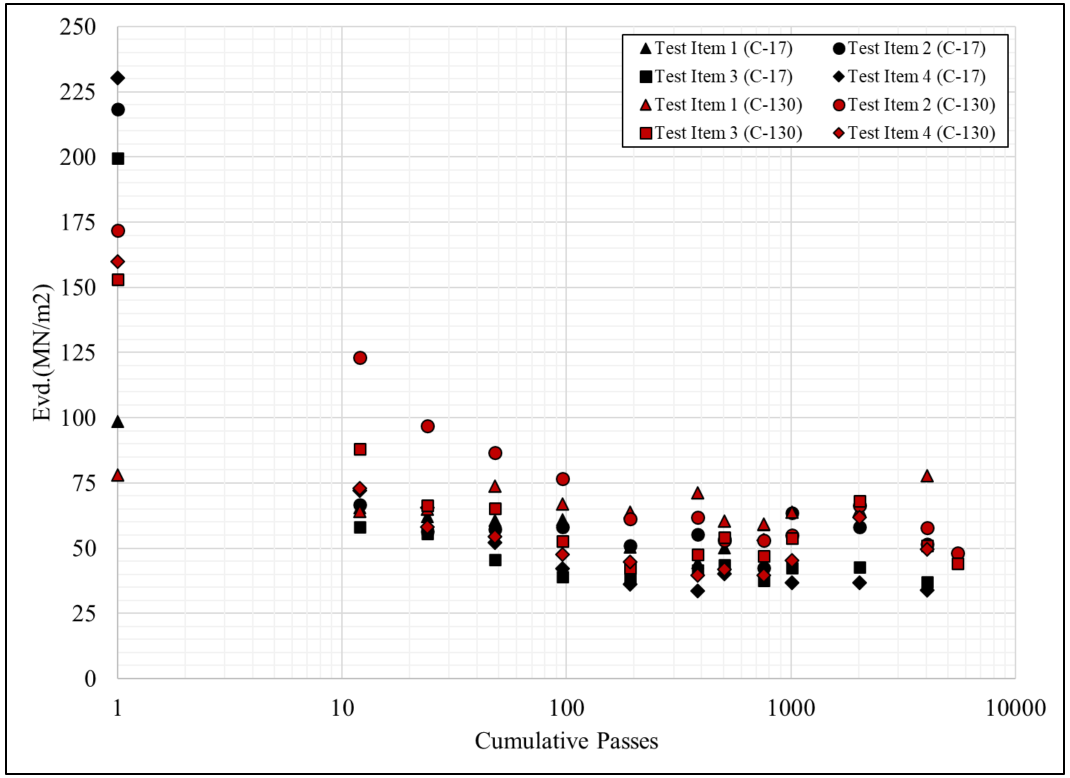
Test Section 1 (SP-SC)



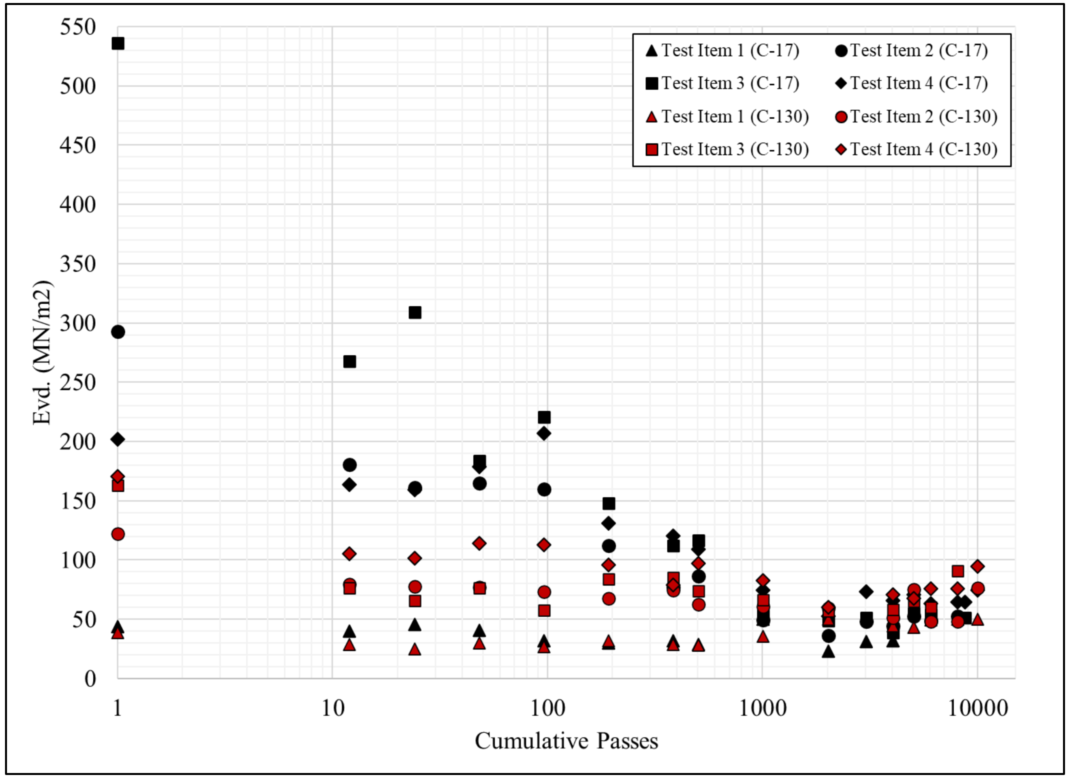
Test Section 2 (SM)

LWD DYNAMIC MODULUS

- Higher initial values in the (SM) material (Similar to FWD trends) compared to (SP-SC)
  - A downward trend in stiffness was observed as traffic passes accumulated until reaching a threshold where additional loading did not result in further decrease
- LWD was sensitive to the increased stiffness values (200+ MN/m2)
  - Possible that the weight of the drop hammer on the LWD was not enough to accurately display the stiffness of the stabilized material in the (SM) material



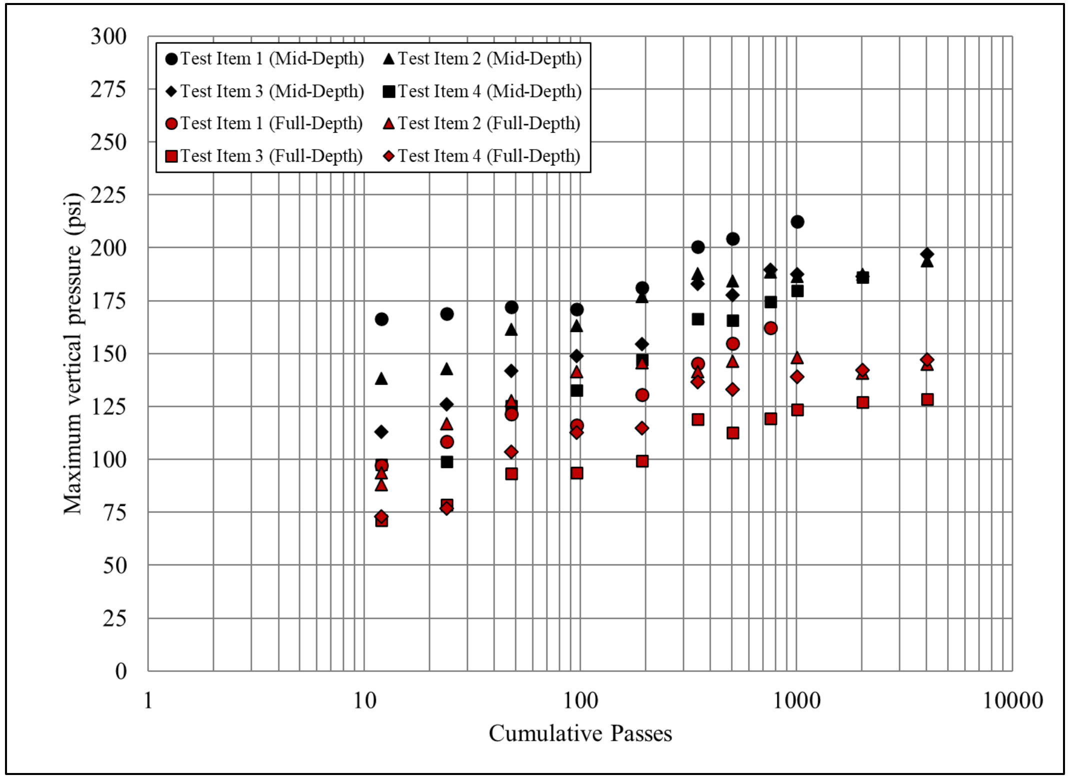
Test Section 1 (SP-SC)



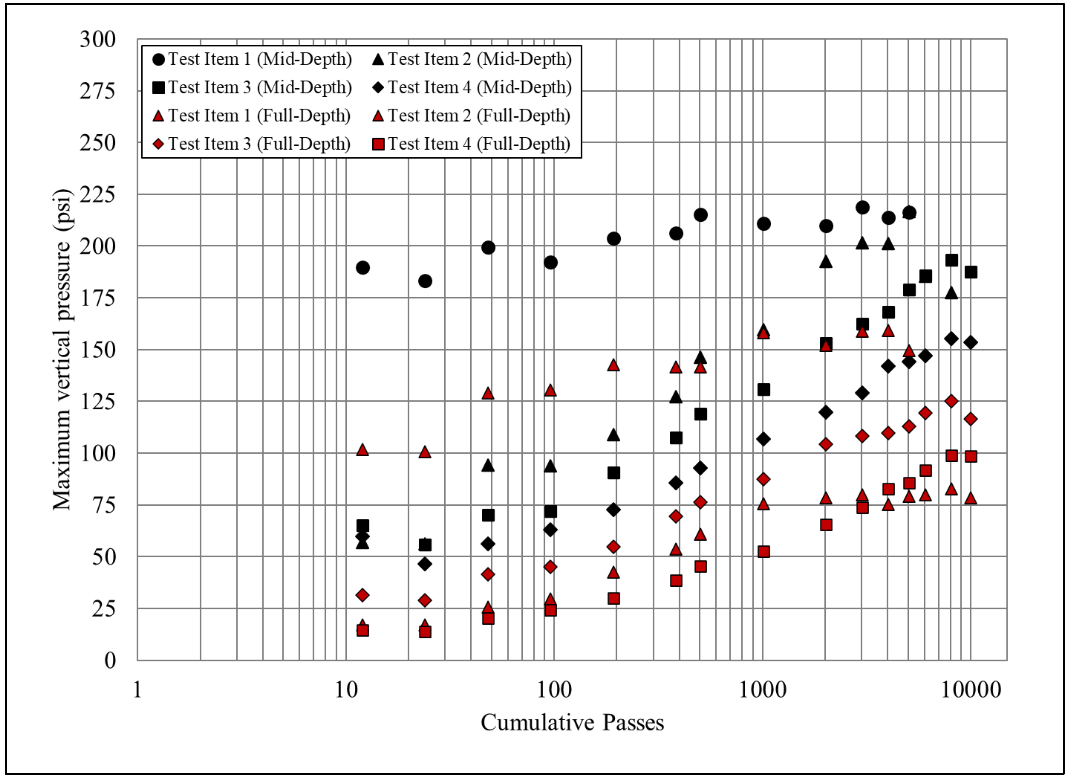
Test Section 2 (SM)

PRESSURE RESPONSE (C-17)

- Lower pressure response due to higher strength and stiffness in the (SM) material
  - High response in the mid-depth Earth Pressure Cell (EPC) in Test Item 1
- Consistent pressure response increase in each Test Section
  - Responses increased (5-10 psi) at each data collection interval
- Some Test Items did not follow expected trends having higher responses with less cement added to the Item (Test Item 3 lower response than Test Item 4 in Test Section 1)



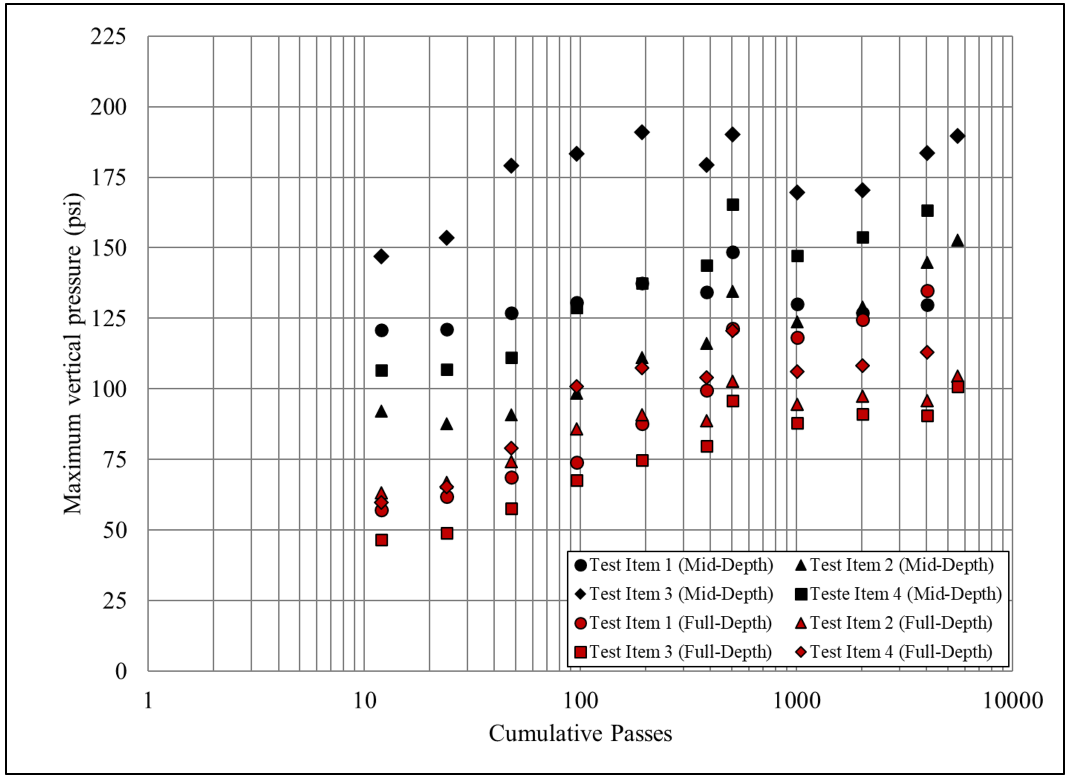
Test Section 1 (SP-SC)



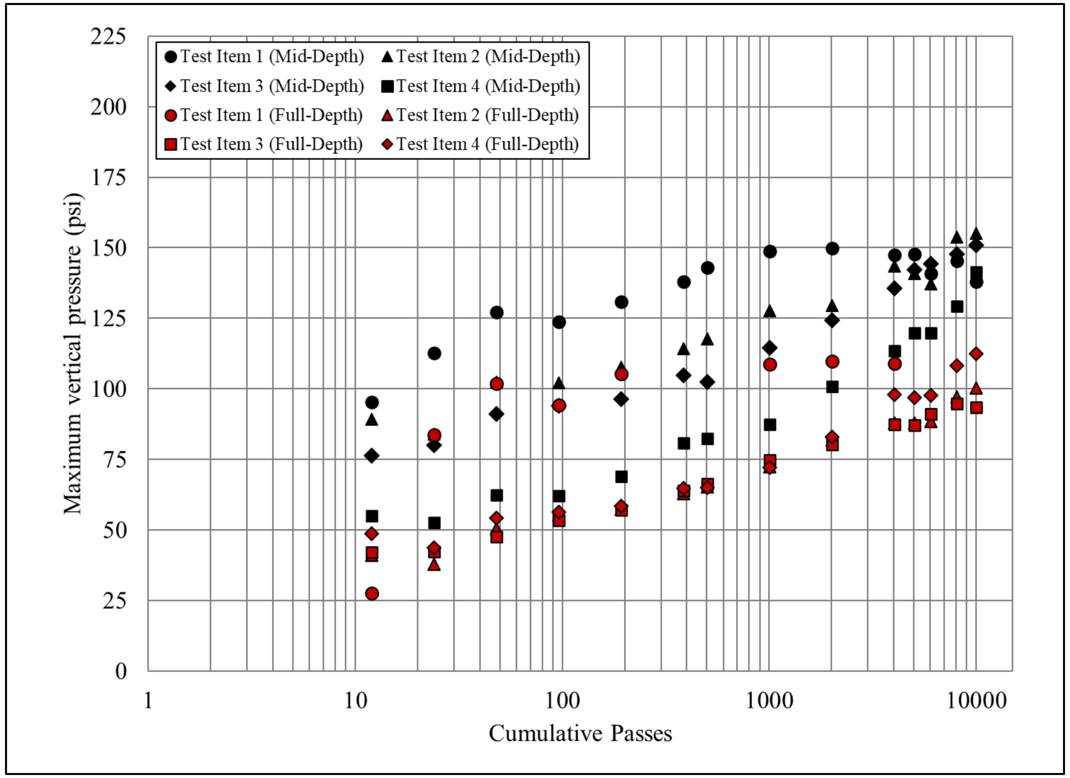
Test Section 2 (SM)

PRESSURE RESPONSE (C-130)

- Lower pressure responses in the C-130 traffic lane due to lower tire inflation pressure
  - C-130 range = (25 psi to 190 psi)
  - C-17 range = (15 psi to 220 psi)
- Test Section 2 followed expected trends with lower responses observed compared to Test Section 1
  - Same as C-17 traffic lanes



Test Section 1 (SP-SC)



Test Section 2 (SM)

FINDINGS

- Construction – time limited
  - Density concerns
  - Cement content variability

- Performance data suggest this is a viable technique to extend operations in a remote location
  - Limited materials, equipment, troop construction
  - Cement-stabilized Test Items withstood 3,000+ more traffic passes in the SP-SC material
  - Cement-stabilized Test Items withstood 6,000+ more traffic passes in the SM material

- EPC data
  - Non-uniform contact area creating high pressure responses

- Ongoing effort to leverage response data to enhance performance models
  - Unconfined Compressive Strength (UCS) may not be a reasonable indicator of performance
  - Appears to be inherent material characteristics that influenced performance

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[Intro to the Fellowship & Application Process Webinar]

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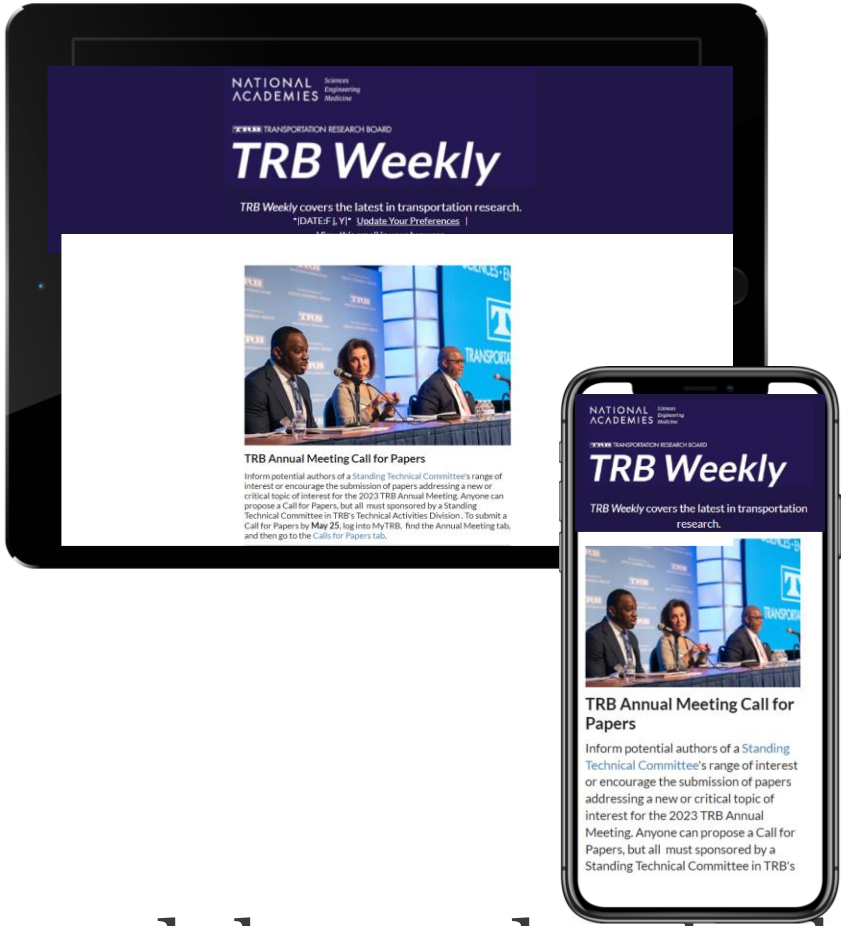

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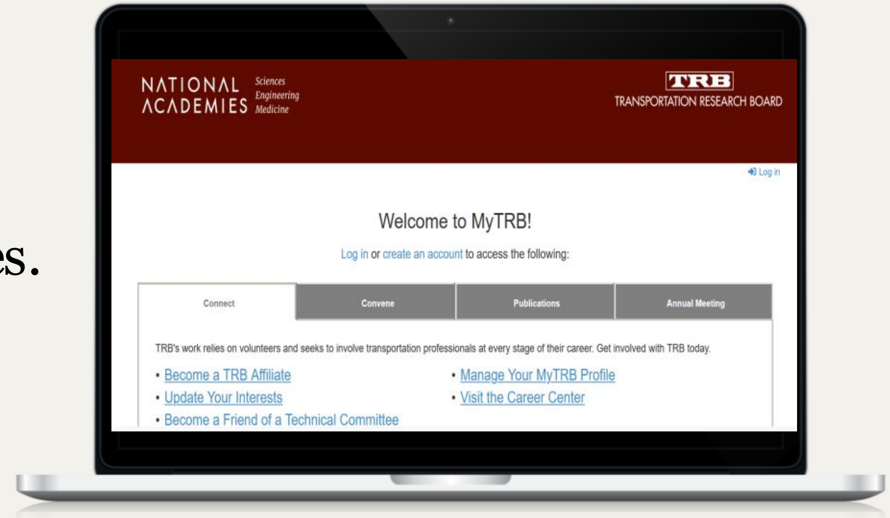

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