

NATIONAL
ACADEMIES

Sciences
Engineering
Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Temporary Pavement Markings and Removal Practices in Workzones

August 16, 2022

2:30 – 4:00 PM

NOVEMBER 2022 UPDATE

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.



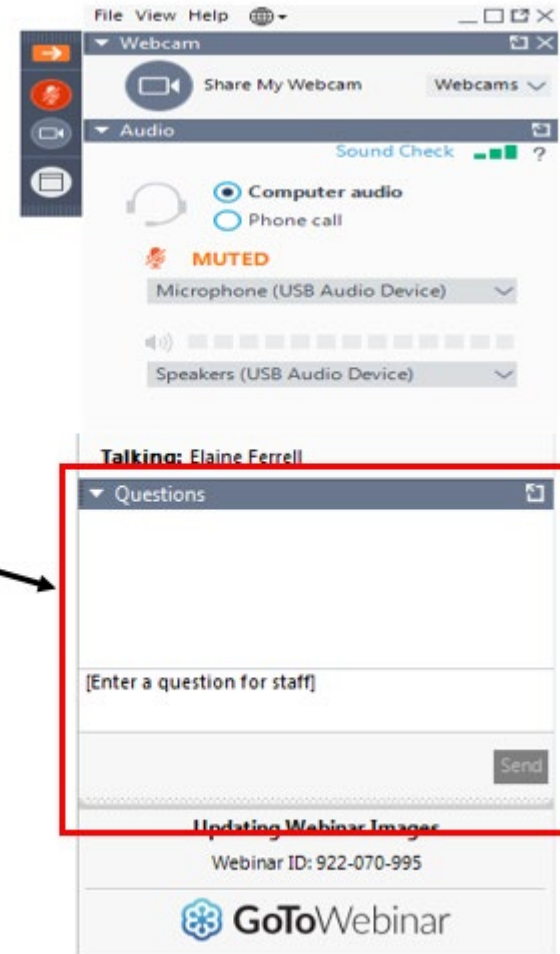
REGISTERED CONTINUING EDUCATION PROGRAM

Learning Objectives

- Describe general DOT practices for temporary pavement markings in work zones and pavement marking removal
- Identify innovative solutions for work zone pavement markings and pavement marking removal such as performance-based specifications, wet reflective markings, foil-backed tape, and pattern masking

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



Henry Brown
brownhen@missouri.edu
University of Missouri



Chris Brookes
BrookesC@michigan.gov
Michigan Department of Transportation



Ken Thornewell
kcthornewell@ncdot.gov
North Carolina Department of Transportation



Juan Pava
Juan.Pava@Illinois.gov
Illinois Department of Transportation

DOT Practices for Temporary Pavement Markings and Pavement Marking Removal

TRB Webinar
Temporary Pavement Markings
and Removal in Work Zones
August 16, 2022

Henry Brown, P.E.

Research Engineer

Praveen Edara, Ph.D., P.E., P.T.O.E.

Professor

University of Missouri

[NCHRP Synthesis Report 574 \(2021\)](#)



(Courtesy of Colorado DOT)

Have you ever wondered?

- How do DOTs decide which types of temporary pavement markings and marking removal methods to use?
- Which types of temporary pavement markings and marking removal methods work the best?
- How to eliminate ghost pavement markings?

Presentation Outline and Learning Objectives

- Introduction
- Guidance and evaluation studies
- DOT policies and standards
- DOT practices
- Conclusion

- Learning Objectives
 - Describe general DOT practices
 - Identify innovative solutions

Motivation, Objective, and Methodology

Motivation

- Importance of helping drivers navigate work zones safely
- Need greater understanding of DOT practices

Objective

- Document DOT policies/procedures for work zone pavement markings and marking removal

Methodology

- Literature review
- DOT survey
- Case examples (interviews)

Overview of Temporary Pavement Markings

Materials	Application	Durability	Pros	Cons
Paint	Machine	1 year or less	Low cost \$0.10-0.15/foot; wet-reflective elements can be added	Low durability under heavy traffic, low quality under wet weather.
Thermoplastic	Machine	3 to 5 years	High durability	High cost \$0.70- 3.00/foot, medium wet weather recovery; difficult to remove.
Epoxy	Machine	3 to 5 years	High durability	High cost \$0.70- 3.00/foot, medium wet weather recovery, and contrast hard to see on new concrete.
Temporary Raised Pavement Markers (TRPM): Tabs	Installed by hand	Less than 1 year; less than 1 month under heavy traffic	Low cost, high visibility under wet weather, flexible installation	Possible littering, vandalism, best in warm weather application.
TRPM: Buttons	Installed by hand or by machine	1 year	Low cost, audible and tactile clue to driver	Not conducive for snow plows, small target value.

Source: [ATSSA 2014](#)

Overview of Pavement Marking Removal Methods

(Cho et al. 2011)



Grinding

(Ellis et al. 1999)



Water Blasting

(KC Power Clean 2015)



Sand Blasting

(© AAA Striping and Seal Coating Service 2017)



Shot Blasting

Guidance for Temporary Markings and Marking Removal

- MUTCD (FHWA 2009)
 - Placement and removal
 - Duration
 - Reviews
- ATSSA Guide on Temporary Pavement Markings (2014)
 - Materials
 - Considerations
 - Pros and Cons
- ATSSA Quality Guidelines for TTC Devices (2017)

Rating	Criteria for Temporary Pavement Markings (Tape and Paint)
Acceptable	<ul style="list-style-type: none"> • All tape or paint in place • In conformance with material specifications
Marginal	<ul style="list-style-type: none"> • Absence of 10% or less of tape, message, or symbol • Absence of two or less consecutive skip lines • Absence of 50 feet or less of continuous solid stripe
Unacceptable	<ul style="list-style-type: none"> • Absence of more than 10% tape, message, or symbol • Absence of more than two consecutive skip lines • Absence of more than 50 feet of continuous solid stripe

Source: ATSSA 2017

Evaluation Studies: Temporary Pavement Markings

- Tape: satisfactory performance, some damage from heavy wear (Hawkins et al. 2012)
- Removable paint: failure after 15 days (Hawkins et al. 2012)
- All-Weather Paint markings higher retroreflectivity, safer lane placement (3M n.d., Cunningham et al. 2013)



(Cunningham et al. 2013)

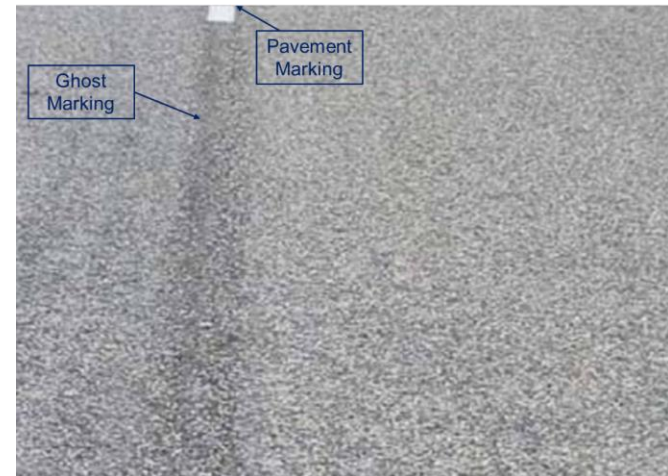
All-Weather Paint Marking (left) and Standard Marking (right)

Evaluation Studies: Marking Removal

- Sand blasting effective, minimal scarring (Bryden and Kenyon 1986)
- Water blasting least damage, grinding most efficient (Berg and Johnson 2009)



Carbide Grinding

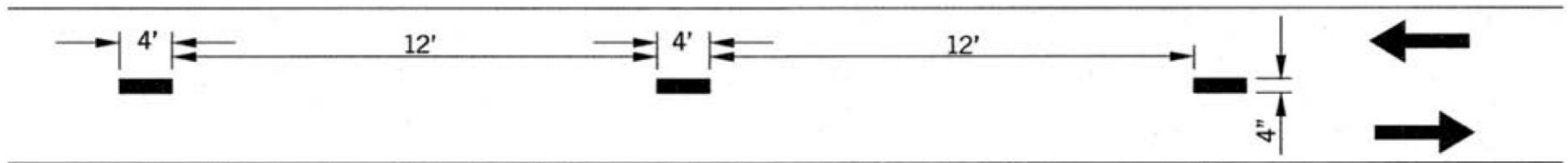


Water Blasting

(adapted from Berg and Johnson 2009)

Policies and Standards for Temporary Pavement Markings

- Materials and construction requirements
- Time considerations
- Measurement and payment
- Monitoring and inspection
- Differences in layouts and dimensions



Two-way Temporary Pavement Marking Layout for Oklahoma DOT

Policies and Standards for Pavement Marking Removal

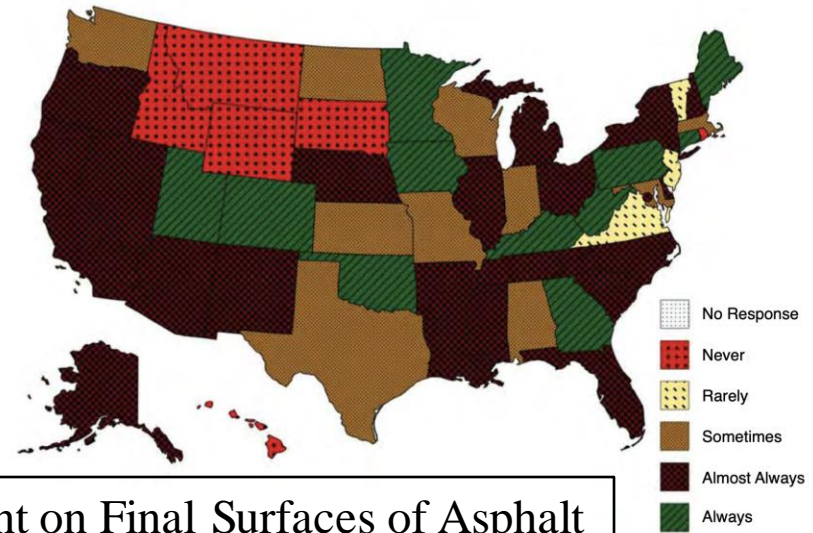
- Allowable methods
- Minimum removal requirements or thickness limits
- Time restrictions
- Removal of residue and debris
- Other



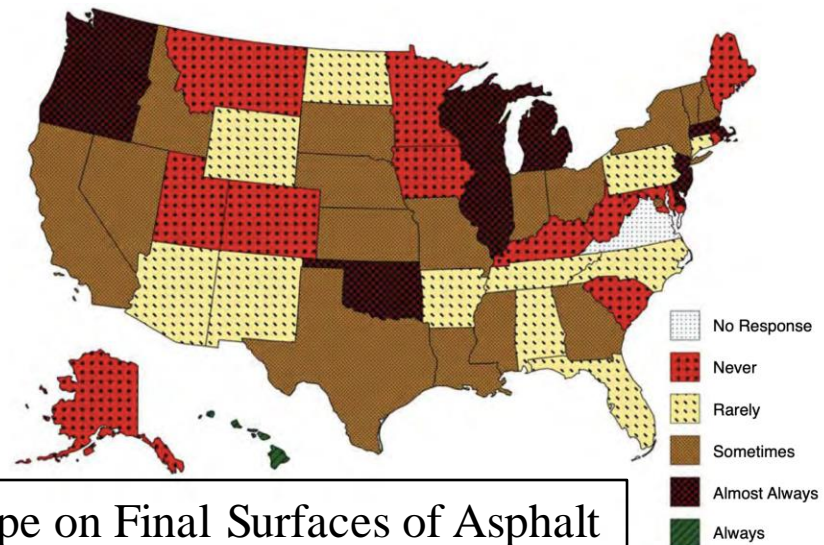
(Courtesy of Hog Technologies)

DOT Practices for Temporary Pavement Markings

- Most frequently used
 - Paint
 - Temporary tape
- Factors considered
 - Work zone duration
 - Past experience
 - Safety
- Perceived performance
 - Highest: Thermoplastic, epoxy
 - Lowest: Temporary tape, tabs



Paint on Final Surfaces of Asphalt

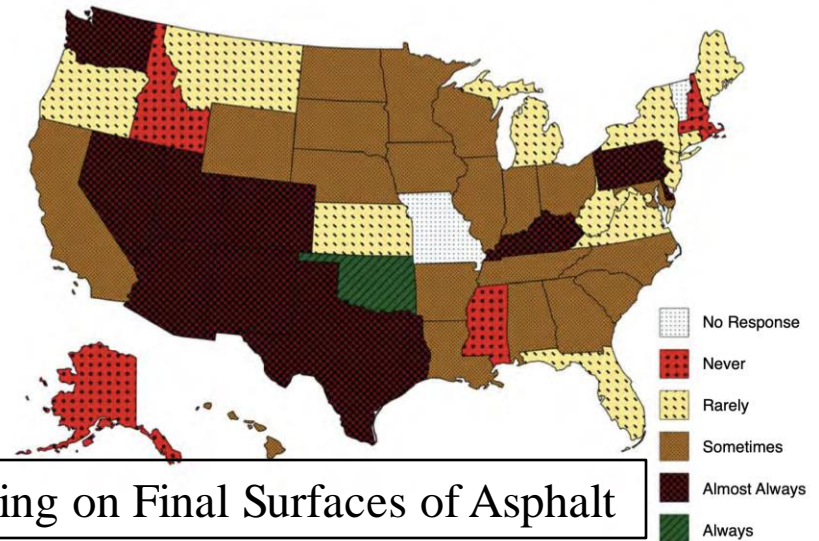
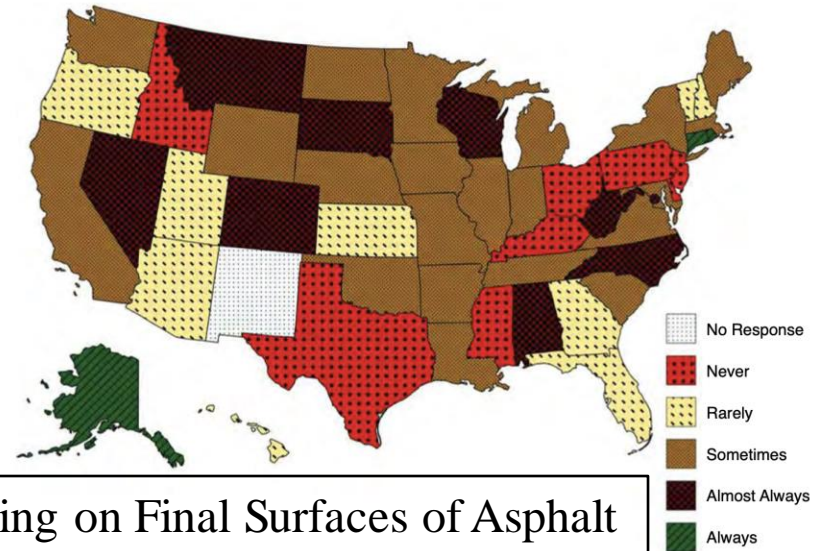


Tape on Final Surfaces of Asphalt

(Maps created with mapchart.net ©)

DOT Practices for Pavement Marking Removal

- Most frequently used
 - Grinding
 - Water blasting
- Factors considered
 - Past experience
 - Pavement scarring
 - Pavement type
- Perceived performance
 - Highest: Water blasting and shot blasting
 - Lowest: Black tape and slurry seal



(Maps created with mapchart.net ©)

Other Survey Findings

- Measured pay items for installation and removal
- Performance evaluations completed by 8 DOTs
- Documented processes for selection of markings or removal methods by 20 DOTs

Development of Policies and Standards by Topic

Topic	Yes	No	NR*
Temporary Traffic Control Requirements	71%	25%	4%
Minimum Quality Requirements (e.g. Color, Retroreflectivity)	67%	29%	4%
Timeline Requirements	61%	35%	4%
Design Requirements	55%	37%	8%
Monitoring and Inspection	51%	43%	6%
Maintenance Requirements	45%	49%	6%
Abbreviated Pavement Marking Patterns	43%	51%	6%
Thresholds for Acceptance of Pavement Removal	39%	55%	6%
Warrants for Temporary Pavement Markings	35%	59%	6%
Other	2%	25%	73%

*NR = No Response

Other Example DOT Practices

- Some use 6-inch markings
- Foil-backed tape for intermediate or base courses
- Wet reflective markings
- Performance specification
- Low-VOC paint for cold weather
- Durable markings (e.g., urethane, polyurea, and epoxy) for high volumes or long durations
- Surface applied polyurea (thinner)
- Abbreviated patterns for short-term markings
- Wider swath for marking removal
- Pattern masking



(Kite n.d.)

Summary of Findings

Temporary Markings

- DOTs have preferred types
- Factors considered
 - Duration
 - Past experience
 - Safety
- Paint and temporary tape most frequently used
- Innovations
 - Special color markings
 - Wet reflective markings
 - Enhanced tape
 - Foil backed tape
 - Performance specification

Marking Removal

- Grinding and water blasting most frequently used
- Factors considered
 - Past experience
 - Pavement scarring
 - Pavement type
- Strategies for ghost markings
 - Pattern masking
 - Wider removal swath

Challenges and Suggestions for Future Research

Challenges

- Ensuring proper application of markings and enforcing contract provisions
- Maintaining temporary markings
- Ghost markings
- Limiting worker exposure to traffic
- Markings for thin surface treatments

Research Needs

- Development of new materials for temporary pavement markings
- Creation of guidance document
- Innovative removal methods to address ghost markings
- Additional field evaluations
- Advancement of more uniform standards



(Courtesy of Florida DOT)



(Shaw et al. 2018)

References

- AAA Striping and Seal Coating Service, “Shot Blasting,” 2017. <http://aaastriping.ca/services/shot-blasting/>.
- ATSSA, *Guidance for the Use of Temporary Pavement Marking in Work Zones*, 2014.
- ATSSA, *Quality Guidelines for Temporary Traffic Control Devices and Features*, 2017.
- Brown, H., and P. Edara, [*Temporary Pavement Markings Placement and Removal Practices in Work Zones*](#), NCHRP Synthesis Report 574, National Academy of Sciences, 2021.
- Berg, K., and S. Johnson, *Field Comparison of Five Pavement Marking Removal Technologies*, Utah Department of Transportation, Salt Lake City, Utah, 2009.
- Bryden, J. E., and W.D. Kenyon, *Methods for Removal of Pavement Markings*, New York State Department of Transportation, Albany, New York, 1986.
- Cho, Y., K. Kabassi, and J. Pyeon, *Effectiveness Study on Temporary Pavement Marking Removals Methods*, Nebraska Department of Roads, Lincoln, Nebraska, 2011.
- Cunningham, C.M., et al., *Temporary Wet-Weather Pavement Markings for Work Zones, Phase II: All-Weather Pavement Marking for Work Zones, Field Evaluation in North Carolina and Ohio*, FHWA, Washington, D.C., 2013.
- Ellis, R. D., B. Ruth, and P. Carola, *Development of Improved Procedures for the Removal of Pavement Markings during FDOT Construction Projects*, Florida Department of Transportation, Tallahassee, Florida, 1999.

References

- FHWA, *Manual on Uniform Traffic Control Devices for Streets and Highways*, Washington, D.C., 2009.
- Hawkins, N., O. Smadi, and B. Aldemir-Bektas, *Evaluating the Effectiveness of Temporary Work-Zone Pavement Marking Products*, Smart Work Zone Deployment Initiative, Ames, Iowa, 2012.
- KC Power Clean, “‘Dustless’ sandblasting to remove street and road markings,” 2015.
<https://m.youtube.com/watch?v=fw6TV98tvFg>.
- Kite, S., “Work Zone Safety Innovations – ‘Pattern Masking’ and ‘Performance’ Pavement Markings,” presentation slides, n.d.
- Oklahoma Department of Transportation, “Traffic Engineering Standards and Specifications,” 2009. <https://www.odot.org/traffic/standards.htm>.
- Shaw, J. W., M.V. Chitturi, K.R. Santiago-Chaparro, L. Qin, L., A.R. Bill, and D.A. Noyce, *Orange Work Zone Pavement Marking Midwest Field Test*, Smart Work Zone Deployment Initiative, Ames, Iowa, 2018.
- 3M, *Temporary Wet-Weather Pavement Markings for Work Zones*, Final Report Phase I, Highways for LIFE Technology Partnerships Program, n.d.

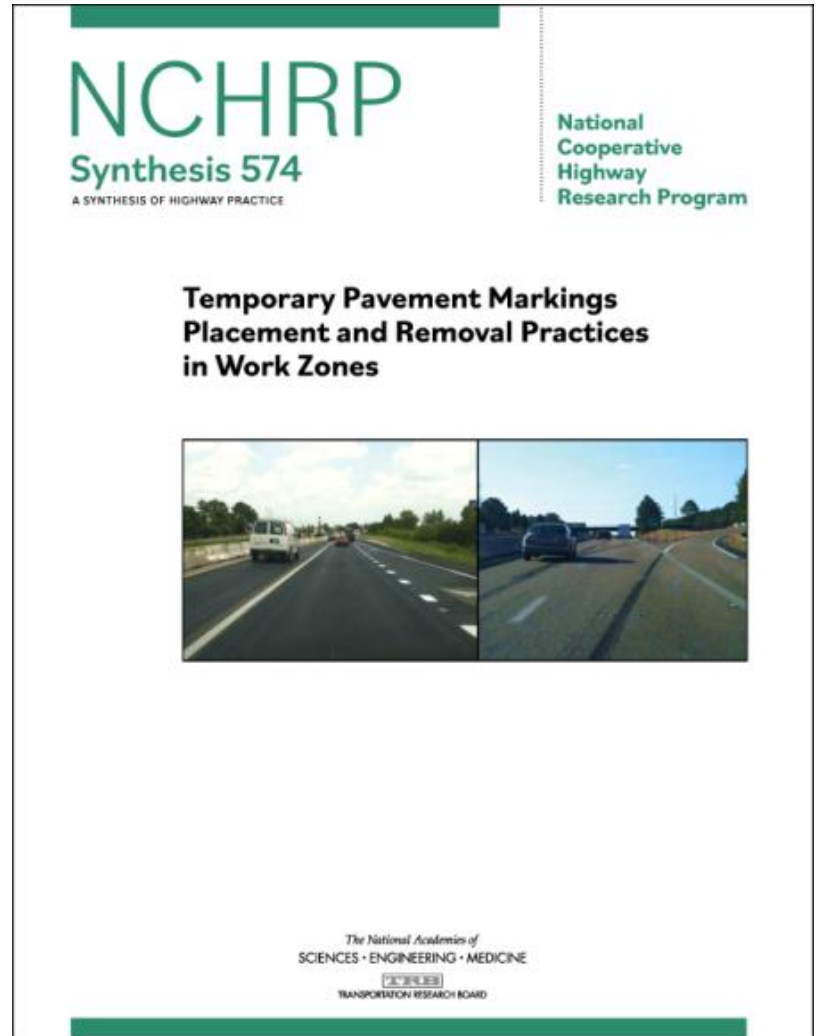
Acknowledgements

- Research funding by National Cooperative Research Program (Project Managers: Andre Primus, Jo Allen Gause)
- DOTs who completed survey and participated in interviews
- Topic Panel
 - Neil Boudreau (Massachusetts DOT)
 - Marshall Douberley (Florida DOT)
 - Maysa Hanna (Arizona DOT)
 - Juan Pava (Illinois DOT)
 - John Shaw (Iowa State University)
 - Jawad Paracha (FHWA)
 - James Bryant (TRB Liaison)

Questions?

E2509 Lafferre Hall
Columbia, MO 65211
573-882-0832
brownhen@missouri.edu

Thank you!



NCHRP Synthesis 574 Link: <http://bitly.ws/te5S>

Temporary Pavement Markings in Michigan

Chris Brookes

Brookesc@Michigan.gov

Work Zone Safety and Mobility Manual



www.michigan.gov/mdotworkzones

Updated 5/28/2021

Work Zone Safety and Mobility Manual Content Managed by Work Zone Management Unit in Construction Field Services.

www.Michigan.gov/mdotworkzones

- ▶ 6.01.12 Temporary Pavement Markings
 - ▶ Pavement Marking Removal
 - ▶ Shift Marking
 - ▶ Temporary Raised Pavement Markers
 - ▶ Pavement Marking Cover
 - ▶ Curing Compound Removal
 - ▶ Edge Line Markings
 - ▶ Capital Preventive Maintenance (CPM) Projects

Shift Markings

- ▶ All temporary traffic shifts (except merging tapers) on freeways should be striped with 6-inch solid Wet Reflective Type R, Tape. 6-inch solid edge and lane lines must be placed 300 feet prior to the traffic shift, through the shift, and 300 feet after the traffic shift. This is required for both entry and exit shifts.
- ▶ Non-freeway shifts (except merging tapers), must be striped with 4-inch solid Wet Reflective Type R, Tape edge lines and lane lines must be placed 150 feet prior to the traffic shift, through the shift, and 150 feet after the traffic shift. This is required for both entry and exit shifts.
- ▶ The leading and trailing markings described above are used to provide motorists with additional guidance and reassure the driver they are in the correct location, as the lane lines will have just been modified



Pavement Markings

▶ PAVE-904-A

▶ Freeway Markings

▶ 6" width:

- ▶ Broken White
- ▶ Solid White Lane or Lane Shift
- ▶ Solid White Edge Line
- ▶ Solid Yellow Edge Line

▶ 12" Width

- ▶ Solid White Gore Marking

▶ Non-Freeway Markings:

▶ 4" Width:

- ▶ Broken White
- ▶ Solid White Lane or Shift
- ▶ Broken Yellow
- ▶ Double Solid Yellow

▶ 6" Width:

- ▶ Solid White Edge Lines
- ▶ Solid Yellow Edge Lines

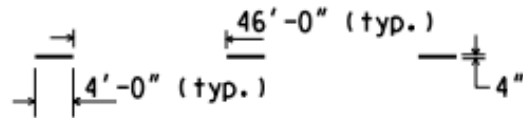
▶ 12" Width:

- ▶ Solid White Gore Markings

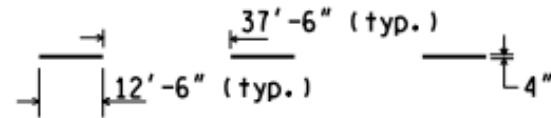
TYPES OF TEMPORARY LONGITUDINAL LINES

NON-FREEWAY APPLICATIONS

BROKEN WHITE LANE LINE (1)



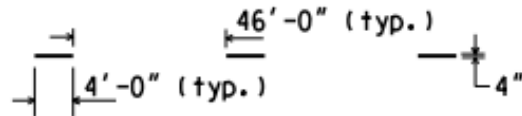
BROKEN WHITE LANE LINE (2)



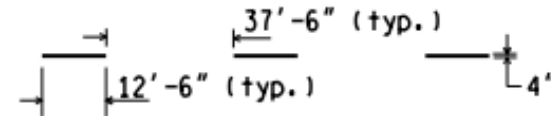
SOLID WHITE LANE LINE OR LANE SHIFT



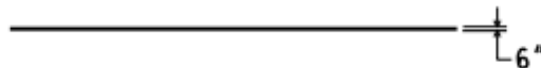
BROKEN YELLOW CENTERLINE (1)



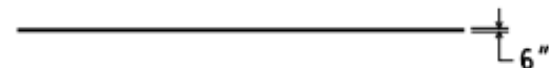
BROKEN YELLOW CENTERLINE (2)



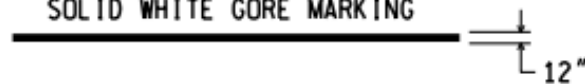
SOLID WHITE EDGE LINE



SOLID YELLOW EDGE LINE



SOLID WHITE GORE MARKING





Old Method



Water Blasting



Shadow Markings



Tape Piles



Tape Breaking



Tape Breaking

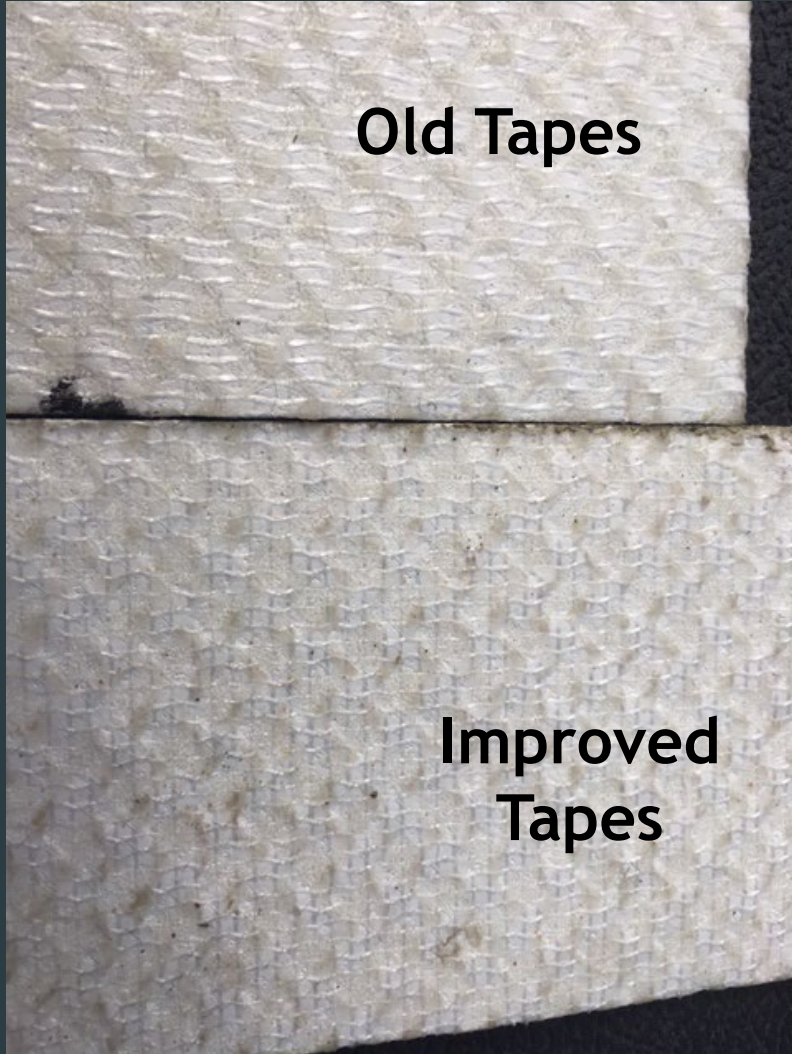


Back Problem's?



Increased Scrim

Old Tapes



**Improved
Tapes**





**Improved
Tape**

Old Tape



Why is this Needed?





Temporary Tape Test

New Tape



Test Tape



Tape Race



MDOT Changes

- ▶ Pavement Marking Changes 2021
 - ▶ 4" to 6 " lane and edge markings
 - ▶ 8" to 12" Gores
 - ▶ Shifts will be changing to 6"
- ▶ The improved removable tape will be required on all freeway projects during the 2020 construction season, both those already under contract and those yet to be let.
- ▶ For jobs currently under contract, a contract mod will be issued increasing the contract price for the Type R. The price increase will be the same on all jobs regardless of the actual bid price.



Improved Tape Removal



Old Tape Removal



Pilot Testing



Test Locations





Hypothetical Construction Season

- ▶ Current Tape
- ▶ 10,000 Linear Ft.
 - ▶ 4 workers
 - ▶ 3 hours to peel
- ▶ Improved Tape
- ▶ 10,000 Linear Ft.
 - ▶ 4 workers
 - ▶ 30 minutes
- ▶ 10 hours reduction in worker exposure
- ▶ Assuming 500 traffic switches in a season
- ▶ Worker exposure hours reduced by 5,000
- ▶ Traffic switch time reduced by 1,250 hours
- ▶ Assuming an average user delay of \$5,000 per hour the saving would be \$6,250,000 in user delay and a reduction in work zone related crashes.



Temporary Pavement Markings in Work Zones

Ken Thornewell, PE, PTOE

Central Region Work Zone Engineer

August 16, 2022

Today's Discussion Topics

- NCDOT in a Nutshell
- Pavement marking eradication challenges
- Work Zone Pattern Masking
- Full-width Pavement Texturing
- Work Zone Performance Markings

Disclaimer of Endorsement

Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the North Carolina Department of Transportation (NCDOT). The views and opinions of authors expressed herein do not necessarily state or reflect those of the NCDOT, and shall not be used for advertising or product endorsement purposes.



NC MOVES 2050
CONNECTING YOUR COMMUNITY,
YOUR VOICE AND YOUR FUTURE

STATE OF THE SYSTEM
Highways

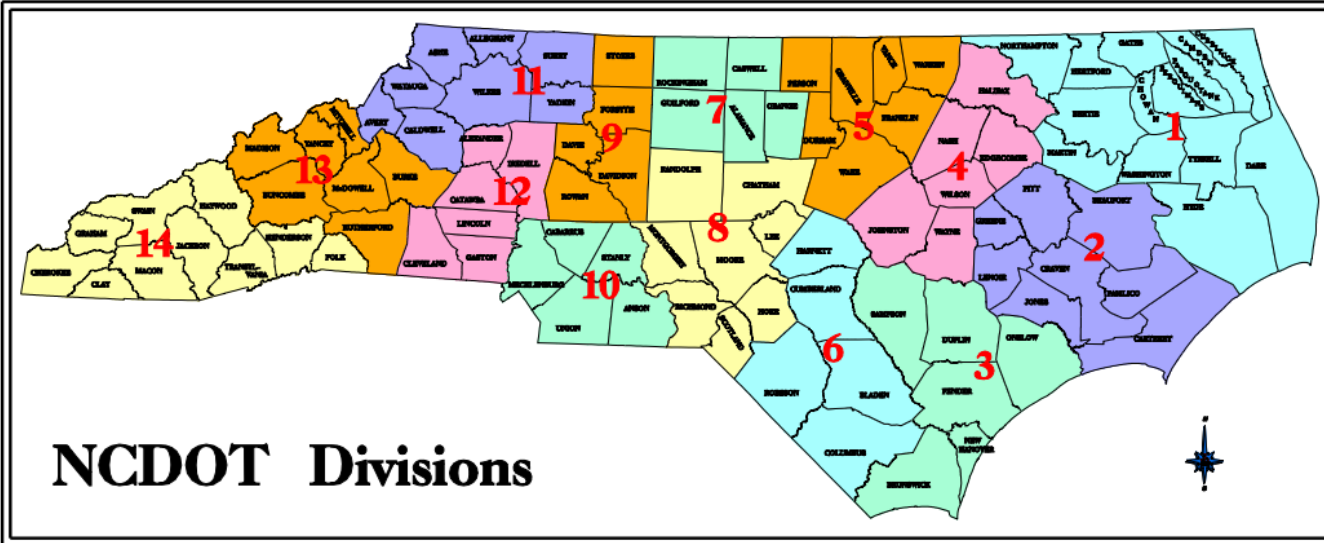


North Carolina's Highway System



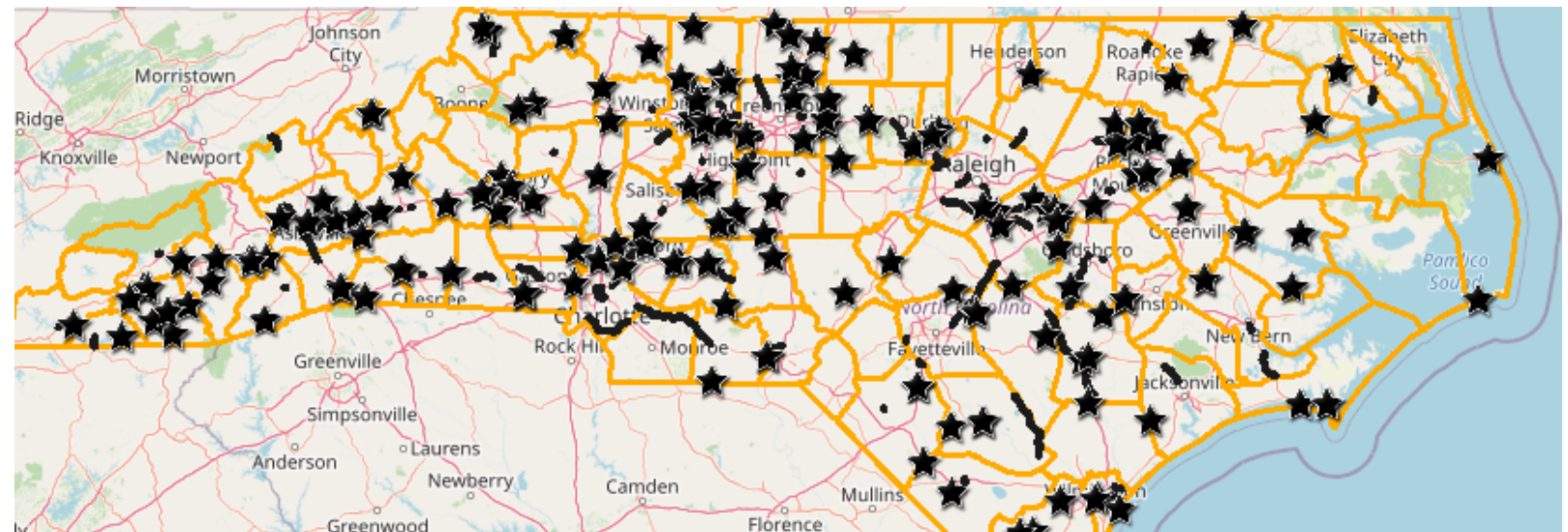
The Division of Highways supports the delivery of statewide transportation projects and is responsible for nearly 80,000 miles of road in North Carolina, making it the nation's second largest state-maintained highway system.

NCDOT in a Nutshell



- 14 Divisions each with their own design project managers, construction offices, and maintenance departments
- \$2.2 billion in new construction FY20-21

- \$1.6 billion in Maintenance
- 714 active projects (\$8.7 billion contract value) as of 7/28/22



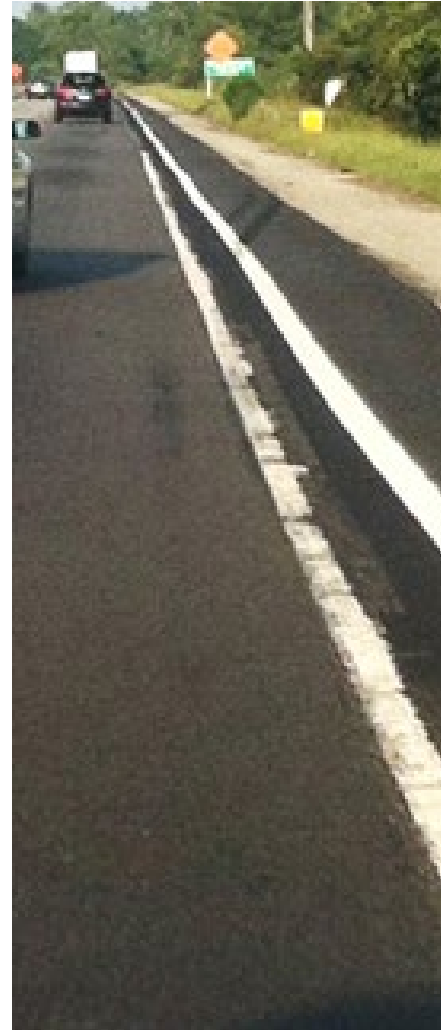
Pavement Marking Eradication Challenges



Four Major Categories of Issues in NC:

- 1) Double Lines
- 2) Multiple Shifts
- 3) Existing Pavement Difficulties
- 4) Poor Night-Time and Rainy-Day Visibility

Pavement Marking Eradication Challenges



- Four Categories of Issues:
 - 1) Double Lines
 - Unclear definition of “conflicting markings”
 - Spec issue – to be corrected with our next specification update

Pavement Marking Eradication Challenges



2) Multiple Shifts

- Grind marks left behind from a single shift is usually acceptable
- Multiple shifts create lots of conflicting ghost lines



Pavement Marking Eradication Challenges

3) Existing Pavement Surface Issues

- Excessive pavement damage to Ultra-Thin surfaces



Pavement Marking Eradication Challenges



3) Existing Pavement Surface Issues

- Excessive pavement damage to Ultra-Thin surfaces
- Remove a skip, reveal a skip

Pavement Marking Eradication Challenges

3) Existing Pavement Surface Issues

- Difficult to remove where an open joint has formed



Pavement Marking Eradication Challenges



3) Existing Pavement Surface Issues

- Temporary tape “either sticks, or it doesn’t”
- Leaves a residue
- Pavement underneath fades/oxidizes differently

Pavement Marking Eradication Challenges

4) Night-Time and Rainy-Day Visibility

- Markings from older pattern that haven't been eradicated have higher visibility at night than temp. markings
- Markings appear to have been removed, but glass beads remain
- Thin layers of traffic paint easily covered by water sheen when raining
- Eradication grooves fill hold “just enough” water

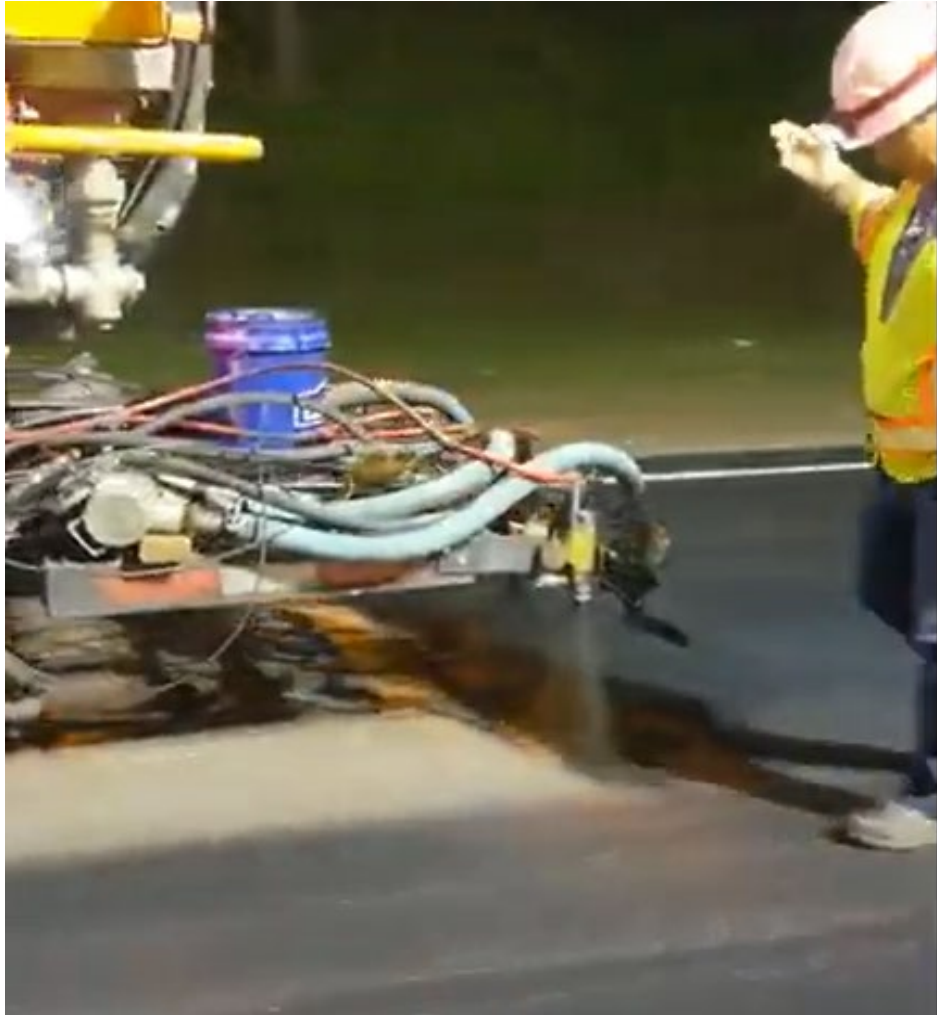
Pavement Marking Eradication Challenges



Pavement Marking Eradication Challenges



Pattern Masking



- A material used during work zone operations on existing pavements to cover and conceal existing pavement markings during shifts in traffic patterns
- When changing a traffic pattern in a long-term work zone (at least 12 months)
- Price is about 60 cents/SF

Pattern Masking

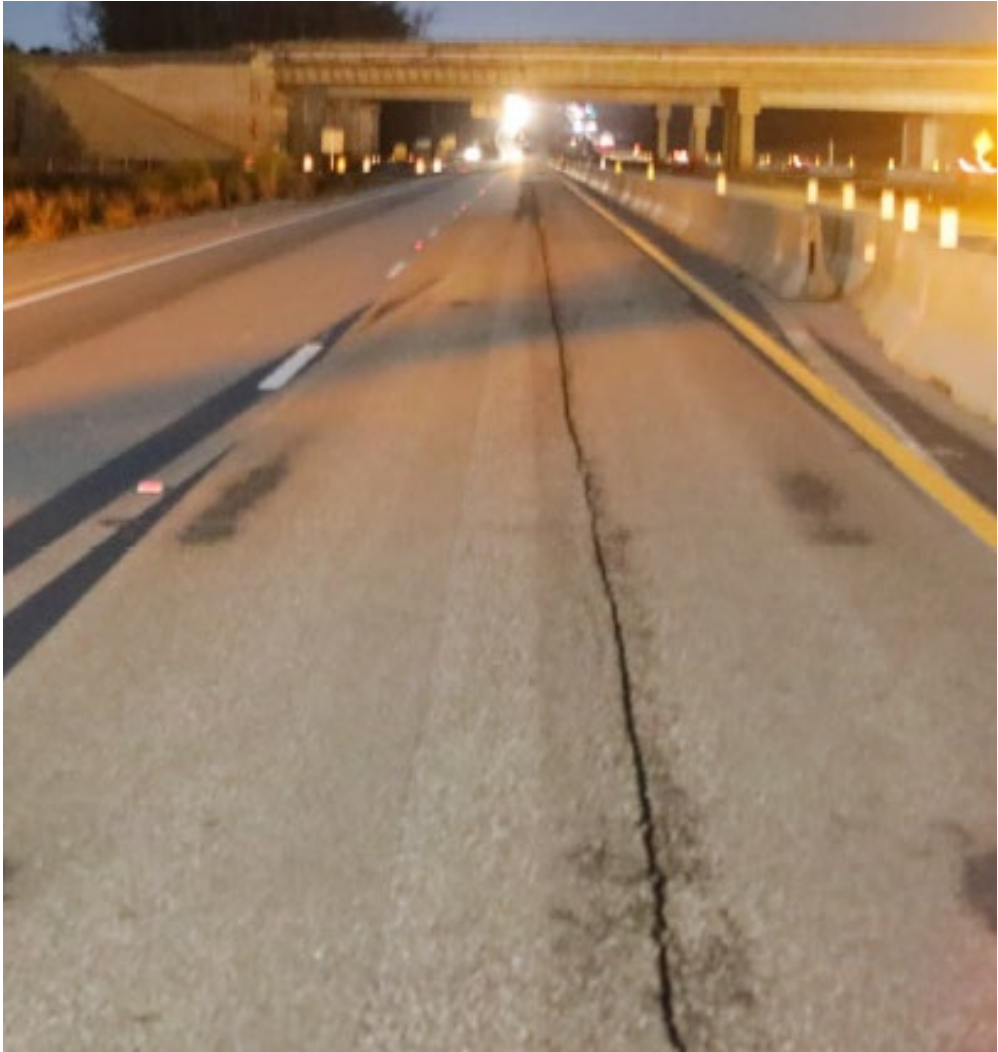


Pattern Masking



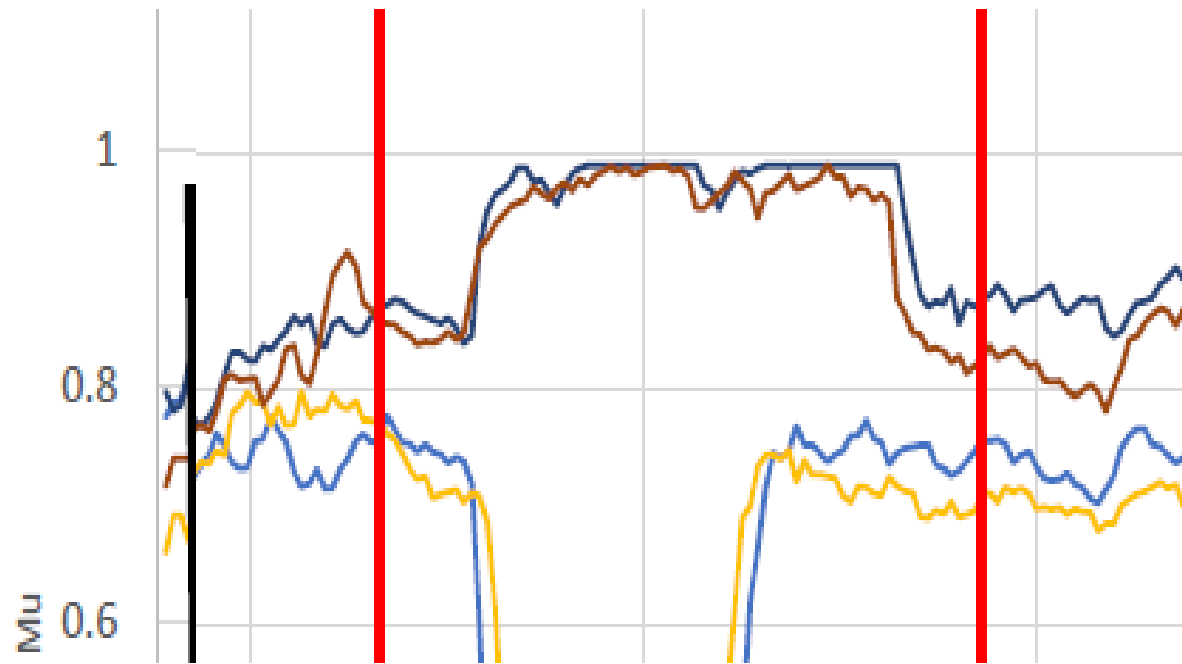
- Results have varied
 - Dry time challenges
 - Volume plays a major factor
 - Monitor long-term skid resistance

Full Width Pavement Texturing



- Utilizes a shotblasting truck to micromill pavement in 6' pass
- Operates as quick as (if not quicker) than traditional grinding
- Creates uniform pavement color

Full Width Pavement Texturing



- Cost is very similar to pattern masking
 - Becomes cheaper in higher quantities
- Added benefit of increasing pavement texture

Work Zone Performance Pavement Markings

- Standard (non-performance) WZ pavement markings are 15 mils of paint, reapplied after 6 months
- Significant fading, esp. in high traffic environments



Work Zone Performance Pavement Markings



- Performance markings require permanent marking materials at a reduced thickness.
- Establishes Initial, 6 month, and 12-month minimum retroreflectivity requirements
- Allows contractor to choose the marking material

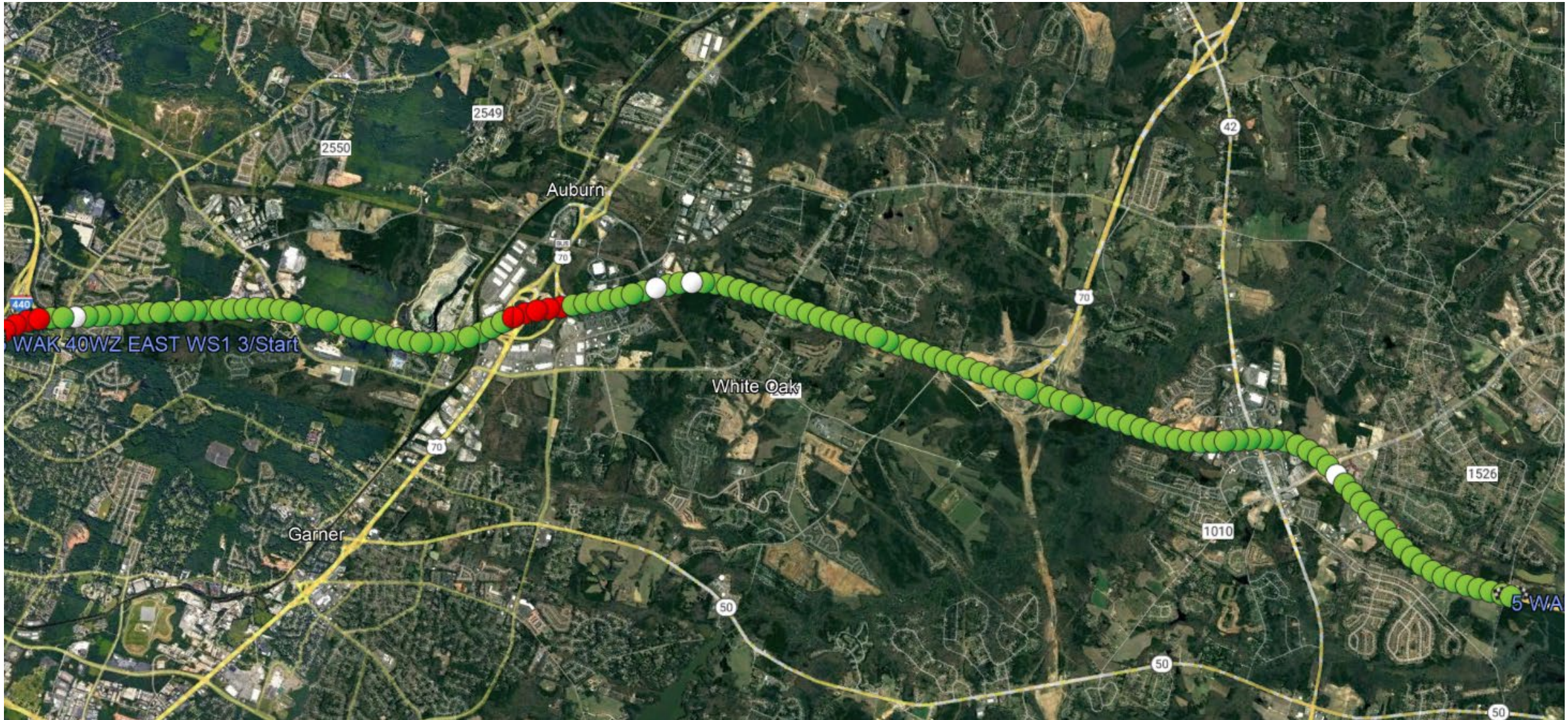
Work Zone Performance Pavement Markings

Polyurea =	20 mils wet
Epoxy =	20 mils wet
Thermoplastic =	50 mils (Extruded or Sprayed)
Polymer =	20 mils wet
Cold Applied Plastic (IV) =	Manufacturer's recommendation

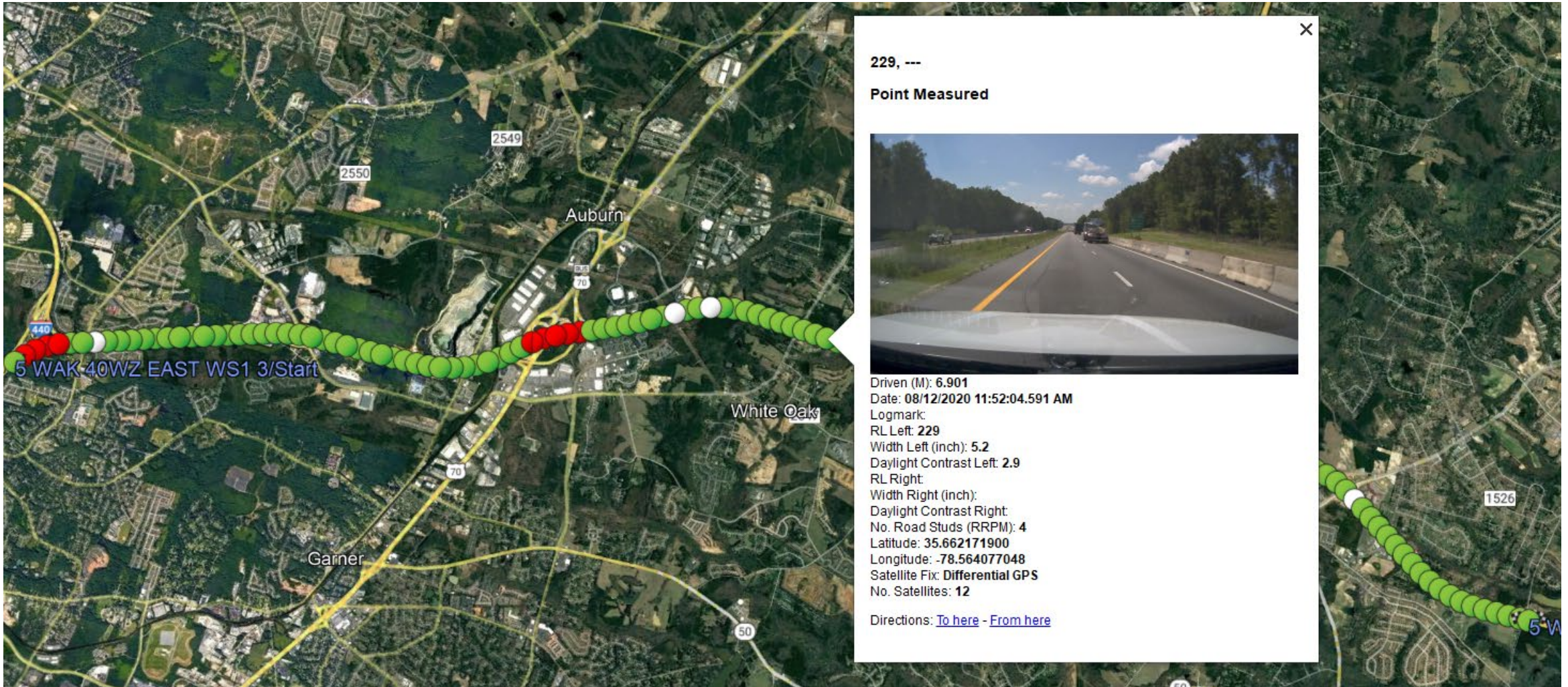
Retroreflectivity Requirements for Work Zone Performance Pavement Markings

Color	Initial	6 Months	12 Months
White	375 mcd/lux/m ²	275 mcd/lux/m ²	150 mcd/lux/m ²
Yellow	250 mcd/lux/m ²	150 mcd/lux/m ²	100 mcd/lux/m ²

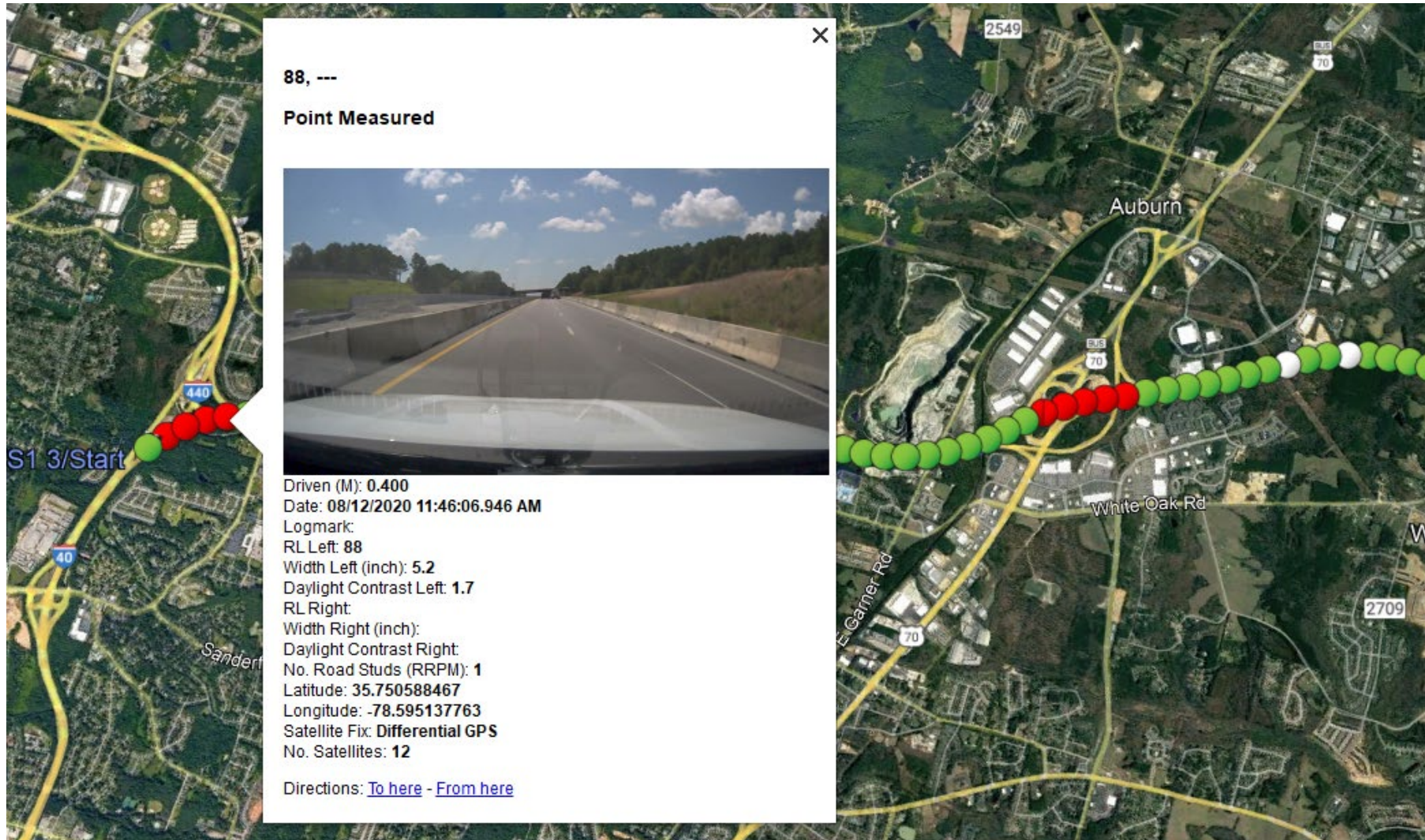
Performance Pavement Marking Readings



Performance Pavement Marking Readings



Performance Pavement Marking Readings



Questions/Comments?

Contact Information:

Ken Thornewell, PE, PTOE

Central Region Work Zone Engineer

Telephone: (919) 814-5037

Email: kcthornewell@ncdot.gov

Today's presenters



Henry Brown
brownhen@missouri.edu
University of Missouri



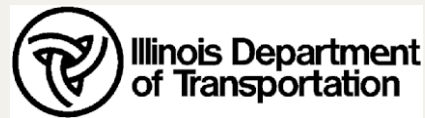
Chris Brookes
BrookesC@michigan.gov
Michigan Department of Transportation



Ken Thornewell
kcthornewell@ncdot.gov
North Carolina Department of Transportation



Juan Pava
Juan.Pava@Illinois.gov
Illinois Department of Transportation



NATIONAL
ACADEMIES

*Sciences
Engineering
Medicine*

Upcoming Events for you

August 29-31, 2022

TRB's Tools of the Trade
Conference

September 12-16, 2022

TRANSED: Mobility, Accessibility,
and Demand Response
Transportation Conference

<https://www.nationalacademies.org/trb/events>

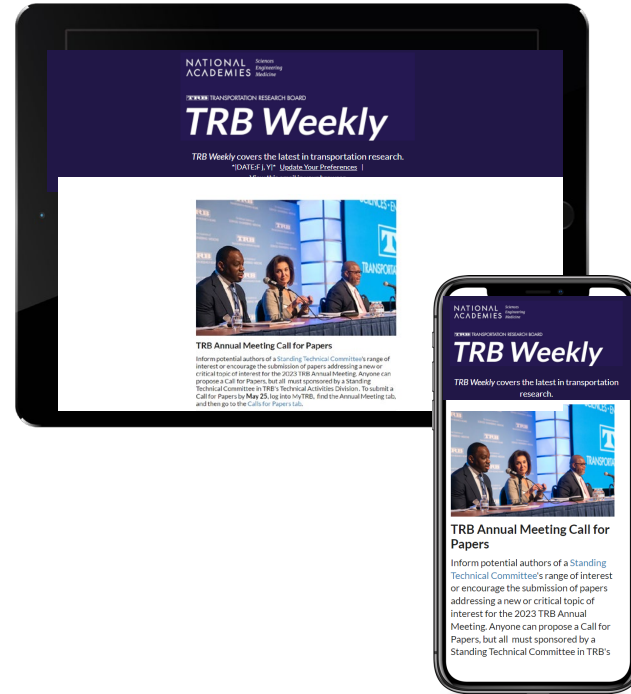


Subscribe to *TRB Weekly*

If your agency, university, or organization perform transportation research, you and your colleagues need the *TRB Weekly* newsletter in your inboxes!

Each Tuesday, we announce the latest:

- RFPs
- TRB's many industry-focused webinars and events
- 3-5 new TRB reports each week
- Top research across the industry

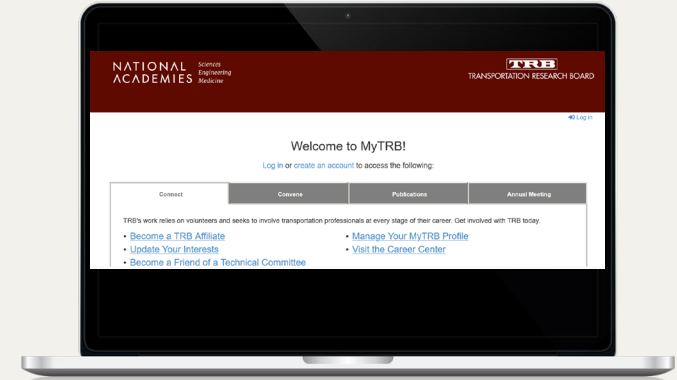


Spread the word and subscribe!

<https://bit.ly/ResubscribeTRBWeekly>

Making our work accessible

- **Join or Become a Friend of a Standing Technical Committee**
Network and pursue a path to Standing Committee membership
bit.ly/TRBstandingcommittee
- **Work with a CRP**
<https://bit.ly/TRB-crp>
- **Keep us updated with your information**
www.mytrb.org



Listen to TRB's podcast



Listen on our website or subscribe wherever you listen to podcasts
<https://www.nationalacademies.org/podcasts/trb>



Apple Podcasts



Spotify



Google Podcasts



Overcast



Castbox



Pocket Casts



RSS feed

Stay in touch

Receive emails about upcoming webinars:

<https://mailchi.mp/nas.edu/trbwebinars>

Find upcoming conferences: <https://www.nationalacademies.org/trb/events>



@NASEMTRB



@NASEMTRB



Transportation
Research Board

We want to hear from you

- Take our survey
- Tell us how you use TRB Webinars in your work at trbwebinar@nas.edu

