



# Building Roads That Last: Exploring Perpetual Pavements in Wet-Freeze Climates

Michael Vrtis, P.E. (MN), Ph.D. | Assistant MnROAD Operations Engineer

# MnROAD's Mission Statement (Michael's Version)

- *Our goal is to provide safe, long-lasting pavements that cost less to the taxpayer and the environment.*



- What is a Perpetual Pavement and where did they come from?
  - How is a Perpetual Pavement designed?
    - Structural design
    - Mix Design
- NRRRA MnROAD WisDOT PP Test Sections
  - MnROAD Sections
  - WisDOT Sections
  - Reclamation and Recycling
- Summary

# Perpetual Pavement History?

- Observed success of “full depth asphalt” or “deep strength” designs
  - Full depth Asphalt =asphalt layers directly on subgrade
  - Deep strength = thicker asphalt on thin granular base
- 1992 I-720 Freeway design in California by Carl Monosmith (1)
- Early 2000’s – Modern Perpetual Pavement process initiated
  - Asphalt Pavement Alliance Awards
  - NCAT Test Track
  - PER ROAD Design Software

# What is a Perpetual Pavement?

2001

The concept of long-lasting pavements is not new.

12/12/2024

## Concepts of Perpetual Pavements

**DAVID E. NEWCOMB**

*National Asphalt Pavement Association*

**MARK BUNCHEER**

*Asphalt Institute*

**IRA J. HUDDLESTON**

*Asphalt Pavement Association of Oregon*

The construction of long-lasting hot mix asphalt pavements has been practiced for a number of decades in the United States. Full-depth (asphalt courses used for all layers above subgrade) and deep-strength (asphalt surface and asphalt base over a minimal aggregate base above subgrade) pavements were originally designed for 20-year life expectancies. One of the primary advantages to these designs was that the total pavement sections were thinner when compared to conventional designs of asphalt over thick aggregate bases. As these full-depth and deep-strength pavements performed beyond their design lives, the vast majority only required surface restoration such as a thin overlays or mill and overlay. This practice of replacing only the surface offers a number of rehabilitation advantages in terms of speed of construction (user delay costs) and construction costs. The challenge for today is to obtain a longer surface life on a long-lasting asphalt support structure. Recent efforts in materials selection, mixture design, performance testing, and pavement design offer a methodology which may be employed to obtain very long-term performance from asphalt pavement structures (greater than 50 years) while periodically (approximately every 20 years) replacing the surface (top 25 to 100 mm) of the pavement. This concept has been proposed for use in Europe and it is rapidly gaining acceptance in the United States. The common theme in these approaches is to combine a rut resistant, impermeable, and wear resistant top structural layer with a rut resistant and durable intermediate layer and a fatigue resistant and durable base layer.

The concept of long-lasting asphalt pavements is not new. Full-depth and deep-strength asphalt pavement structures have been constructed since the 1960s. Full-depth pavements are

# What is a Perpetual Pavement?

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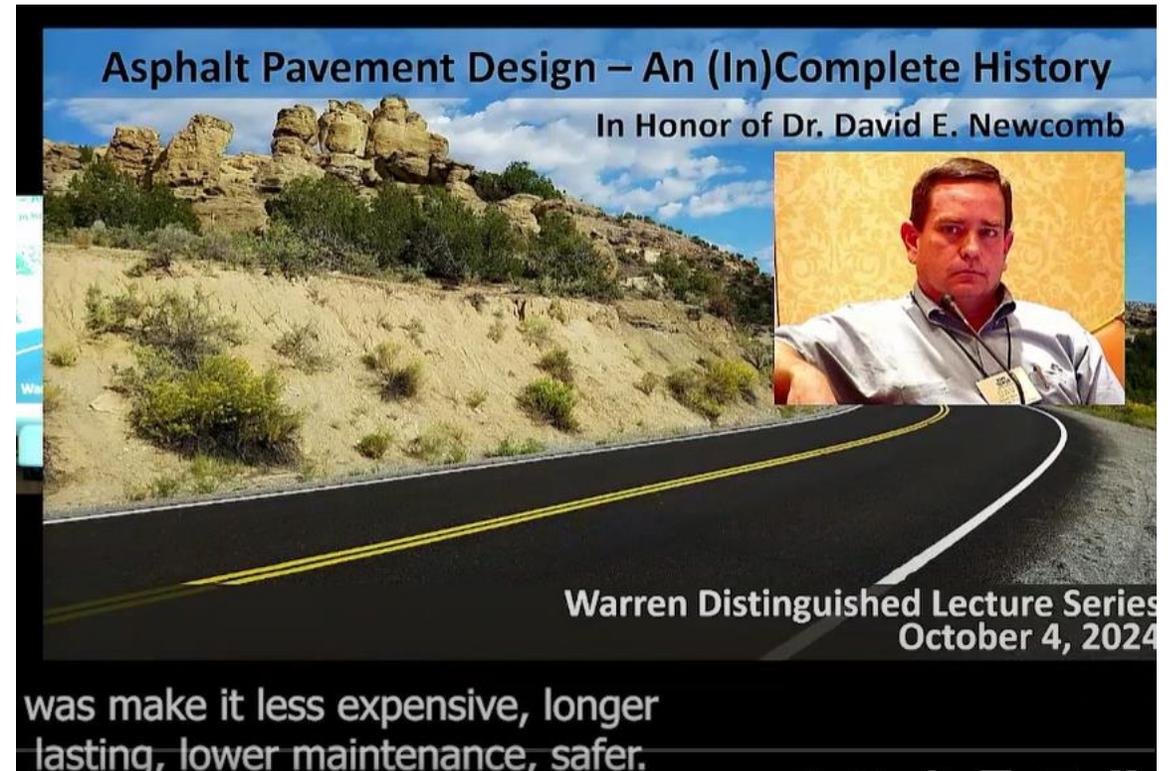
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<https://www.youtube.com/watch?v=ZtZokD98Ils>

Presented by Dr. David Timm at Auburn University

# What is a Perpetual Pavement?

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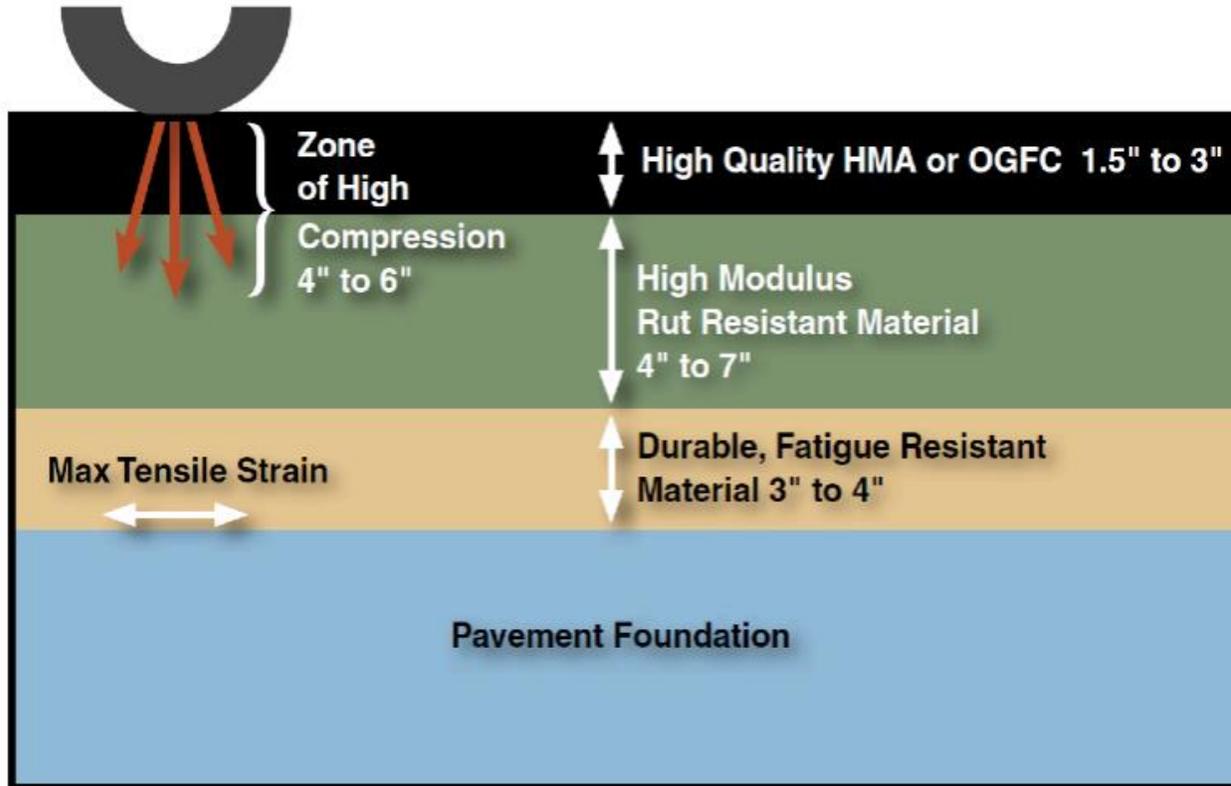
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- Asphalt pavement structures designed **and built** to last greater than 50 years with surface maintenance every 20 years
- Accomplished by: material selection, mix design, structural design, and performance testing

# What is a Perpetual Pavement?



**Total HMA thickness=**

$$1.5'' + 4'' + 3'' = 8.5''$$

to

$$3'' + 7'' + 4'' = 14''$$

(2) Newcomb, D., R. Willis, and D. Timm. Perpetual Asphalt Pavements: A Synthesis, APA, Lanham, MD, 2010.

# Perpetual Pavement Mix Design

**Top Layer** : High Quality HMA Layer. Withstand wear of traffic. Seal pavement.  
Protect rest of structure

**Middle Layer** : Stiff, Rut Resistant Layer. Reduce strain at bottom of HMA

**Bottom Layer** : Flexible, strain absorbing mix. Durable to prevent stripping /  
deterioration from moisture in unbound layers

# Perpetual Pavement Mix Design

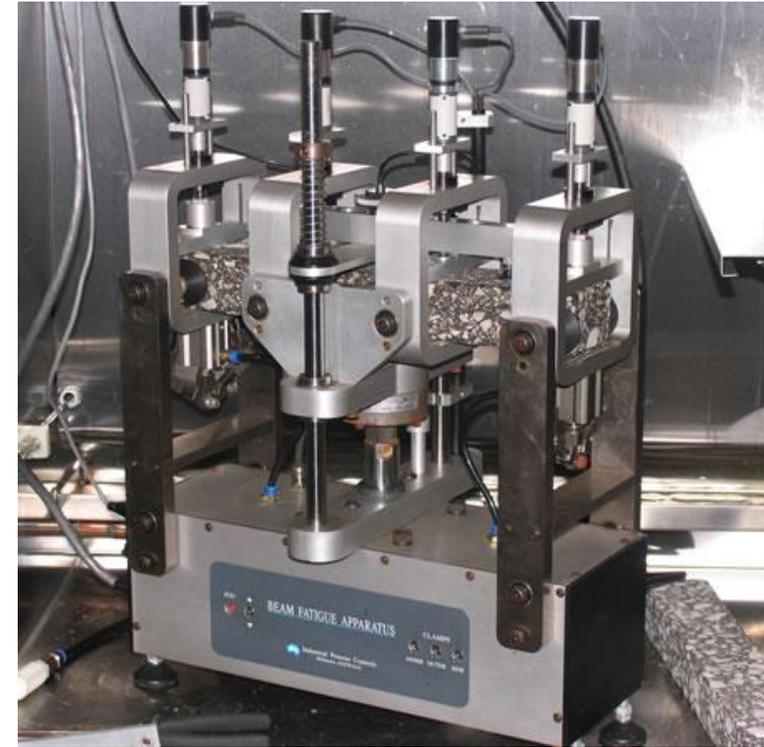
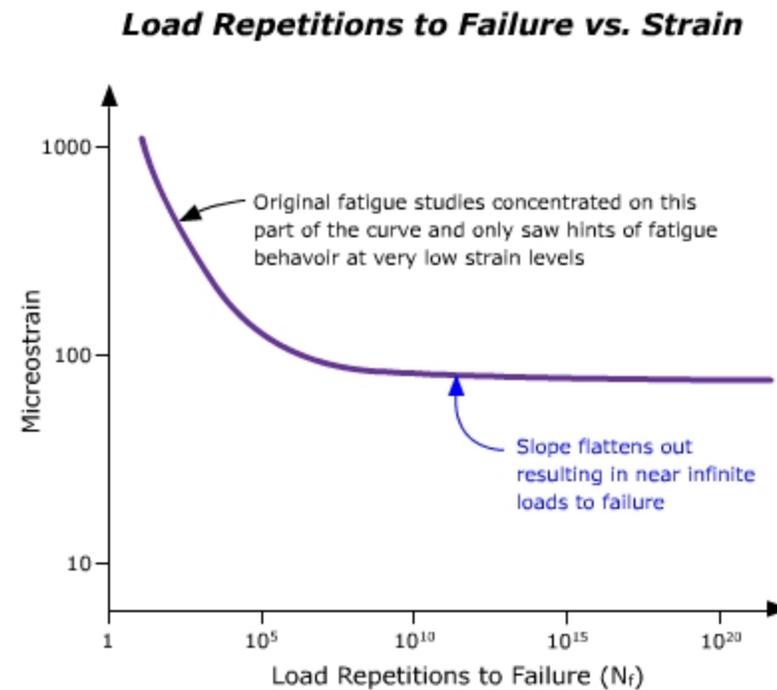
Top Layer : High Quality HMA Layer

Middle Layer : Stiff Rut Resistant Layer

Bottom Layer : Flexible and Durable



Figure 5: Hamburg Wheel Tracking Device (HWT) from (Stuart and Youtcheff, 2001<sup>[3]</sup>).



<https://pavementinteractive.org/reference-desk/testing/pavement-tests/flexural-fatigue/>

# Perpetual Pavement Structural Design

- Traditional Structural Design
  - Limit cumulative horizontal tensile strain at bottom of HMA
    - Miner's Law
  - Limit vertical pressure on unbound layers
  - Focused on total HMA/ unbound layer thickness

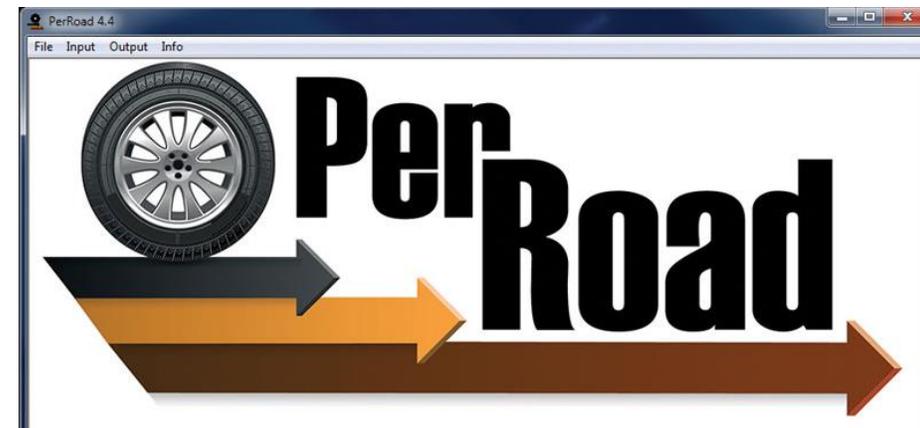
- Perpetual Pavement Structural Design
  - Limit horizontal strain under Fatigue Endurance Limit or Cumulative Strain Distribution



MnPAVE7

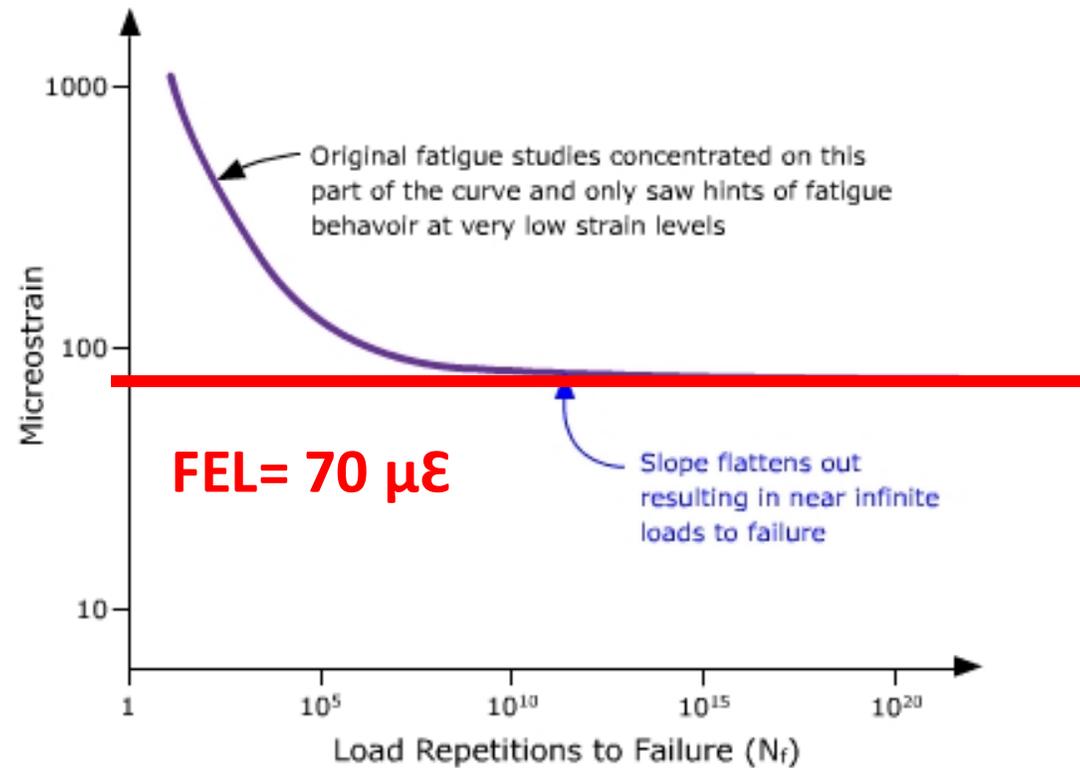
Published by MnDOT

Install

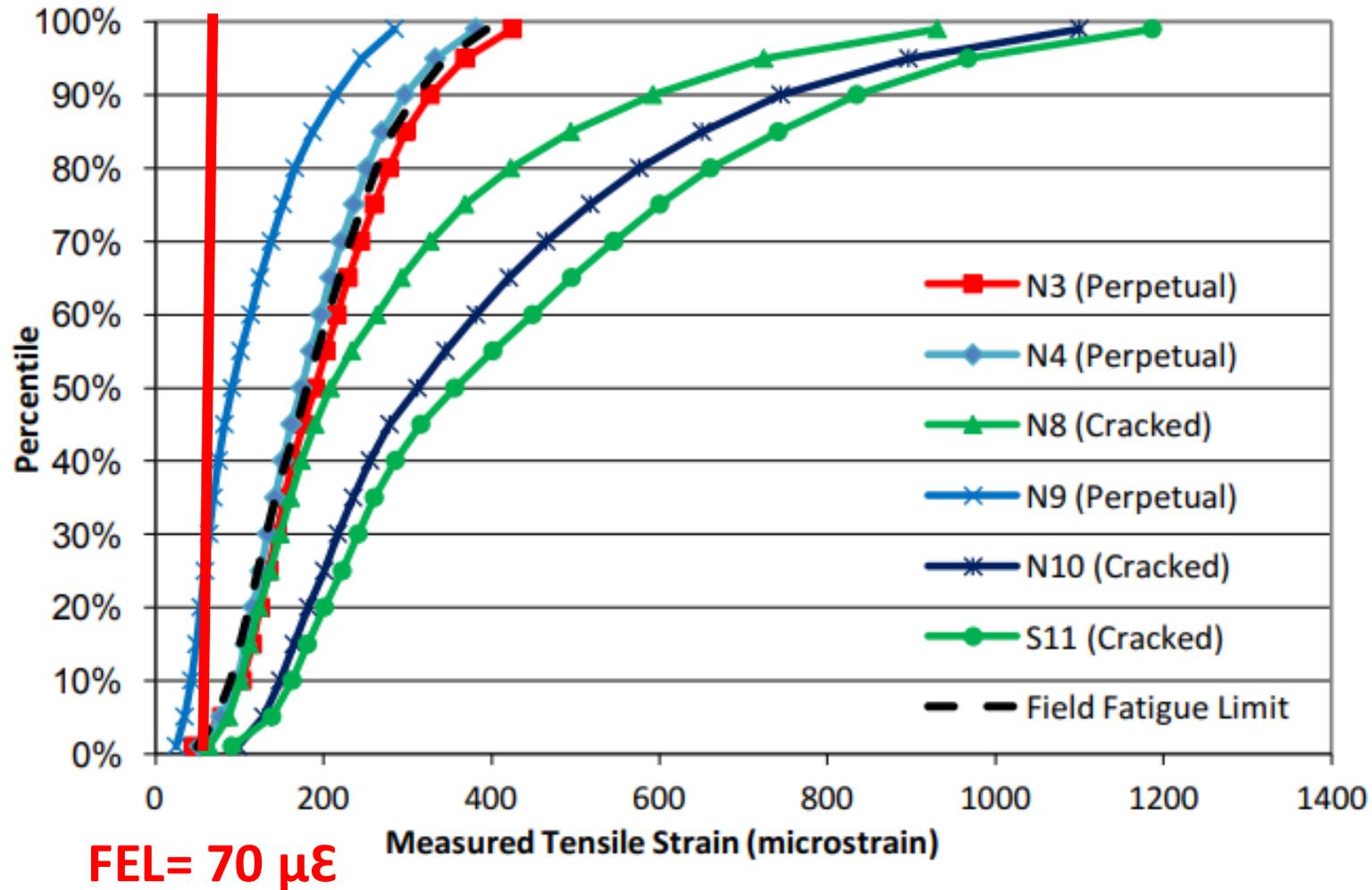


# Perpetual Pavement Structural Design Fatigue Endurance Limit and Cumulative Strain Distribution

**Load Repetitions to Failure vs. Strain**



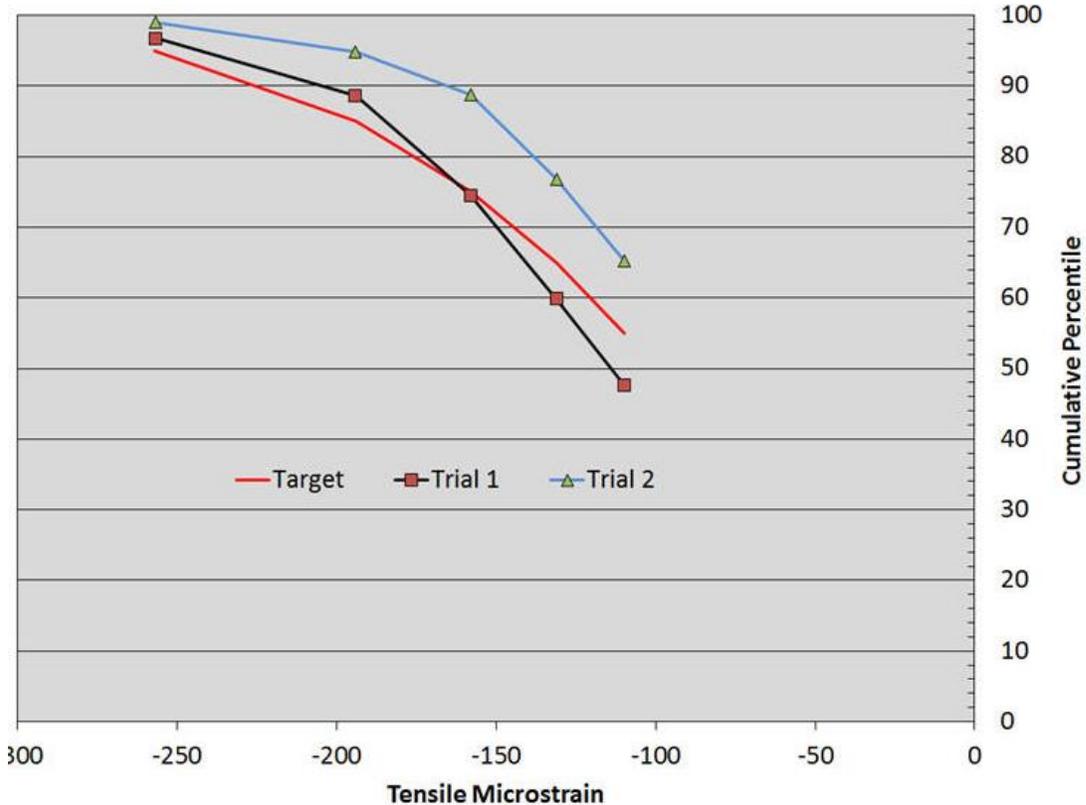
# Perpetual Pavement Structural Design Fatigue Endurance Limit and Cumulative Strain Distribution



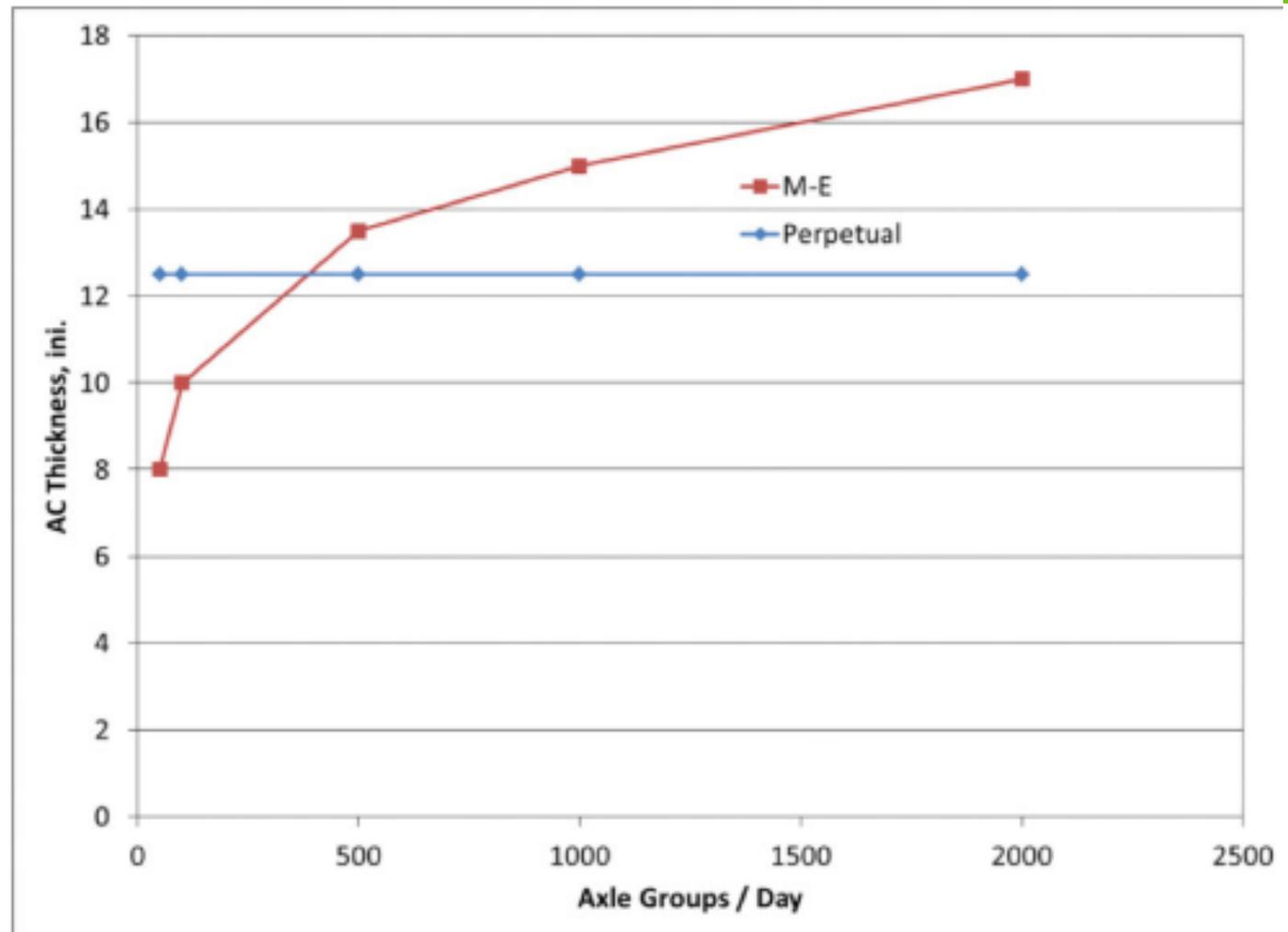
Bottom Horizontal Strain Distribution

Percentile	Microstrain
95th	-257
85th	-194
75th	-158
65th	-131
55th	-110

Note: The following sign convection is used...  
Negative = Tension  
Positive = Compression  
Deflection is Positive Downward



- Comparison under with conventional design



# Thicker is not Better!!!

- After maximum thickness is reached, additional HMA does not reduce rutting or cracking potential

Subgrade Mr (ksi)	Base Mr (ksi)	Calculated AC Thickness (in.)				Range of Maximum Thicknesses (in.)
		Minneapolis (PG 64-34)	Phoenix (PG 70-22)	Baltimore (PG 64-22)	Average	
5	30	12.5	15	14	13.8	12.5-15
5	50	11.5	14.5	13.5	13.2	11.5-14.5
5	100	11	13	12.5	12.2	11-13
10	30	10.5	13	11.5	11.7	10.5-13
10	50	10	12	11.5	11.2	10-12
10	100	9	11	10.5	10.2	9-11
20	30	9	12.5	10.5	10.7	9-12.5
20	50	8.5	12	10	10.2	8.5-12
20	100	7.5	10.5	9	9.0	7.5-10.5

\*8" base thickness

# Perpetual Pavement Construction

- Basics!
  - But implications on missed basics is much larger as this is a larger investment
- Use all available tools for quality
  - Mix transfer device, Paver mounted thermal, intelligent compaction, etc.





# Perpetual Pavement Awards in Minnesota

- 16 awards in Minnesota
- “By conversion”
- Built from 1959-1977

## Minnesota Awards



### MINNESOTA SH 89 (RP 21.3 TO 26.03) IN BELTRAMI COUNTY

Minnesota Department of Transportation

**Constructed:** 1977

**Awarded:** 2017



### MINNESOTA SH 371 IN CASS COUNTY, 0.573 MILES NORTH OF SH 84 TO 0.7 MILES SOUTH OF SH 87

Minnesota Department of Transportation

**Constructed:** 1971

**Awarded:** 2016

# MnROAD / WisDOT Test Sections

- Partnership through National Road Research Alliance (NRRRA)
- MnROAD Sections built in 2022 on I-94 in Albertville, MN
- WisDOT Sections built in 2023 on I-94 in Osseo, WI
- Dynamic and Environmental Instrumentation at both sites
- MnDOT RFP will be posted in early 2025
  - Develop strain distribution criteria

<https://www.dot.state.mn.us/mnroad/nrra/structure-teams/flexible/perpetual-pavement-test-sections.html>

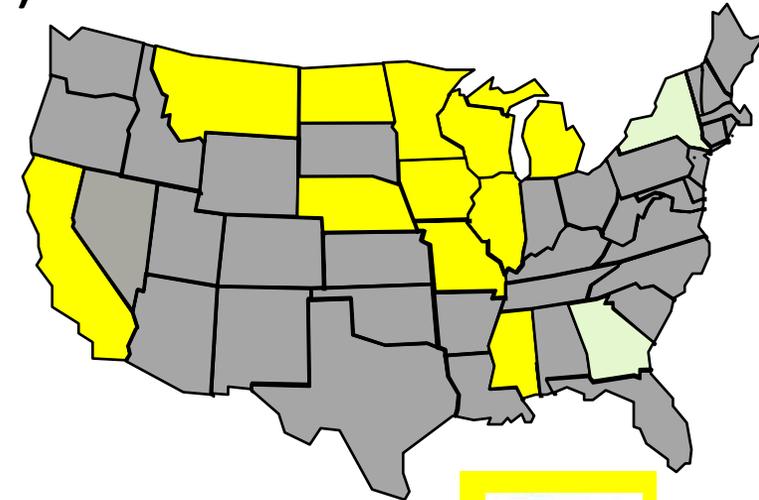


# National Road Research Alliance Membership Overview



## TPF-5(466) - Fee Structure / year (five years)

- **Phase-1 complete (5 yr) – Now into Phase-2 (year 2/5)**
- **13 Full Agency Commitments (yellow)**
  - \$75K /\$150K Annual Commitment
  - 11 States, Illinois Tollway, LRRB
  - FHWA is also a contributing partner
- **2 ICT Commitments (Green)**
  - \$25K (ICT Team only – Veta Efforts)
  - GA and NY
- **~85+ Associate membership**
  - 2K/year - Associations, Industry, Consultants, Universities



# National Road Research Alliance Overview

- **NRRA has averaged ~\$1 million research/year**
- **NRRA Funded 48 projects (phase1) and 14+13 (phase2)**
  - Short and long term research
  - Multiple Researchers Contracted
- **2023 Call for Innovation ~\$1.7 million**
  - 55 Proposals Received
  - 22 Proposals Prioritized by the Technical Teams
  - 13 Projects being funded (counted above)
    - TAP being developed
    - TAP finalize workplans
    - MnDOT contracting
- **2017 & 2022 MnDOT provided MnROAD construction funding**
- **2024 MnROAD is expecting on 1 million in mainline construction funding**



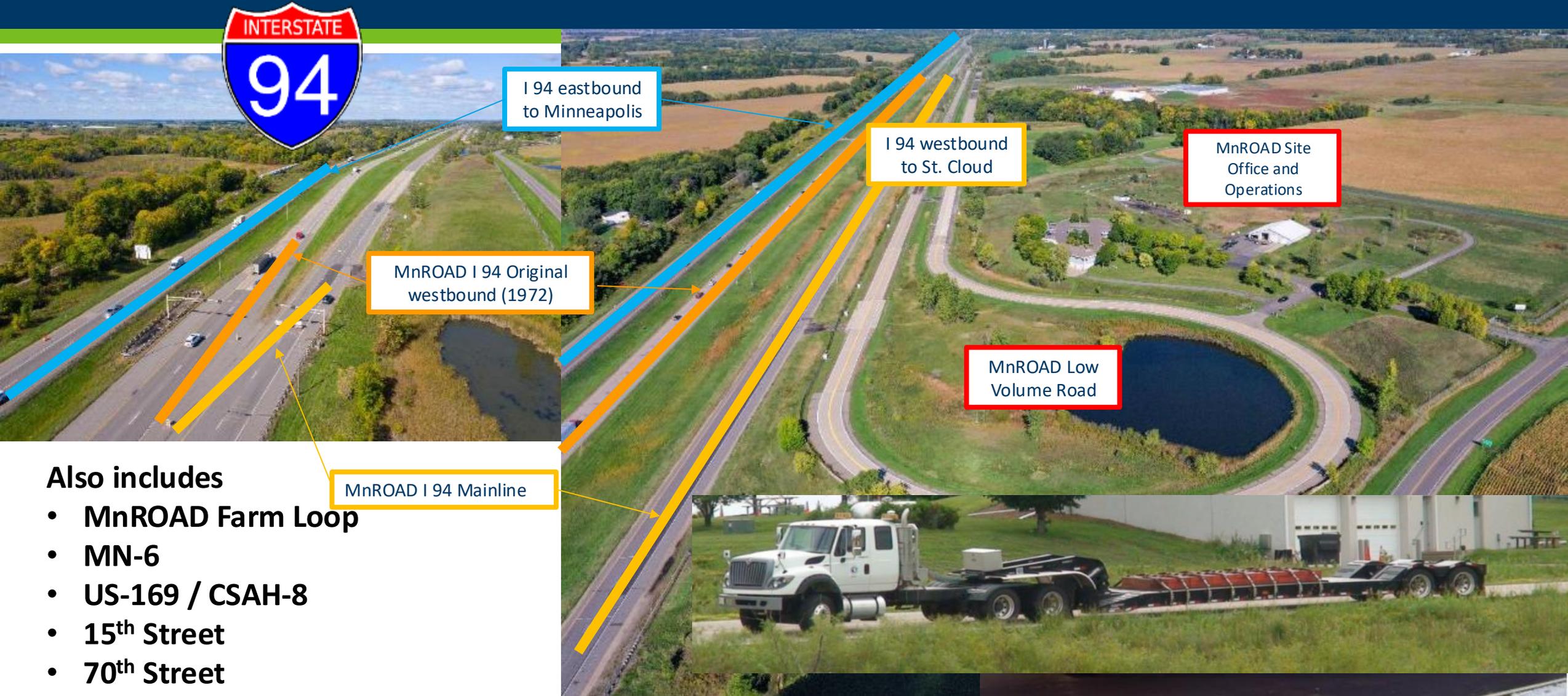
# National Road Research Alliance Overview

- **Organizational Structure**

- Executive Committee (2 reps/agency)
- 5 Technical Teams (agency and associate reps)
  - Technical Chairs
  - MnDOT Representative
- MnROAD Facility Utilized
- Outreach is done in the technical teams
  - Lauren Dao, MnDOT



# MnROAD- Minnesota Road Research Facility



I 94 eastbound to Minneapolis

I 94 westbound to St. Cloud

MnROAD Site Office and Operations

MnROAD I 94 Original westbound (1972)

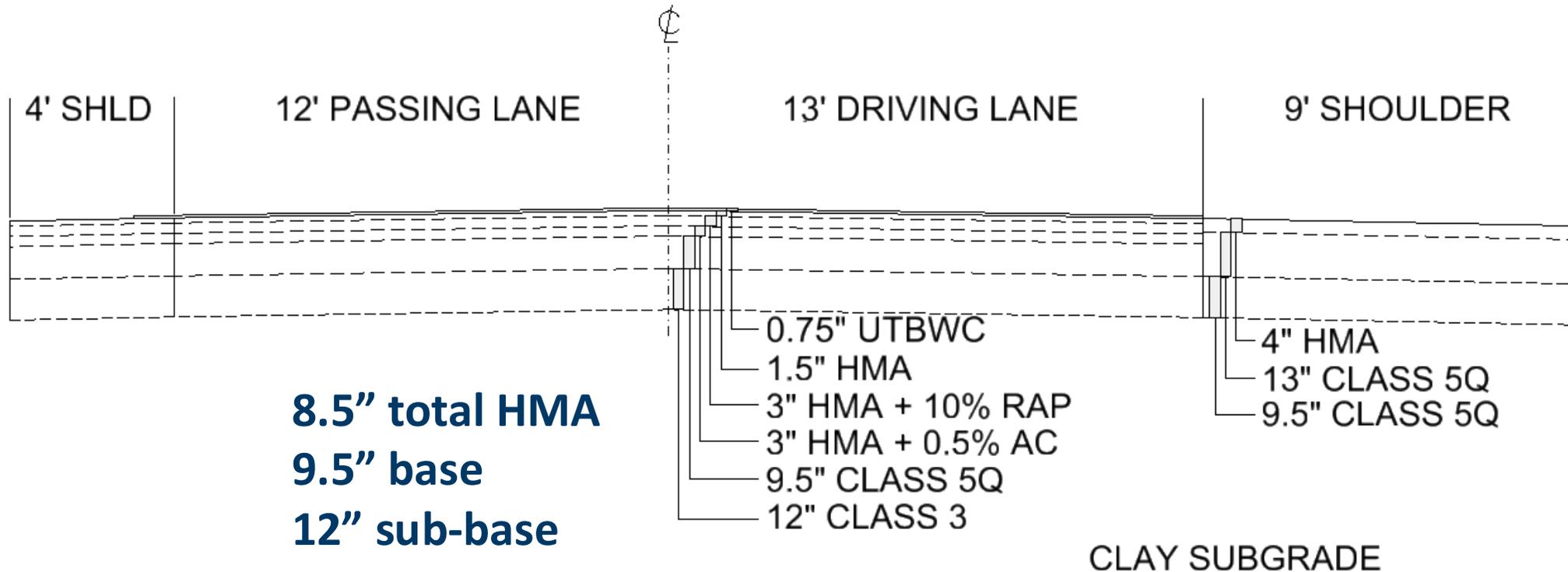
MnROAD Low Volume Road

MnROAD I 94 Mainline

## Also includes

- MnROAD Farm Loop
- MN-6
- US-169 / CSAH-8
- 15<sup>th</sup> Street
- 70<sup>th</sup> Street
- + Others

# MnROAD Section Structure

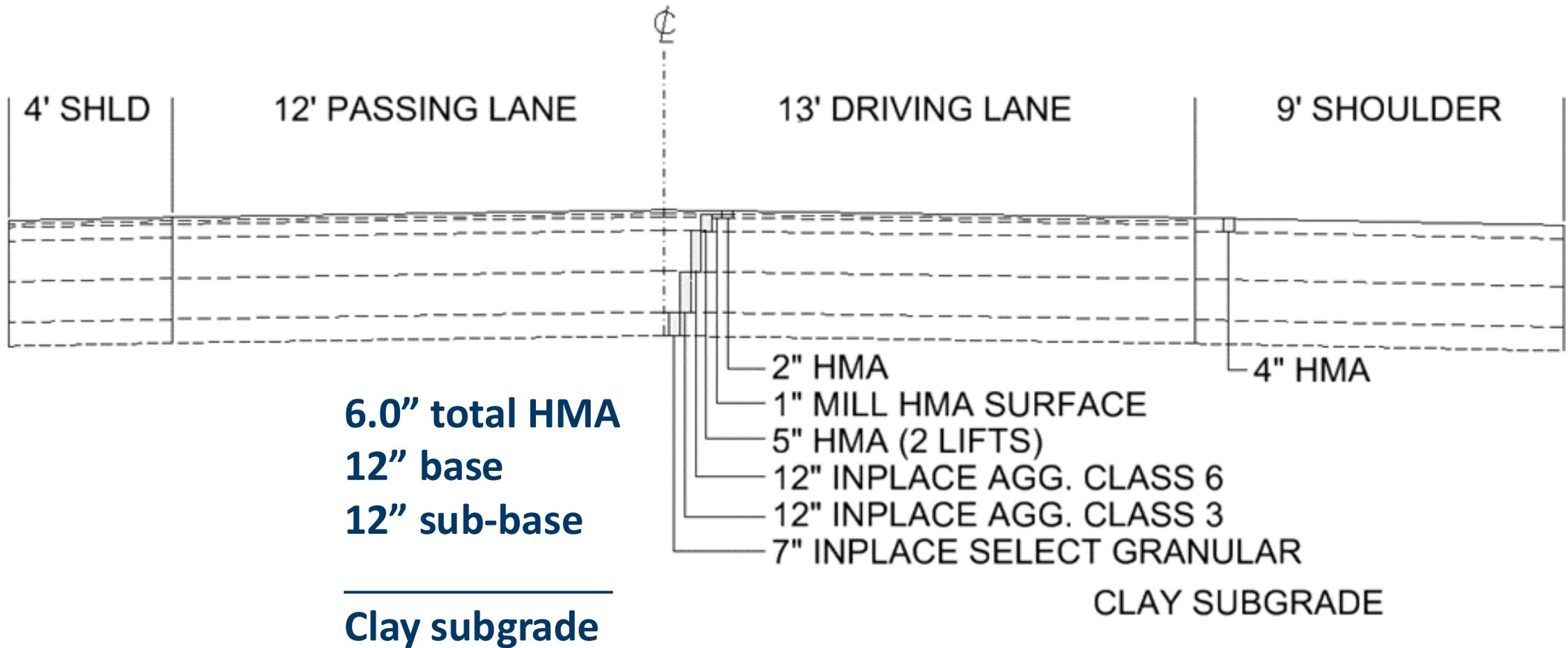


**8.5" total HMA**  
**9.5" base**  
**12" sub-base**

---

**Clay subgrade**

# MnROAD Section Structure



# MnROAD Section Asphalt Mix Designs

- 1. 5/8 inch Ultra Thin Bonded Wearing Coarse (UTBWC).** *This mix was selected provide a high-friction and high-quality surface.*
- 2. 1.5 inch (MnDOT SPEWB540C) PG 58H-34, 19 mm NMAS, MnDOT traffic level 5, ≈20% RAP.** *This mix is the MnDOT recommend mix for the traffic level (westbound I-94) and climate (Monticello, MN).*
- 3. 3.0 inch (MnDOT SPEWB540B) PG 58S-28, 19 mm NMAS, MnDOT traffic level 5, ≈30% RAP.** *RAP content was increased in this mix to stiffen asphalt structure and reduce strains at lower HMA layer.*
- 4. 3.0 inch (MnDOT SPEWB540C) PG 58H-34, 19 mm NMAS, MnDOT traffic level 5, ≈20% RAP, +0.5% asphalt cement.** *Polymer modified binder was selected and the binder content was increased 0.5% to increase flexibility at the location of maximum tensile strain.*

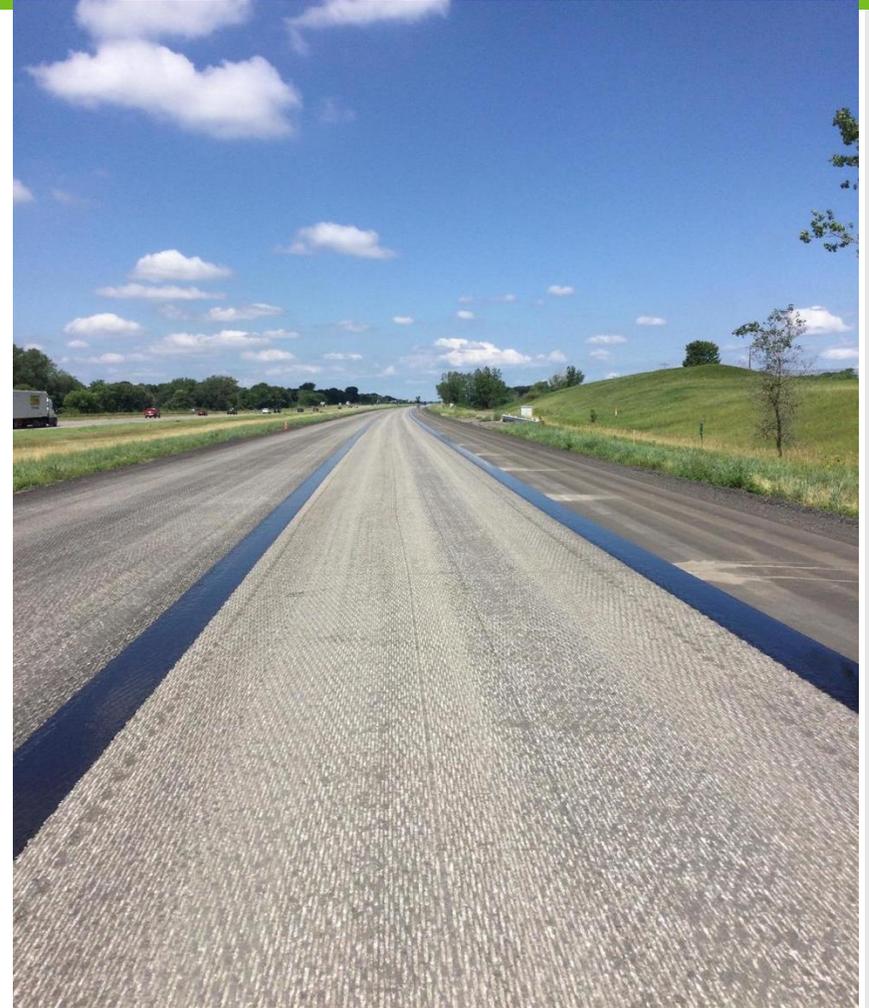
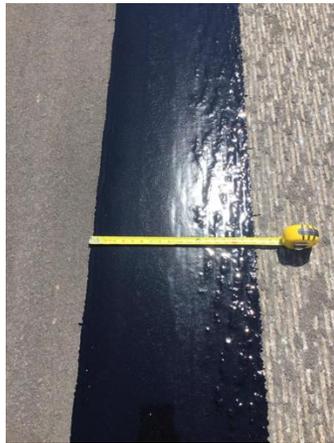
# Construction – Modern Tools

- Mix Transfer Device
- Paver Mounted Thermal Profile
- Intelligent Compaction
  - HMA
  - Unbound layers
- Density Profile System
- Longitudinal Joint Treatment



# Construction - Longitudinal Joint Treatment

- J-Band applied on centerline and longitudinal shoulder joint
- Driving lane paved 13' wide with 12' lane to push longitudinal joint away from traffic
- J-Band donated application for this effort



10/09/24 picture of cell 2232 built in 2022 in MnROAD NCAT Additive Group

ment

- J-Band should
- Driving push l
- J-Band



2019 picture of cell 18 built in 2016 in MnROAD NCAT Cracking Group

- J-Band  
shoulder
- Driving  
push lo
- J-Band



# Performance Monitoring

## Ruts, Cracks, and Ride



November 2023



November 2024



April 2023

12/12/2024



May 2024

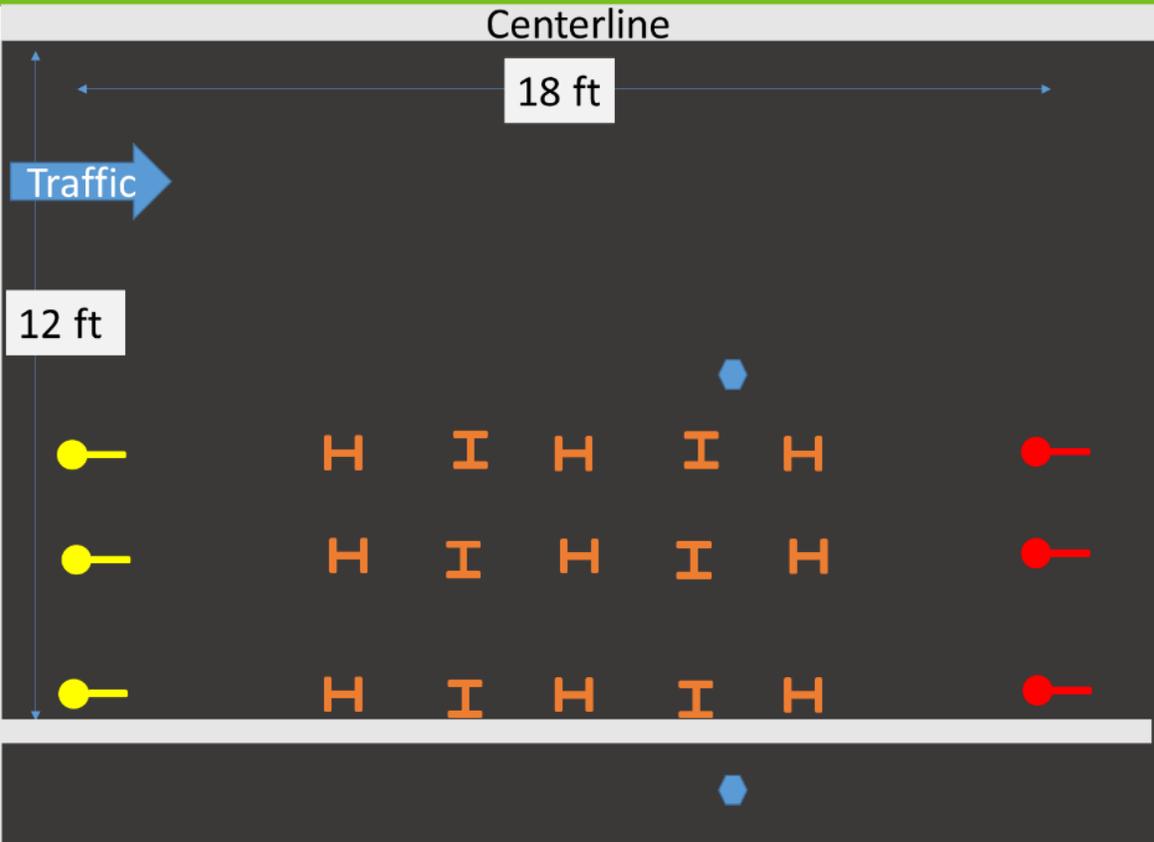
[mndot.gov](http://mndot.gov)

# Structural Performance Monitoring

- Regular Falling Weight Deflectometer (FWD) Testing
  - Monthly/Seasonal FWD to characterize over full range of temperatures
- Dynamic Load Response
  - Monthly/Seasonal
  - Response under live interstate traffic, MnROAD tractor trailer, and other loadings

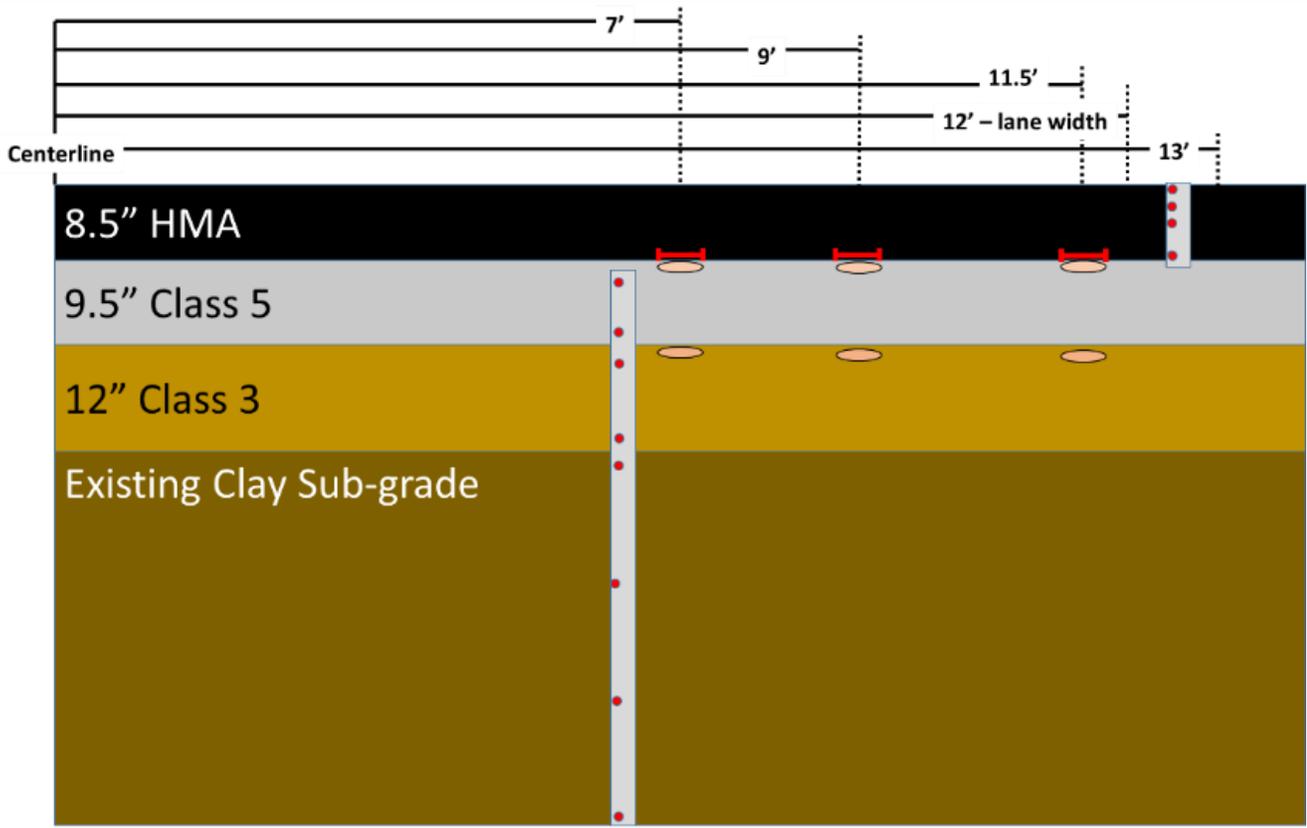


# Instrumentation Layout



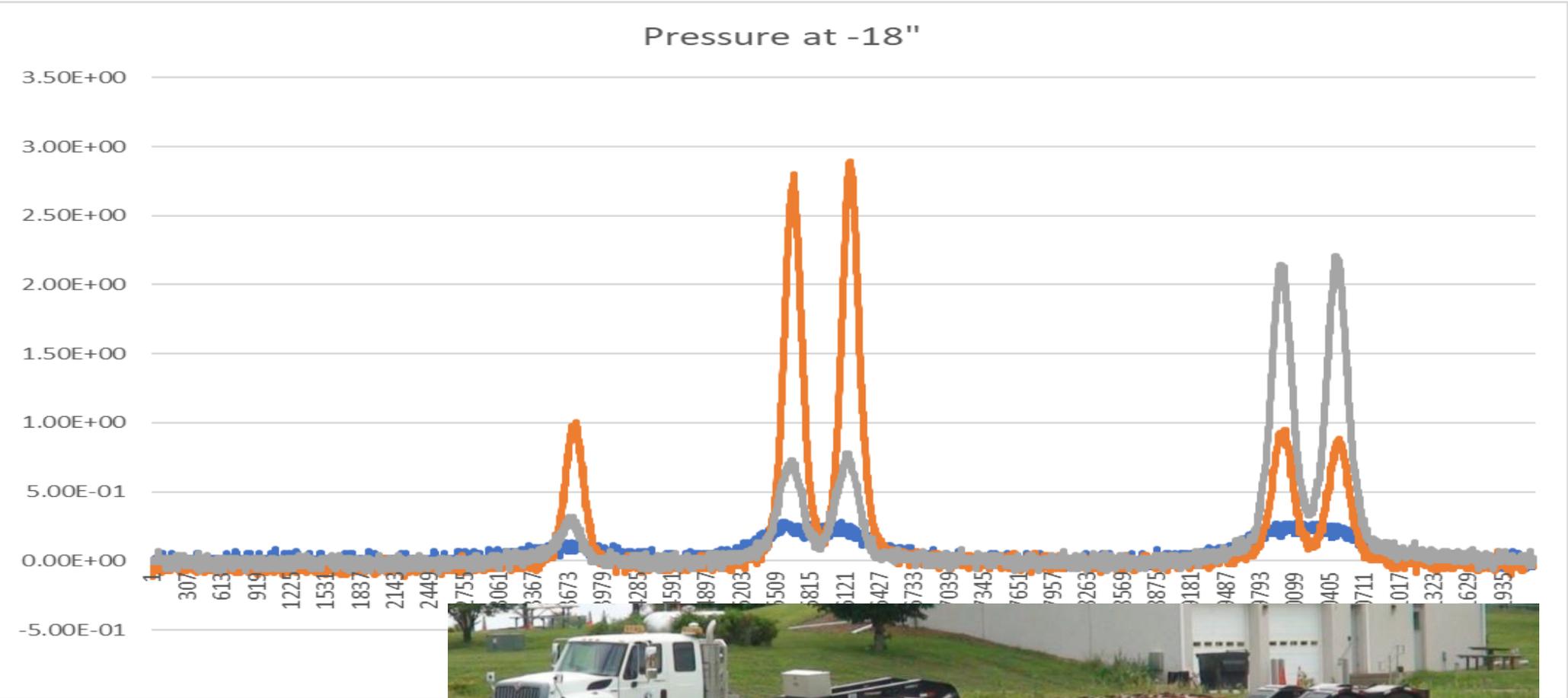
### Legend

- Pressure Cell at 8.5 in. from surface
- Pressure Cell at 18 in. from surface
- ◆ Temperature Array
- H Dynamic Strain Gauge



- Thermocouple Tree
- Asphalt Strain Gauge
- Pressure cell

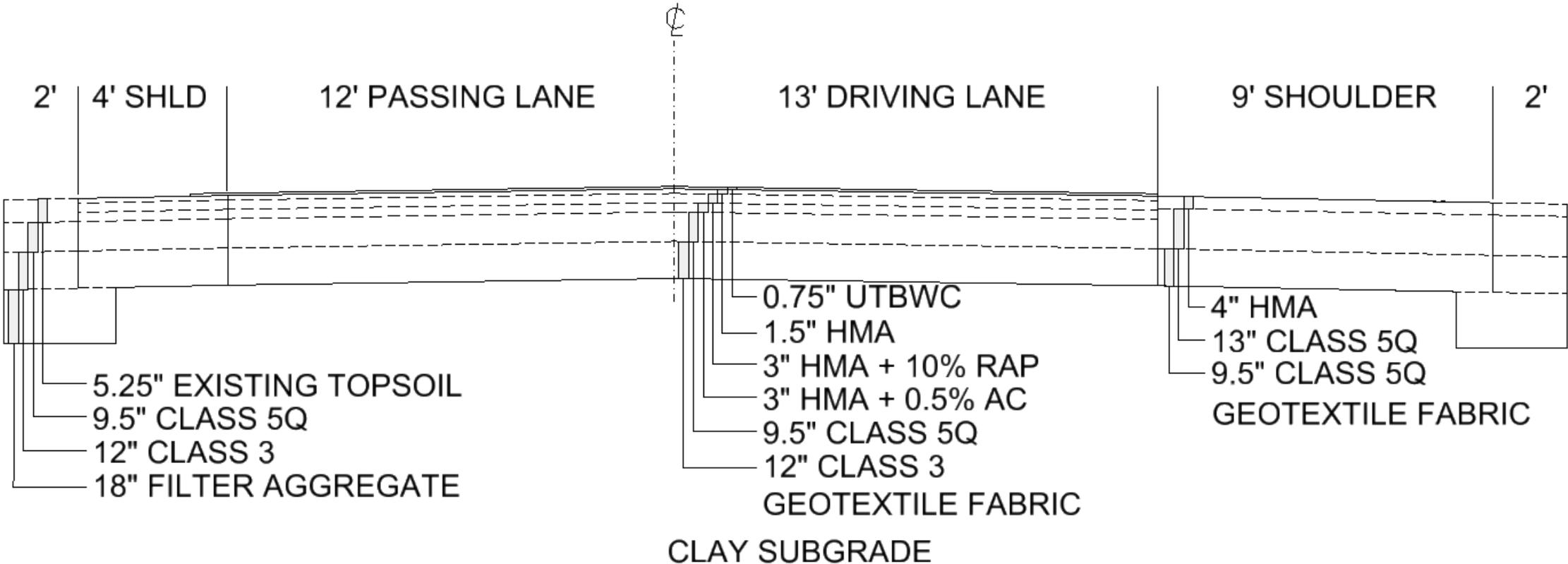
# Dynamic Response



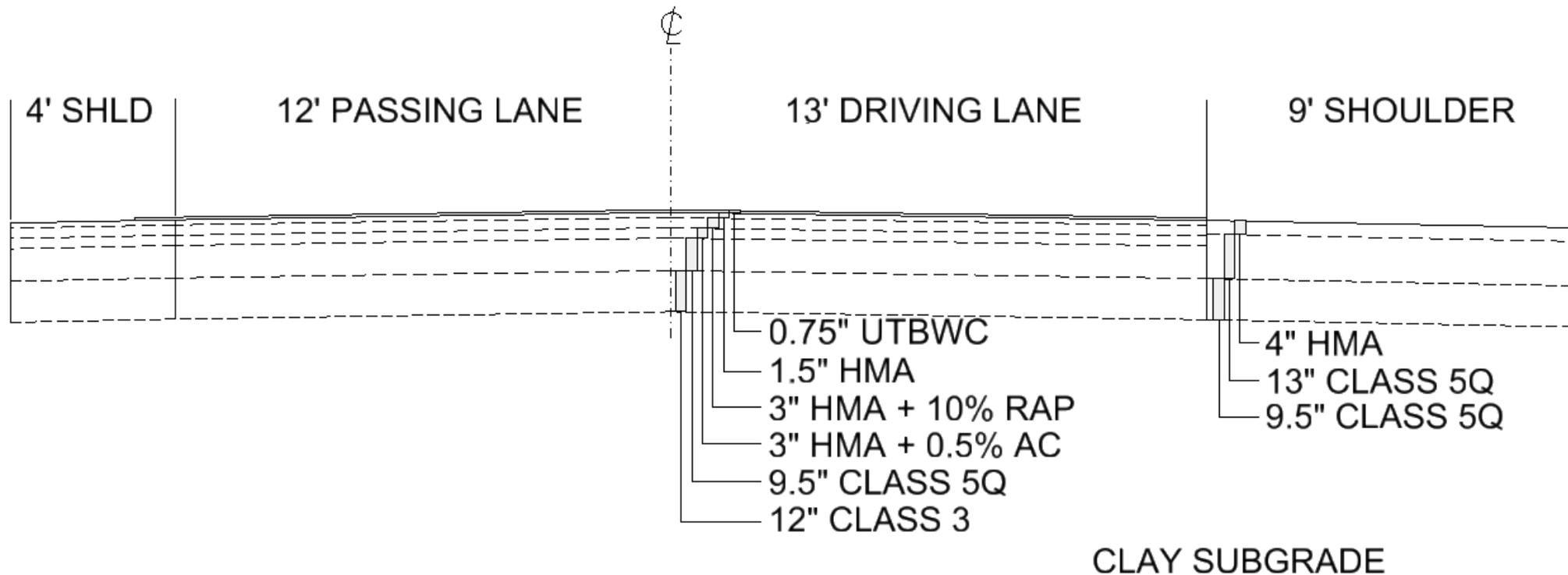
# Environmental Performance Monitoring

- Thermocouples down to 6' deep
  - Monitor temperature profile and frost depth
- Additional Test section and study added by NRRRA Geotechnical Team = *Performance Evaluation of Wicking Geotextiles for Improving Drainage and Stiffness of Road Foundation*
  - MnDOT TL = Dr. Raul Velasquez; Dr. Ceren Aydin
  - Research Team = Michigan State University

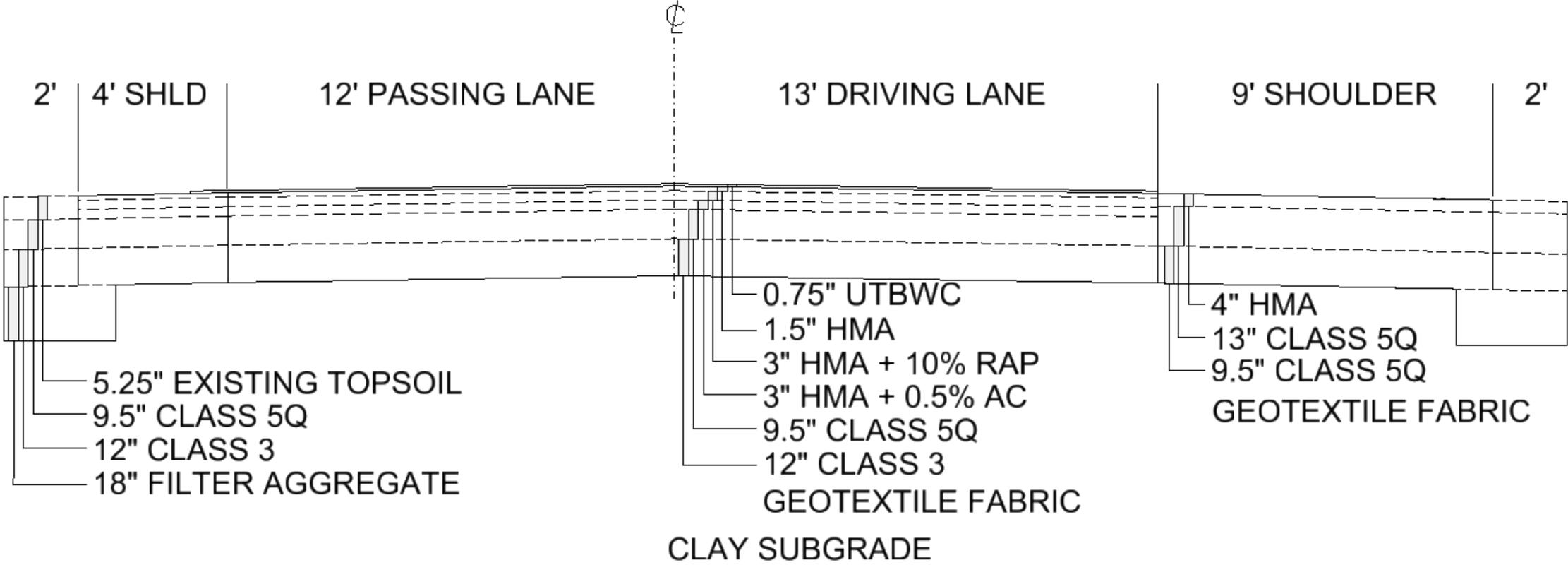
# Wicking Geotextile Perpetual Pavement Section



# MnROAD Section Structure

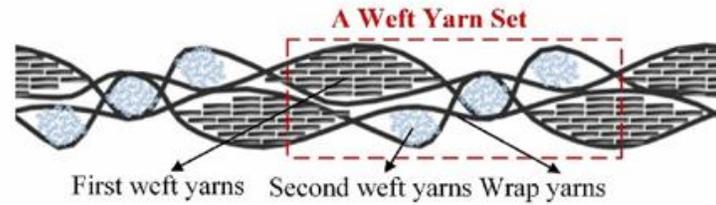


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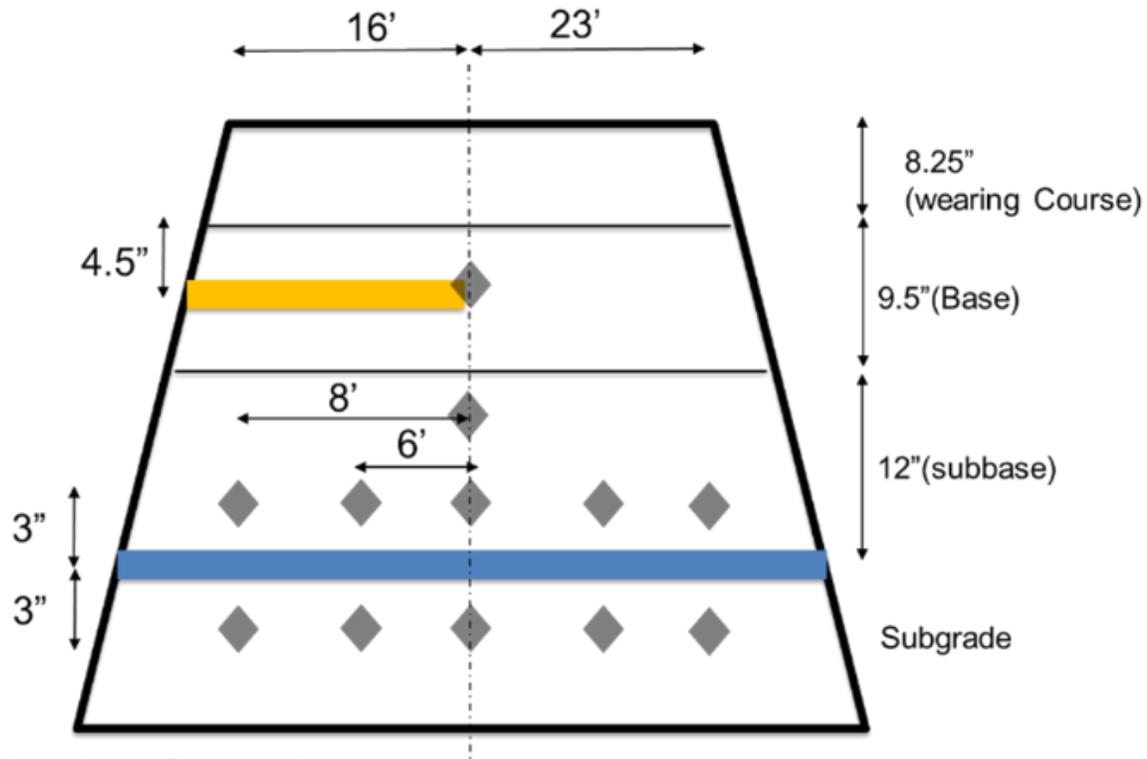


# Wicking Geotextile Perpetual Pavement Section

- Partnered with Solmax
  - Tencate



# Environmental Monitoring



-  Wicking Geotextile
-  Moisture & Suction Sensor (Teros 10 & Teros 21)
-  Shape Array



# WisDOT Test Sections

- WisDOT Deep Strength HMA sections (12.5" HMA) built in Osseo, WI on I-94 (EB/WB)
- Bridge approach
- All sections have instrumentation for temperature, moisture, strain and pressure
- Constructed October 2023



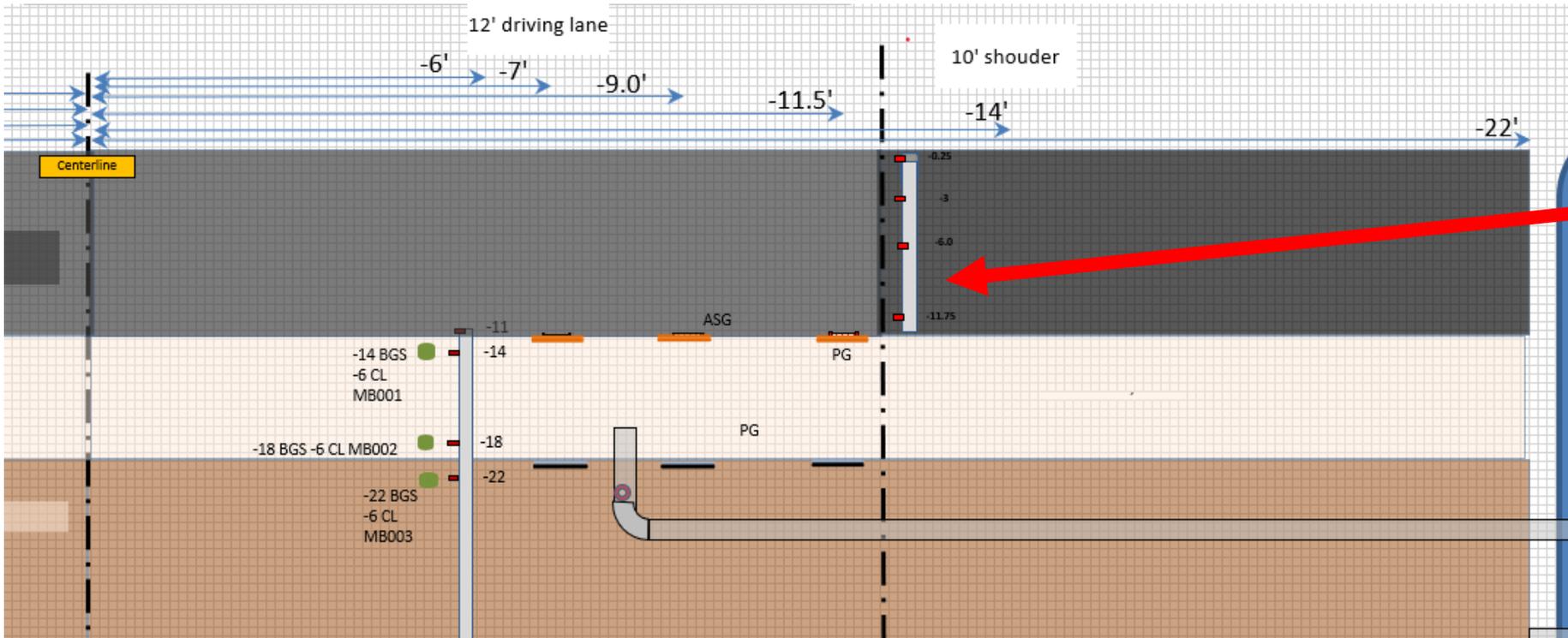
12/12/2024



mndc

# Thermocouple in Asphalt

- Installed in driving lane after paving final surface



# Recycling and Reclamation to Achieve Perpetual Pavements

- NRRRA project on 2022 MnROAD test sections
- Originally constructed in 1993
- Full Depth Reclamation in 2008
- GREAT PERFORMANCE!
- Some rehabs in 2022 (micro-surface, CIR, UTBWC)
- Research Team = Braun Intertec and University of New Hampshire

# Summary Perpetual Pavements

- Last 50 years without major rehab. Only surface maintenance
- Older PP had combination of good materials, design and locations
- Modern structural and mix design tools available:
  - PER ROAD 4.4; Balanced Mix Design; Hamburg Wheel Track Test; Bending Beam Fatigue
- Designed **and built** for 50 years
  - Construction must not be overlooked.
  - Modern tools to improve quality: Paver mounted thermal profile, intelligent compaction, density profile system, Mix transfer device

# Summary – Michael's Soapbox

- Safety, Quality, and Performance are critical in all pavements
- Low carbon and sustainability are currently emphasized in our industry
- Perpetual Pavements keep focus on PERFORMANCE side of equation
- Not able to sacrifice performance for “Green Initiatives”
- MnROAD example: changed 2.5” of base to HMA and changed design life from 20 years to 50 years!!!



- **Special Thanks to:**

- MnDOT District 3
- MnDOT D3 – Monticello Truck Station
- C.S. McCrossin
  - Jerry Siever Mix designer
  - Paving crew
- WisDOT
- Hoffman Construction
- Monarch Paving

- **MnROAD Team**

- Jacob Calvert
- Craig Nolden
- Steve Olson
- Dan Roushar
- Jesse Shank
- Jeff Tabery
- Troy Hubner
- Joe Podolsky
- Ben Worel



# UND Oversize Load Testing at MnROAD

WORK IN PROGRESS

# Vehicle 1 = MnROAD Truck



# Vehicle 2 = Tridem Truck



12/12/2024

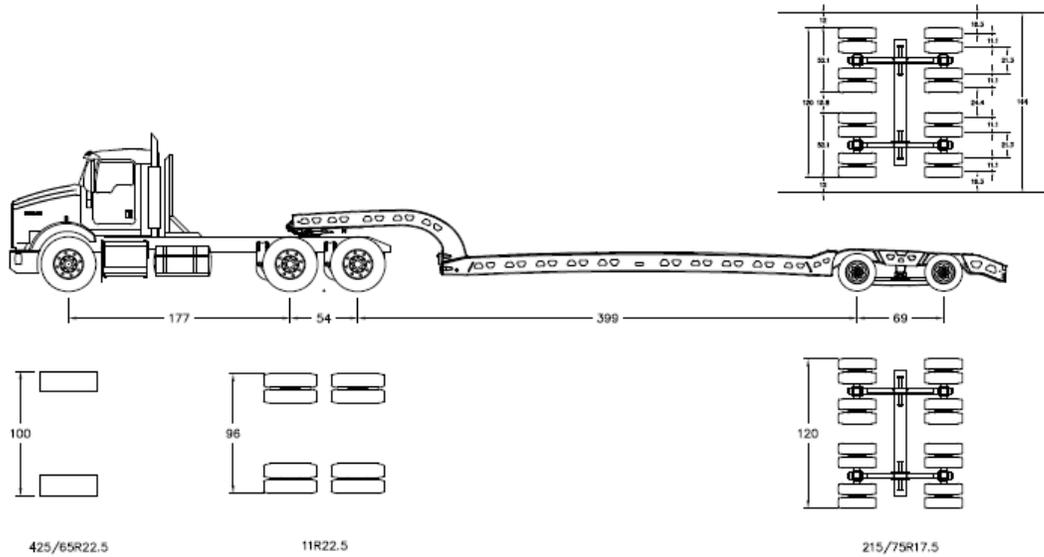
[mndot.gov](http://mndot.gov)



# Vehicle 3- Trunnion



# Vehicle 3- Trunnion

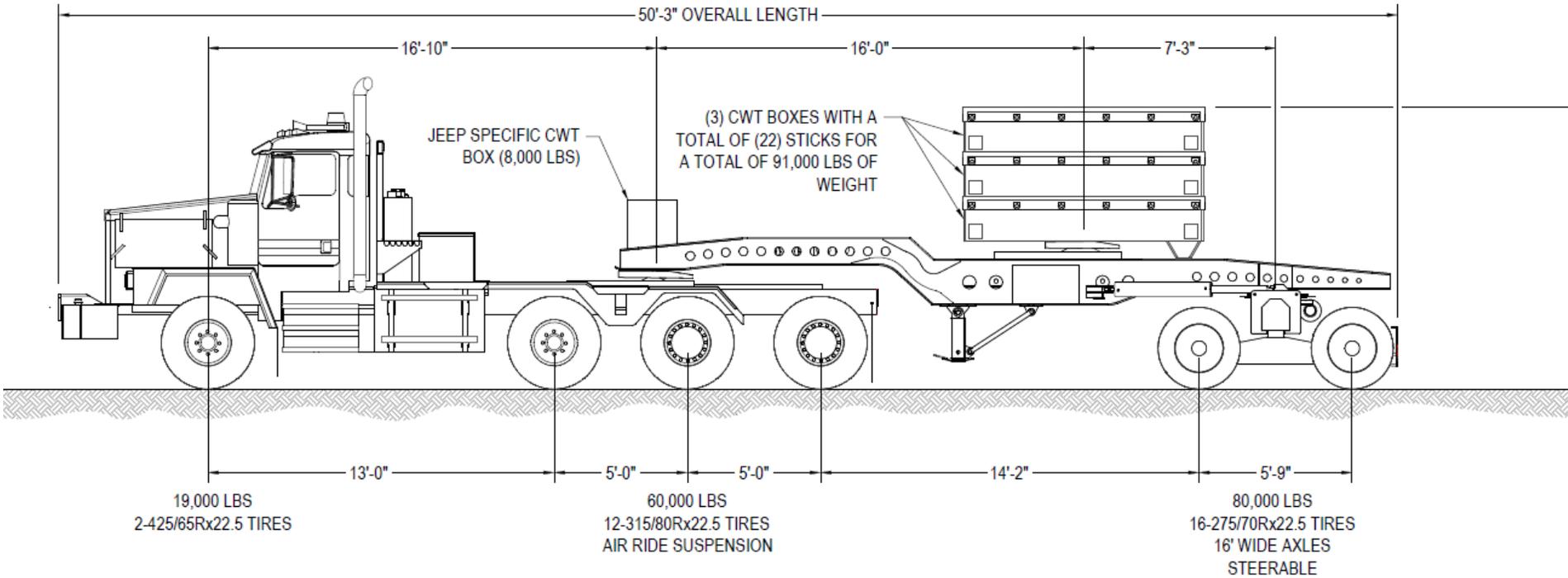


# Vehicle 4 – Dual Lane



# Vehicle 4 – Dual Lane

PERKINS SPECIALIZED TRANSPORTATION LAYOUT



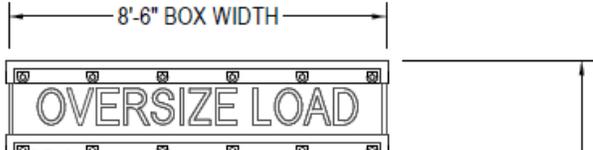
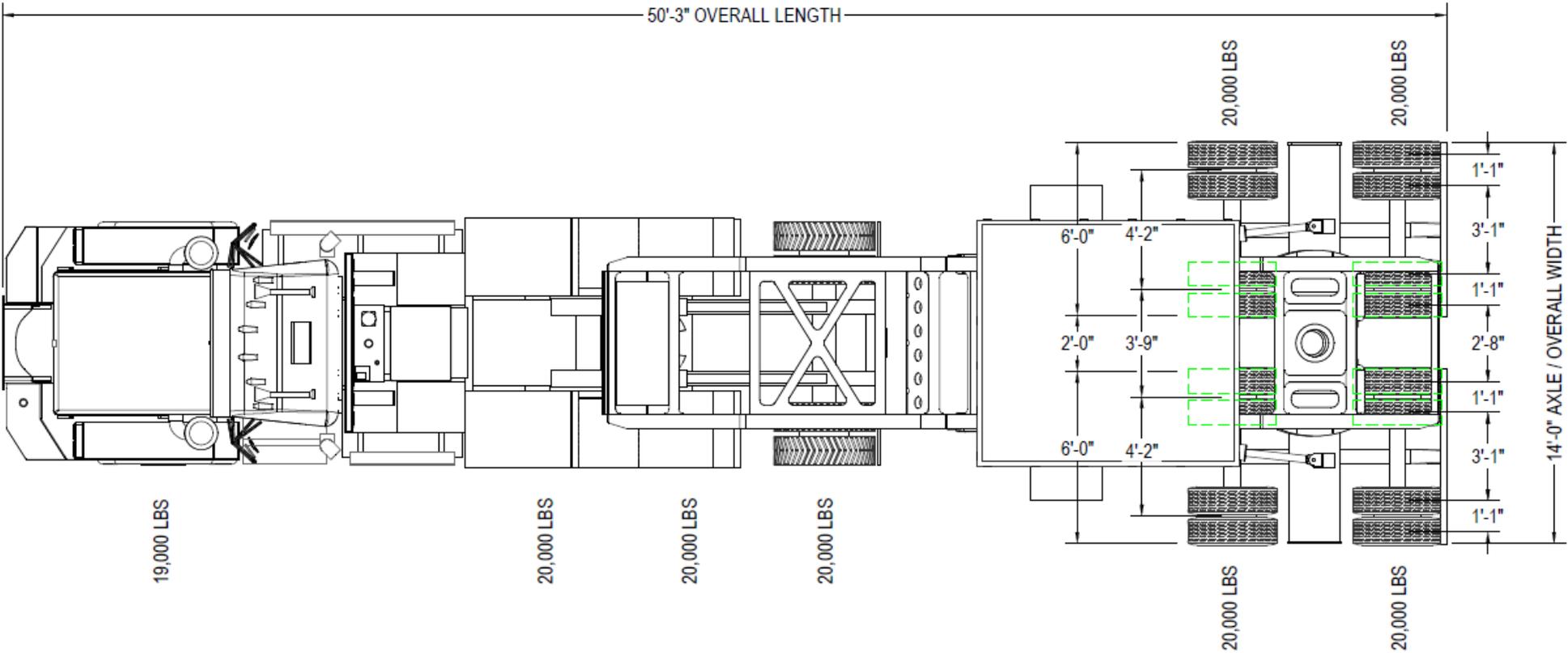
## DUAL LANE LOADING

GROSS VEHICLE WEIGHT = 159,000 LBS

ORIGIN INFORMATION	DESTINATION INFORM
SHIPPER: PERKINS STC / T.J.P POTTER TRUCKING	CONSIGNEE: -

# Vehicle 4 – Dual Lane

PERKINS SPECIALIZED TRANSPORTATION LAYOUT

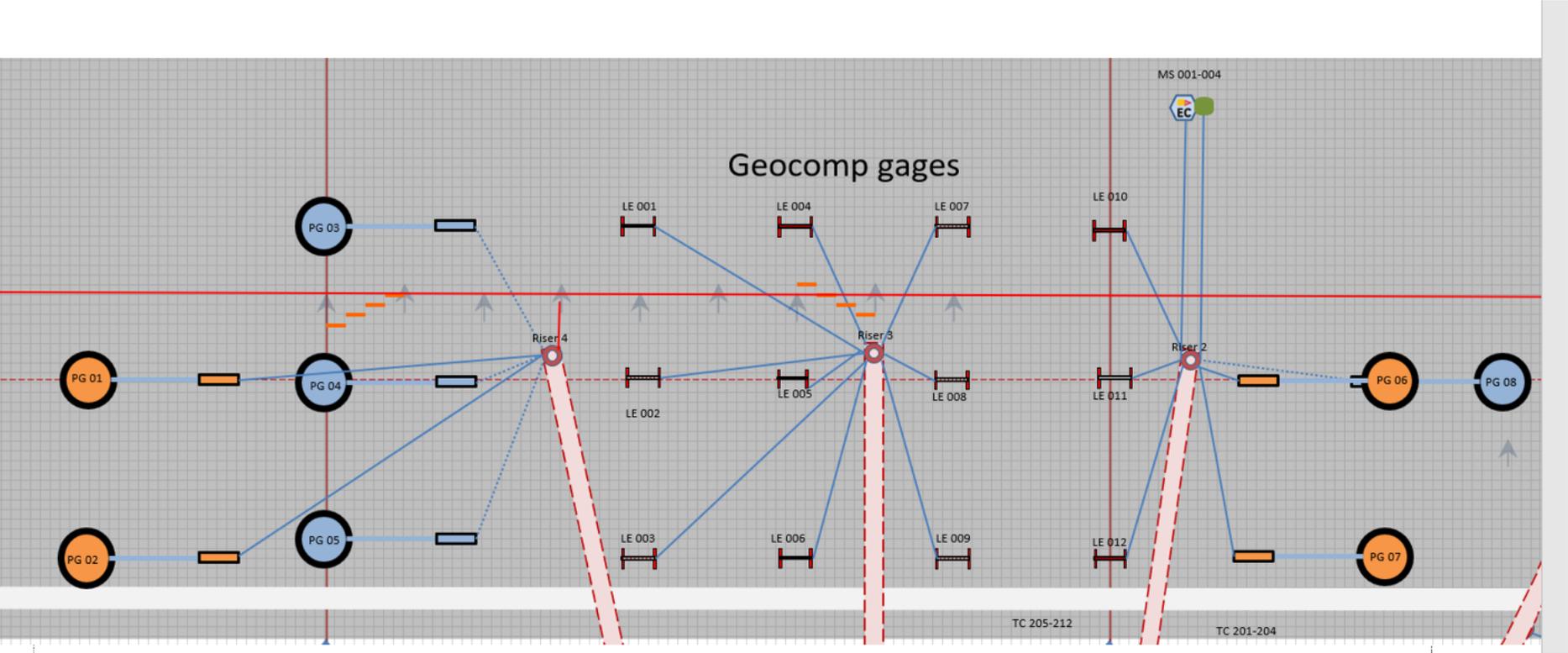


**DUAL LANE LOADING**  
 GROSS VEHICLE WEIGHT = 159,000 LBS

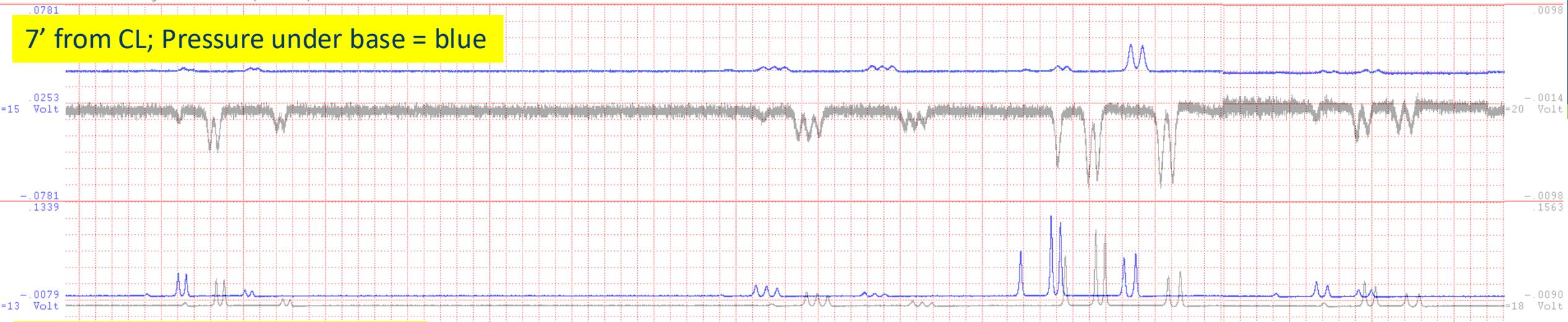
# Loading Schedule

- Start set #1 = 8 15 am
  - 5 mph = x3
  - 35 mph = x3
  - 55 mph = x3
- FWD testing over sensors =10:15 am
- Start set #2 = 11 am
  - 5 mph = x3
  - 35 mph = x3
  - 55 mph = x3
- FWD testing over sensors =1:00 pm
- FWD testing over sensors =1:30 pm
  - Increased to 15k drop height
- Start set #3 = 2:00 pm
  - 5 mph = x2
  - 35 mph = x3
  - 55 mph = x3

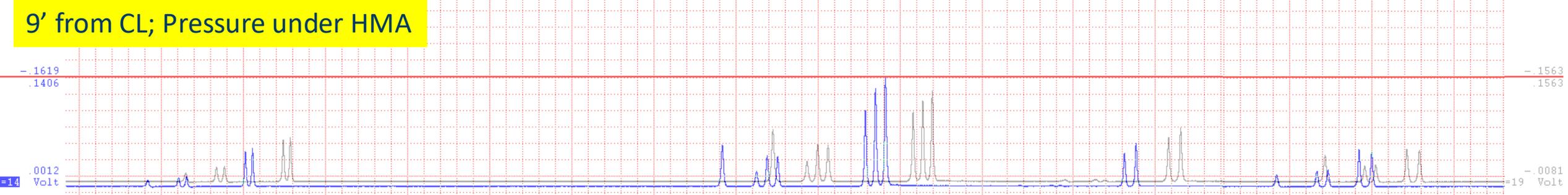
# Instrumentation Layout



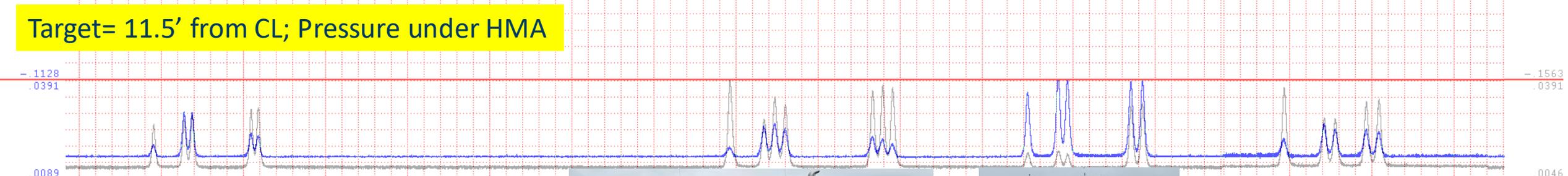
7' from CL; Pressure under base = blue



9' from CL; Pressure under HMA

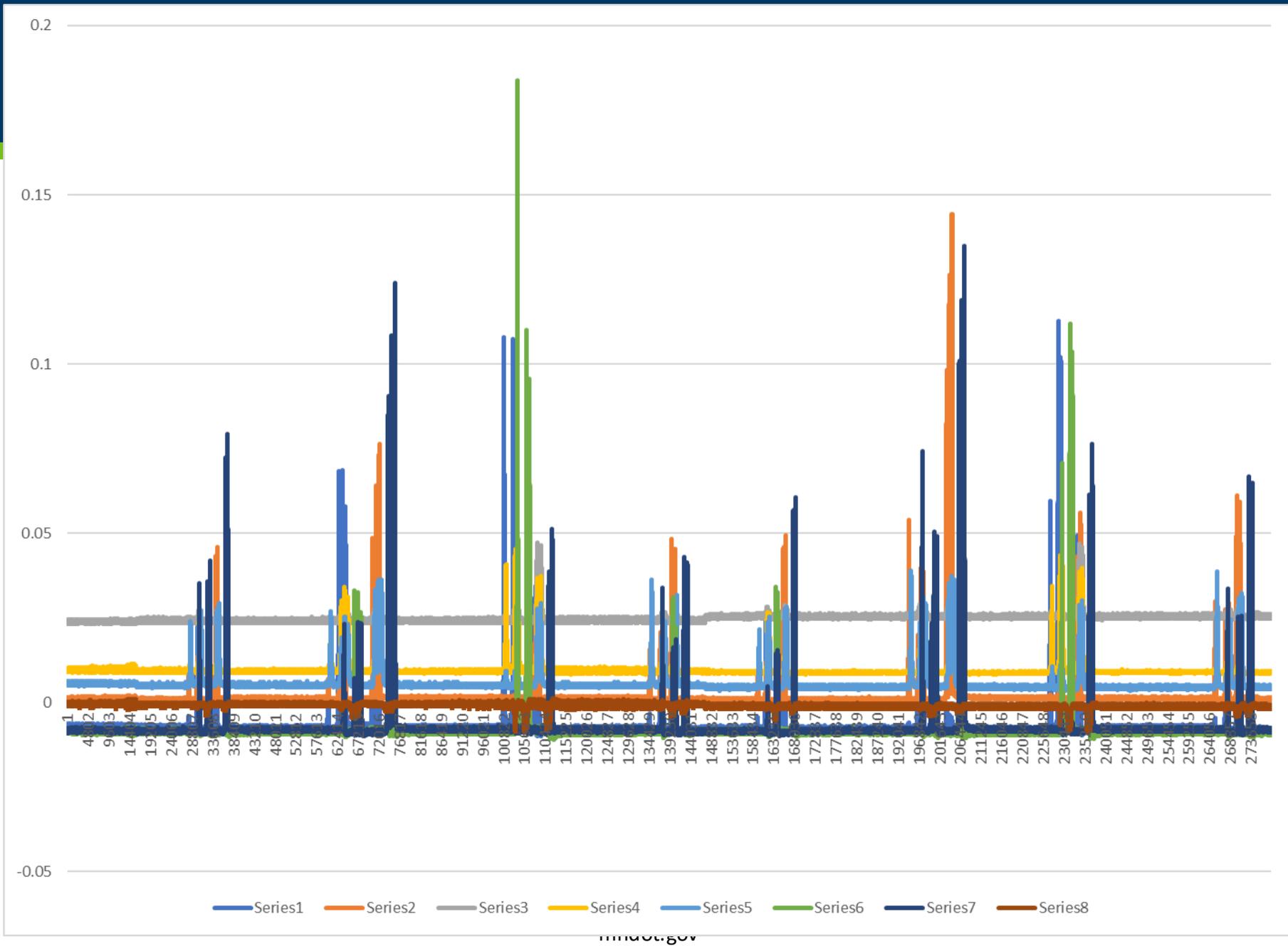


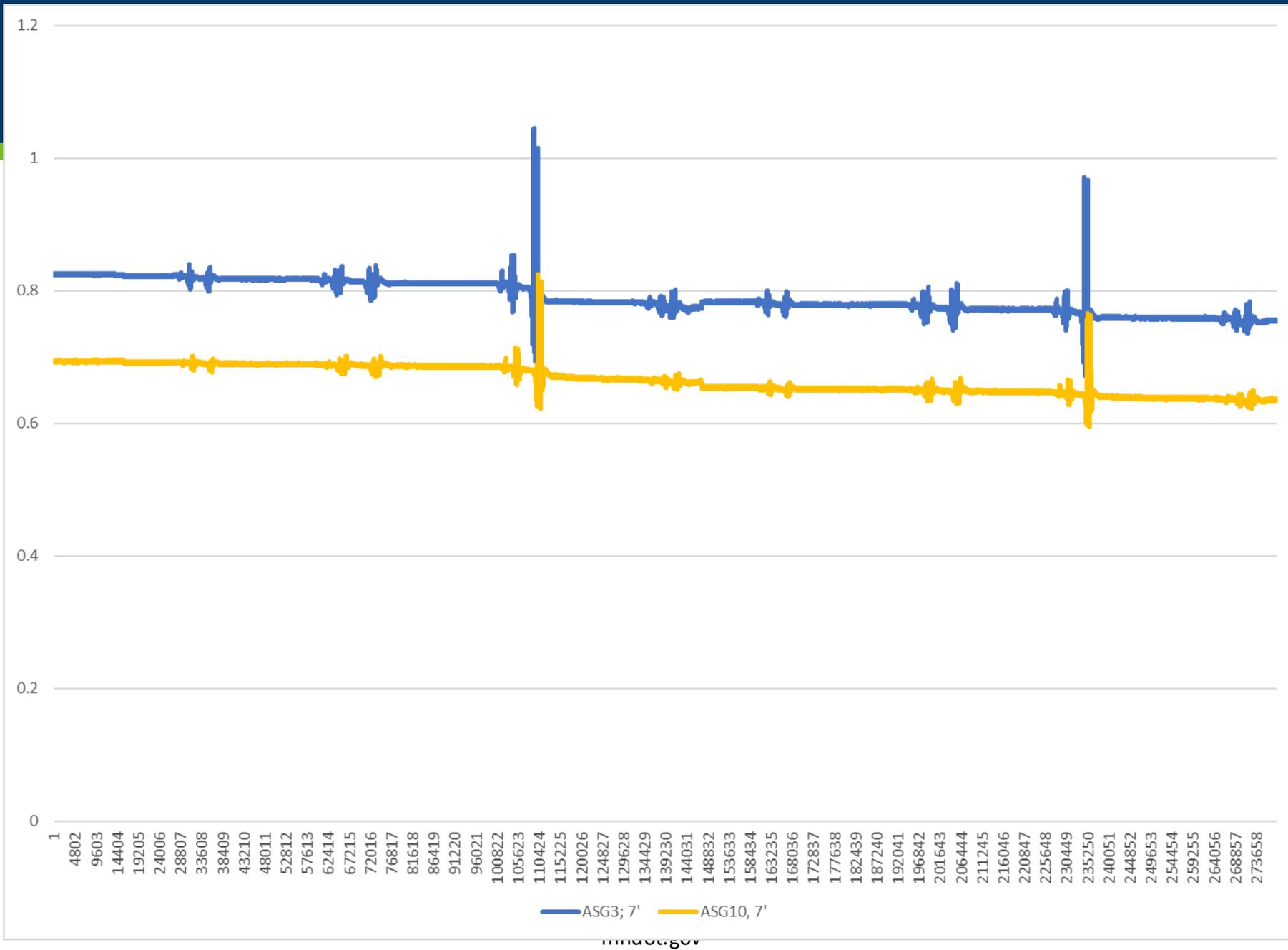
Target= 11.5' from CL; Pressure under HMA

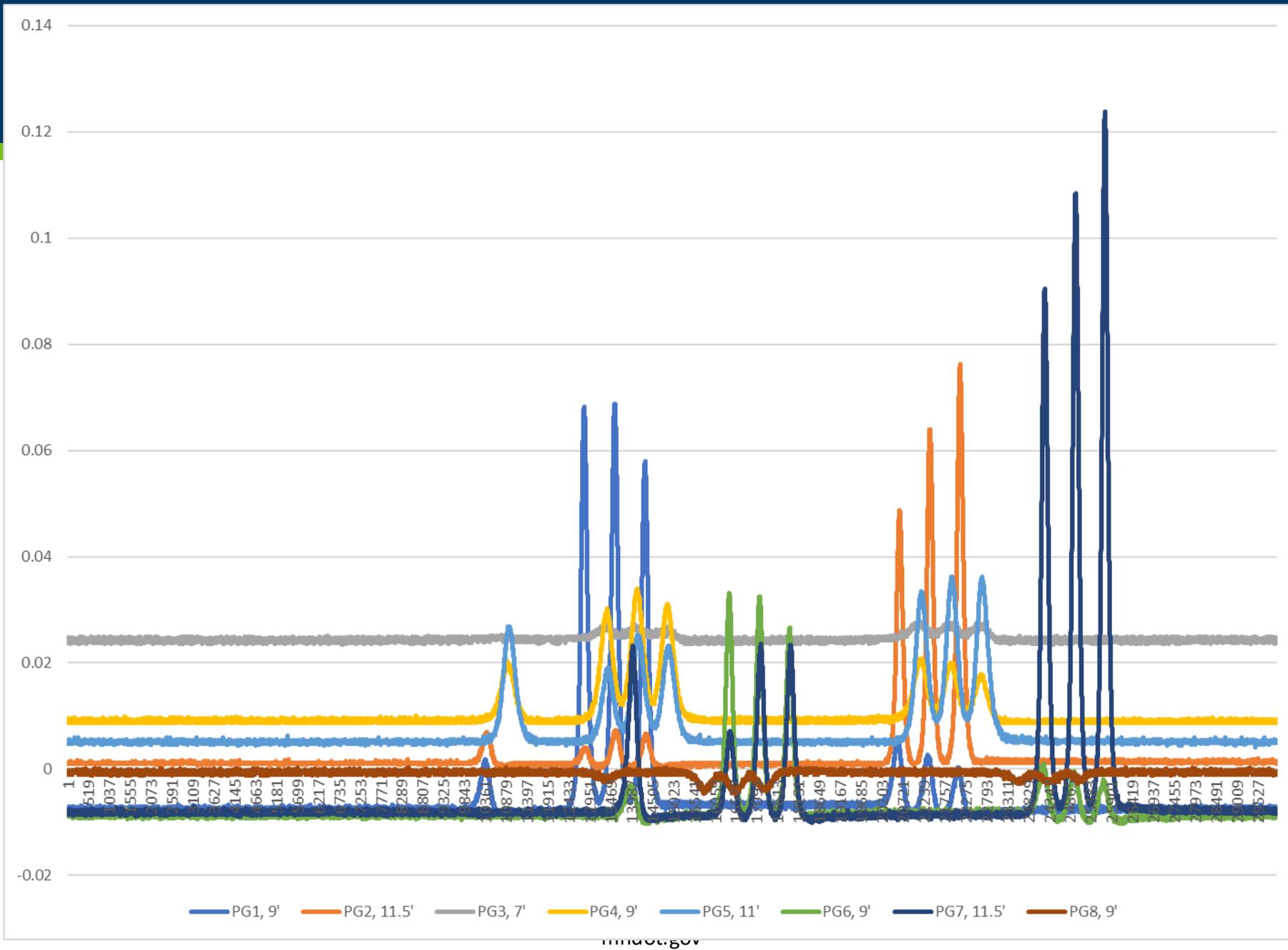


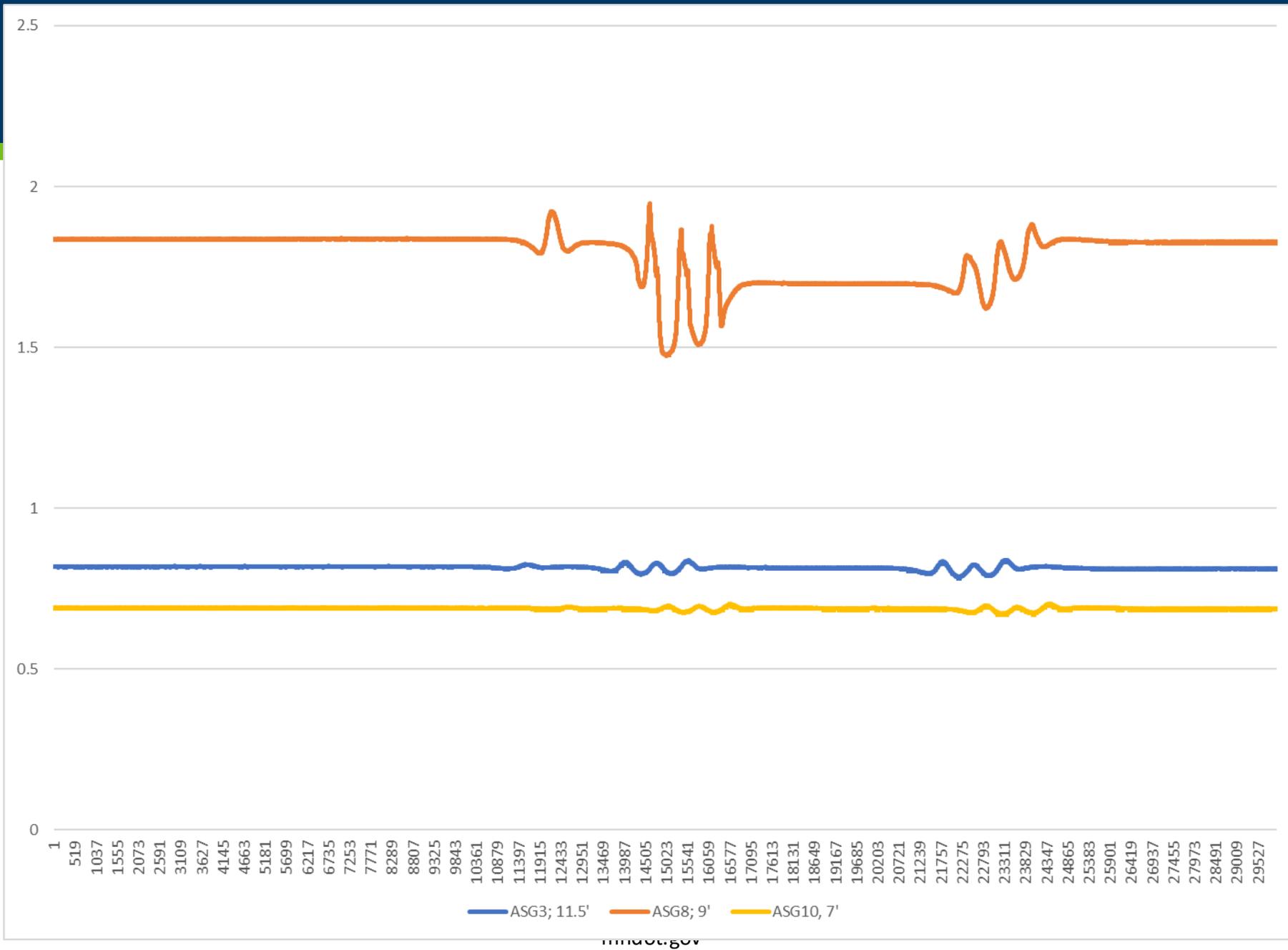
Target= 9.5' from CL; Pressure under base











# References and Resources

- (1) [https://www.driveasphalt.org/uploads/documents/Perpetual\\_Pavement\\_Synthesis.pdf](https://www.driveasphalt.org/uploads/documents/Perpetual_Pavement_Synthesis.pdf)
- (2) <https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep15-05.pdf>
- (3) Nam Tran, P. E., et al. "Refined Limiting Strain Criteria and Approximate Ranges of Maximum Thicknesses for Designing Long-Life Asphalt Pavements." (2016).
- (4) <https://pavementinteractive.org/reference-desk/testing/pavement-tests/flexural-fatigue/>
- (5) <https://www.dot.state.mn.us/mnroad/nrra/structure-teams/flexible/perpetual-pavement-test-sections.html>

# References and Resources cont.

- (6) <https://mdl.mndot.gov/index.php/flysystem/fedora/2024-01/202337.pdf>
- (7) <https://www.dot.state.mn.us/mnroad/nrra/structure-teams/flexible/reclamation-recycling-for-perpetual-pavement-characteristics.html>
- (8) <https://www.youtube.com/watch?v=ZtZokD98lls>
- (9) <https://eng.auburn.edu/research/centers/ncat/newsroom/2017-fall/perroad.html>

## 2022 MnROAD Construction Activities

**Emil G. Bautista**

Office of Materials and Road Research  
Minnesota Department of Transportation

**November 2023**

Research Project of the National Road Research Alliance  
Final Report 2023-37

**MnROAD**

SAFER, SMARTER, SUSTAINABLE PAVEMENTS

# Thank You!

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