

# Advanced Technologies for Smart Pavement Performance Monitoring and Maintenance: A Step Towards Intelligent Transportation Infrastructure

**Dr. Vimy Henderson, PhD, PEng**

President, Principal Engineer, PTech Engineering Solutions Inc.

Adjunct Professor, Civil Engineering, McMaster University

# Outline

- Factors in pavement performance
- Destructive versus non-destructive testing
- Roughness
- Traffic loading
- Structural capacity and pavement response
- Surface condition
- Existing pavement structure
- Pavement performance prediction
- Maintenance and treatment
- Conclusion



# Factors in Pavement Performance

- Loading
- Environment
- Materials
- Construction



# Factors in Pavement Performance

- Loading
  - Quantity of vehicles
  - Size of vehicles
  - Static, low speed or high speed



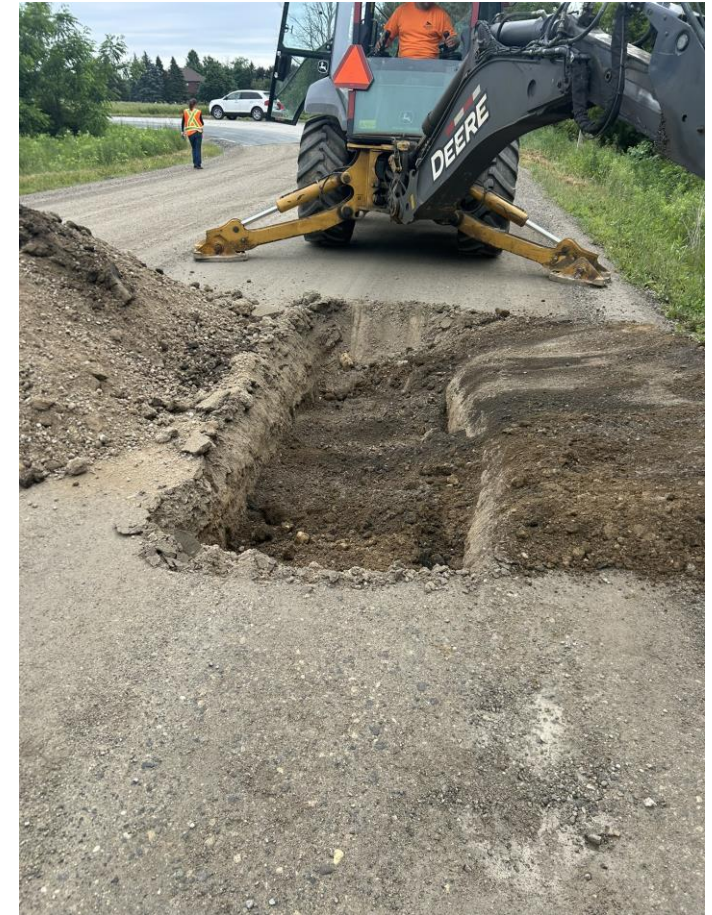
# Factors in Pavement Performance

- Environment
  - Natural drainage conditions
  - Wet or dry climate
  - Freeze-thaw cycles
  - Site restrictions



# Factors in Pavement Performance

- Materials
  - Existing subgrade soil
  - Existing pavement structure
  - Available granular materials



# Factors in Pavement Performance

- **Materials**
  - **Modifications**
    - Stabilization
    - Geosynthetics



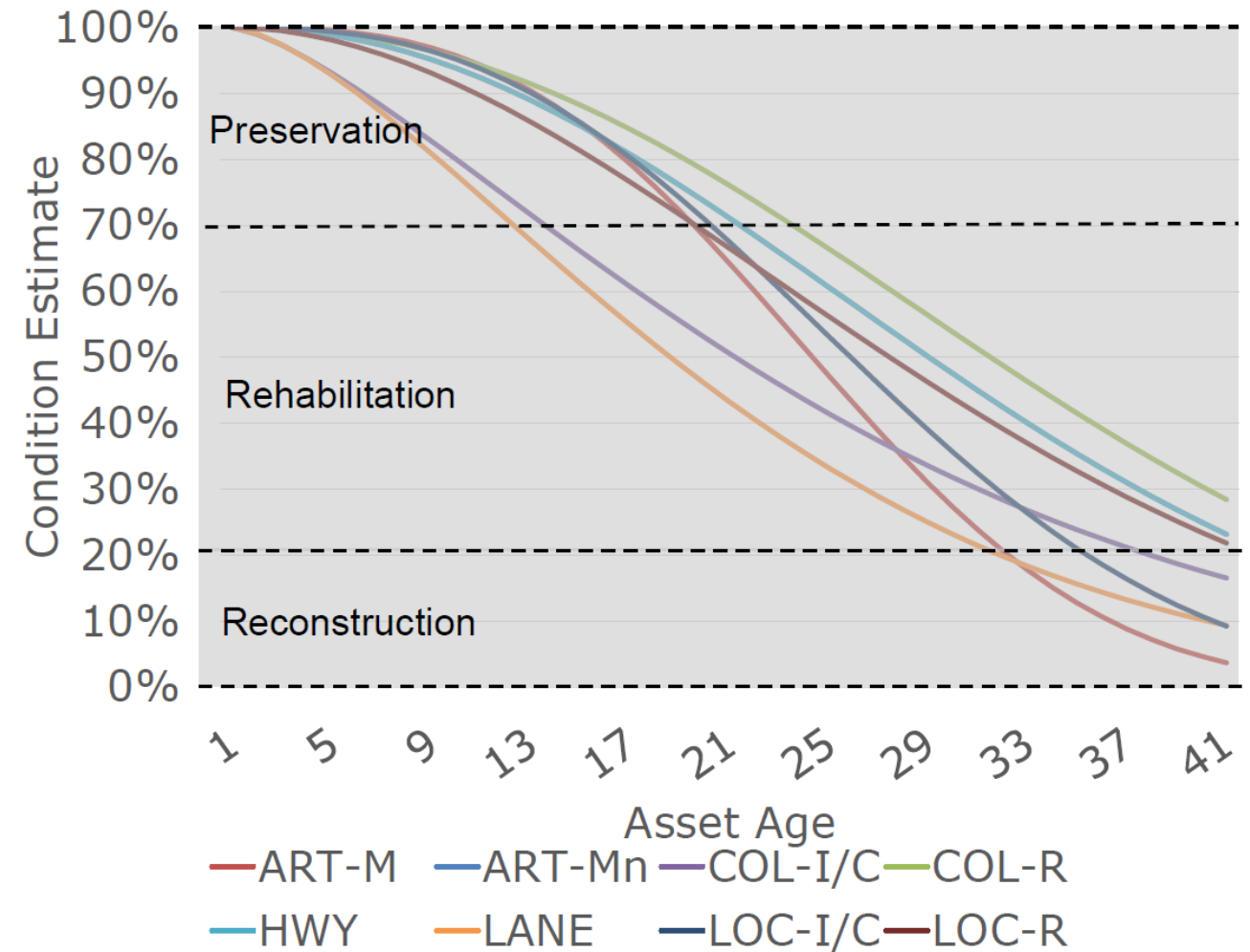
# Factors in Pavement Performance

- Construction
  - Quality and workmanship
  - Experience
  - Available resources
    - Materials
    - Equipment



# Objective

- Understand pavement performance based on data
- Functional Pavement Management System (PMS)
- Predict pavement performance based on
  - History
  - Measured data
  - Models



# Objective

- What performance challenges exist?
- What questions exist?
- What data is needed?

A word cloud visualization featuring the following terms: materials, loading, environment, concrete, construction, seal, rural, chip, compaction, precipitation, data, traffic, urban, subgrade, soil, weather, asphalt, and maintenance. The words are arranged in a cluster, with 'materials', 'loading', and 'environment' being the largest and most prominent.

# Destructive vs. Non-destructive Testing

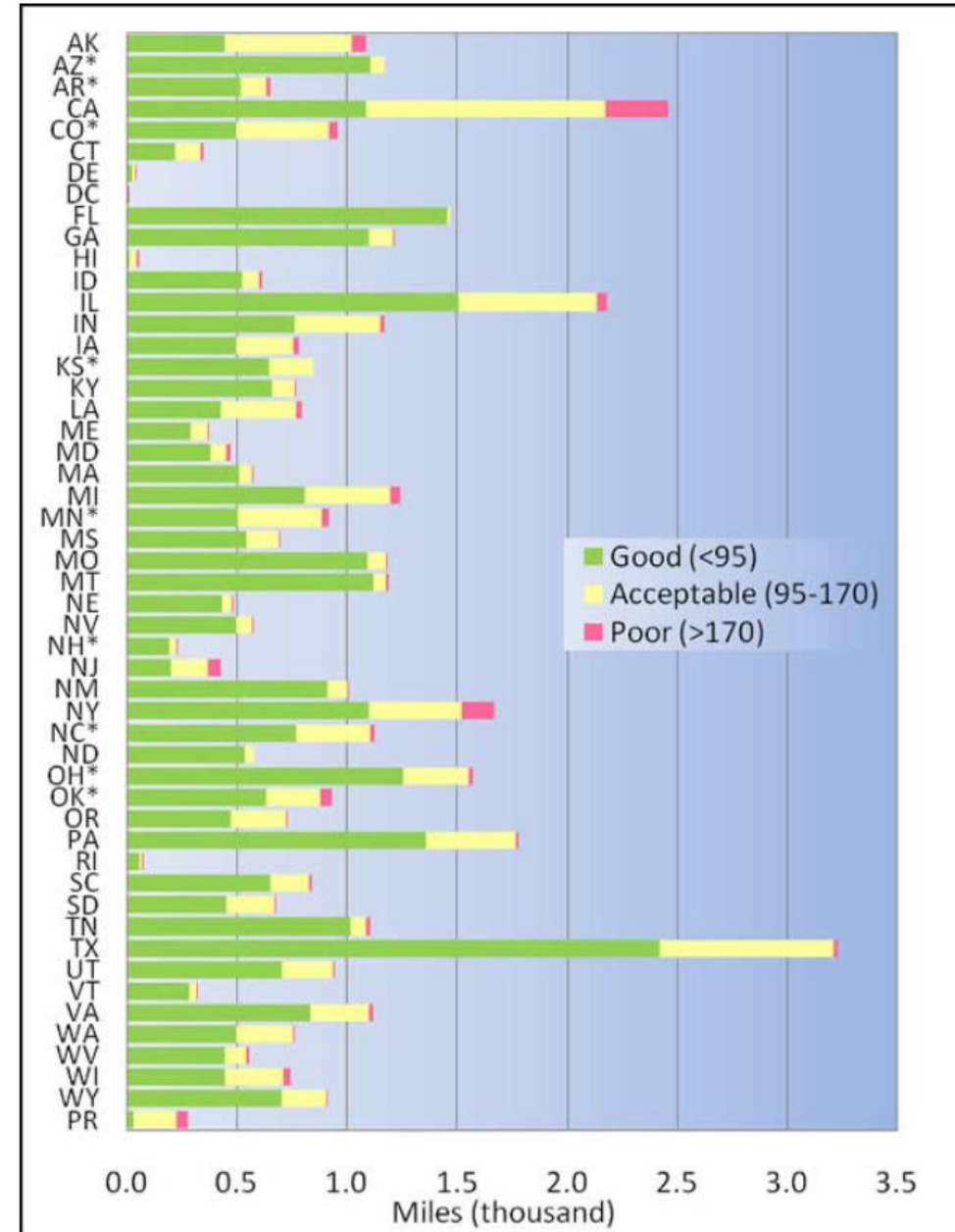
- Destructive
  - Time consuming
  - Disruptive to road users
  - Less data
  - Mandatory for verification
- Non-destructive
  - Data throughout road length
  - Time efficient, limited to no disruption to road users



# Roughness

- Indication of network condition
- Smooth pavement has limited distresses, is in good condition
- Rough pavement is in poor condition, variety of causes

Figure 7-1: Interstate Pavement Smoothness (IRI) by State: 2009

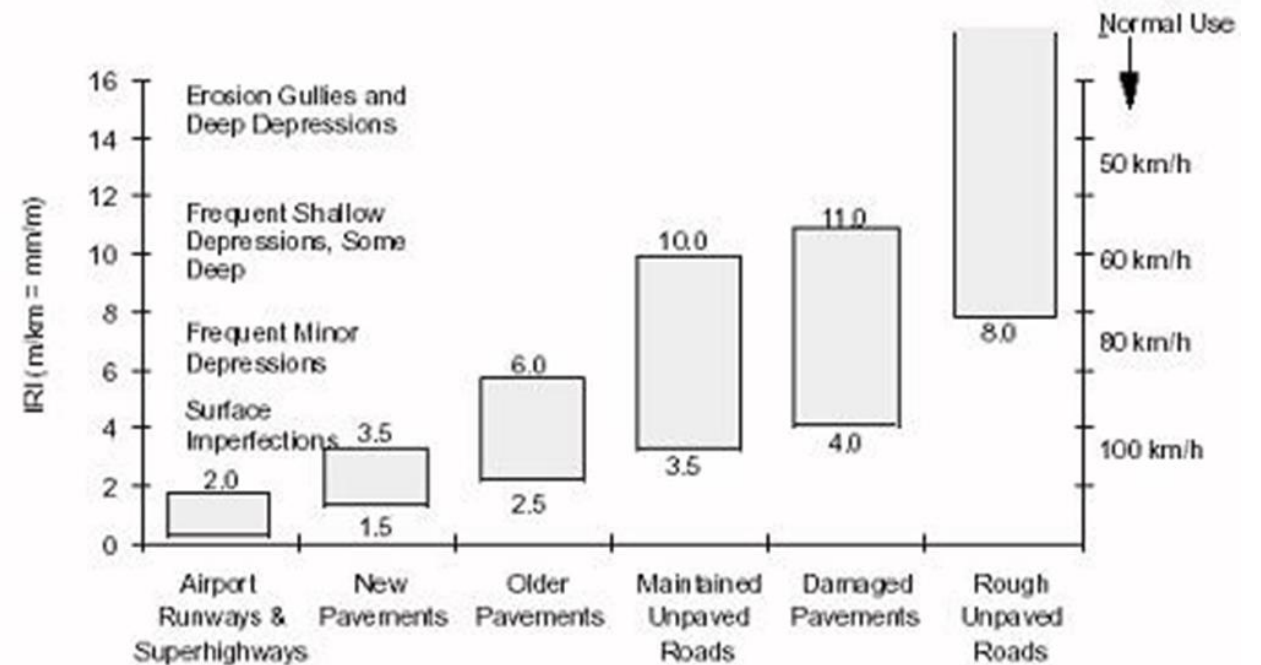


\* 2008 data

Data Source: FHWA OHPI, Highway Performance Monitoring System

# Roughness

- International Roughness Index (IRI)
  - Non – destructive
  - Inertial profiler
  - LiDAR



<https://pavementinteractive.org/reference-desk/pavement-management/pavement-evaluation/roughness/>

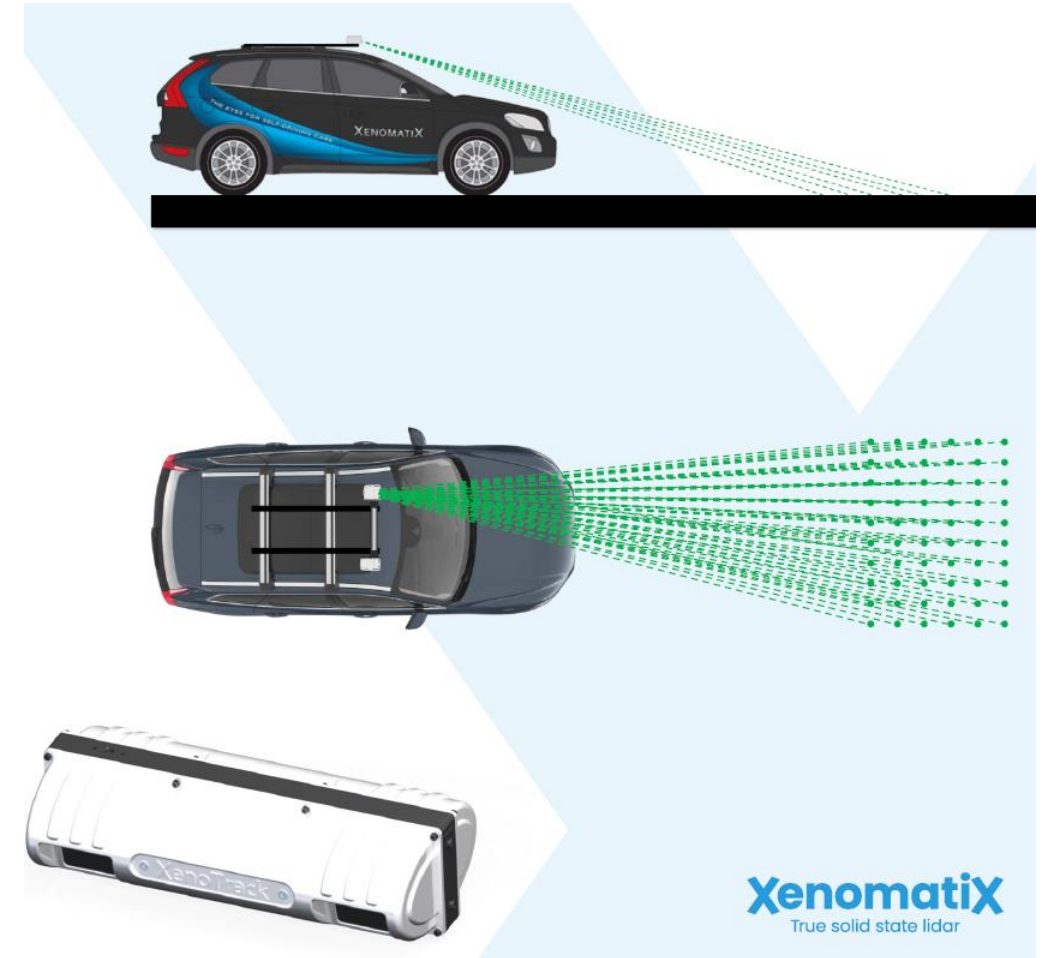
# Surface Condition

- Type of distresses indicates the causes of poor performance
- Type, severity and density of surface distresses
- Manual or automated data collection
- Network or project level



# LiDAR

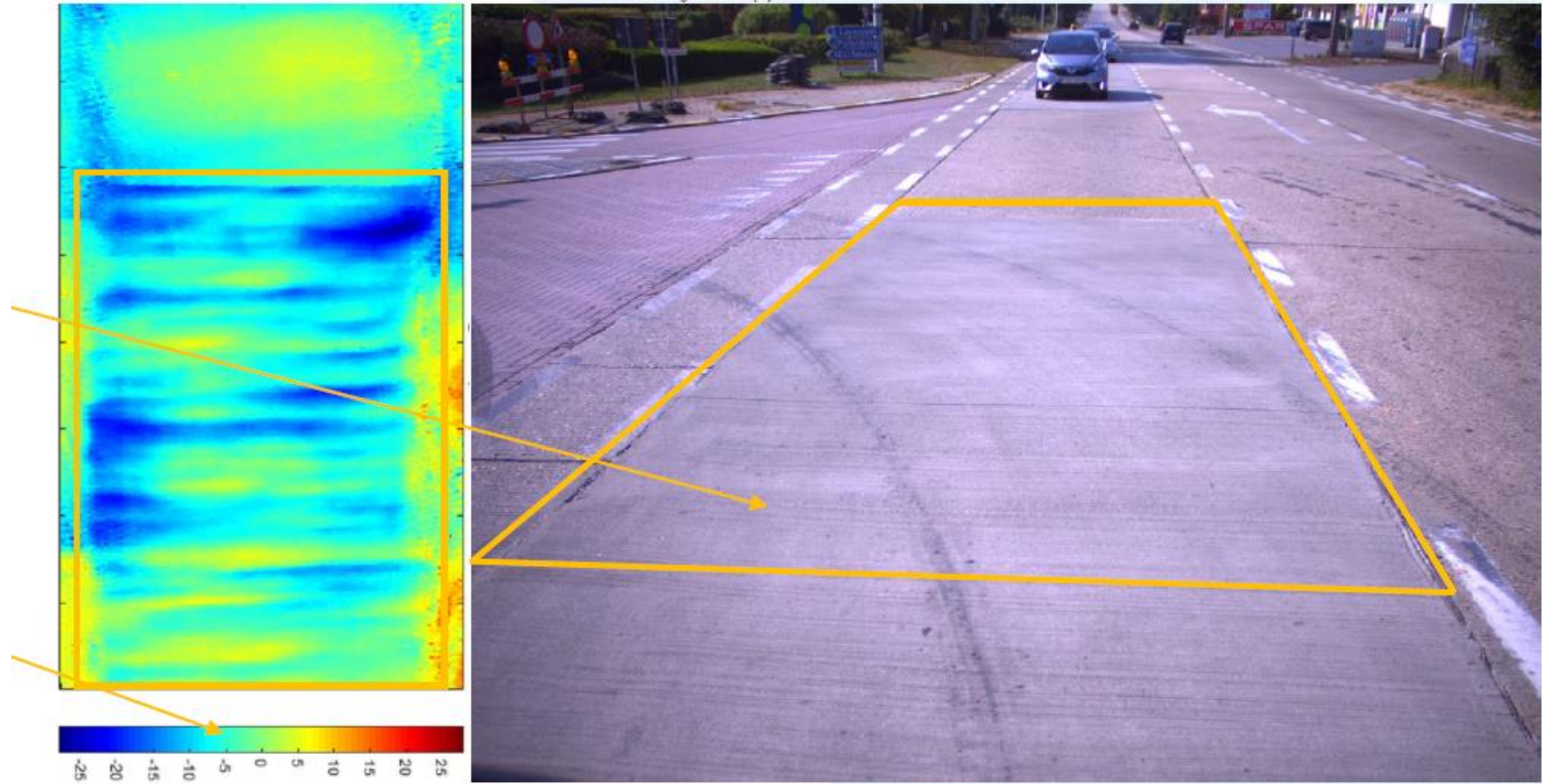
- Portable solid state LiDAR (Light Detection and Ranging) technology
- Produces point cloud of the road surface
- Can determine
  - Roughness
  - Rut depth
  - Road profile/survey



# LiDAR

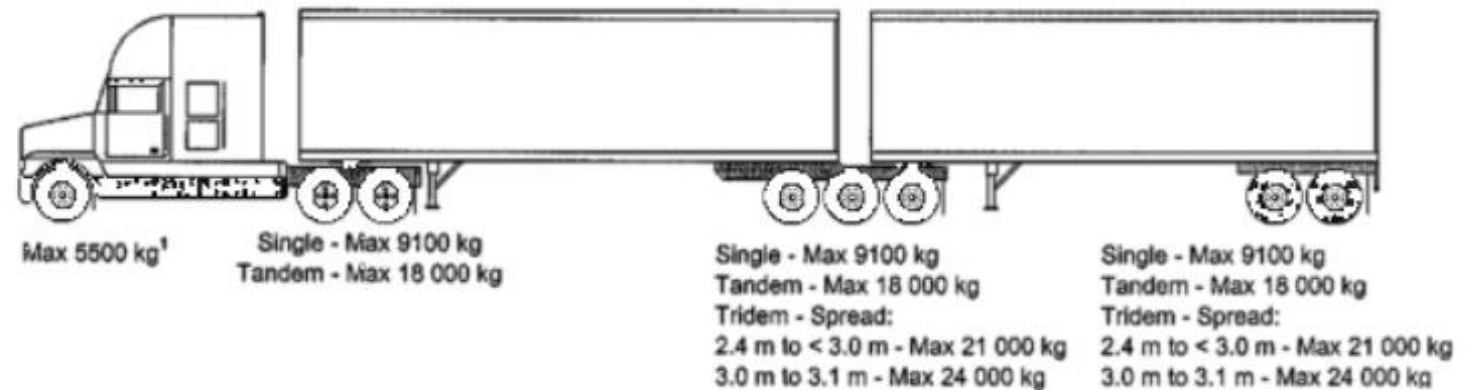
Repaired concrete pavement

Surface profile



# Traffic Loading

- Equivalent Single Axle Loads (ESALs)
- Type of vehicles
- High speed versus static
- Traffic counts
- Weight of vehicles



Nova Scotia, Canada

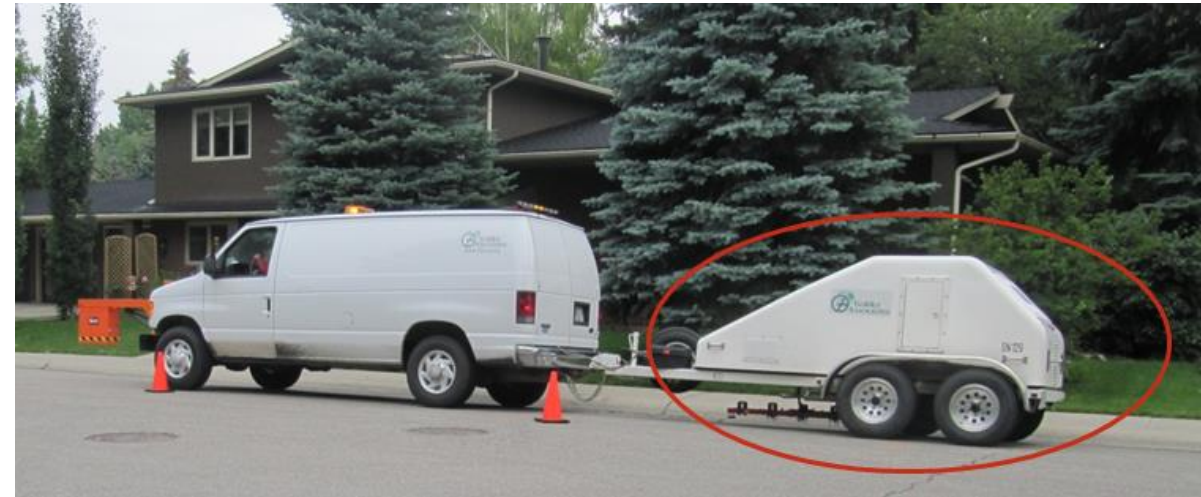
# Traffic Loading – Weigh in Motion

- Permanent vs. Portable
- Piezo sensors

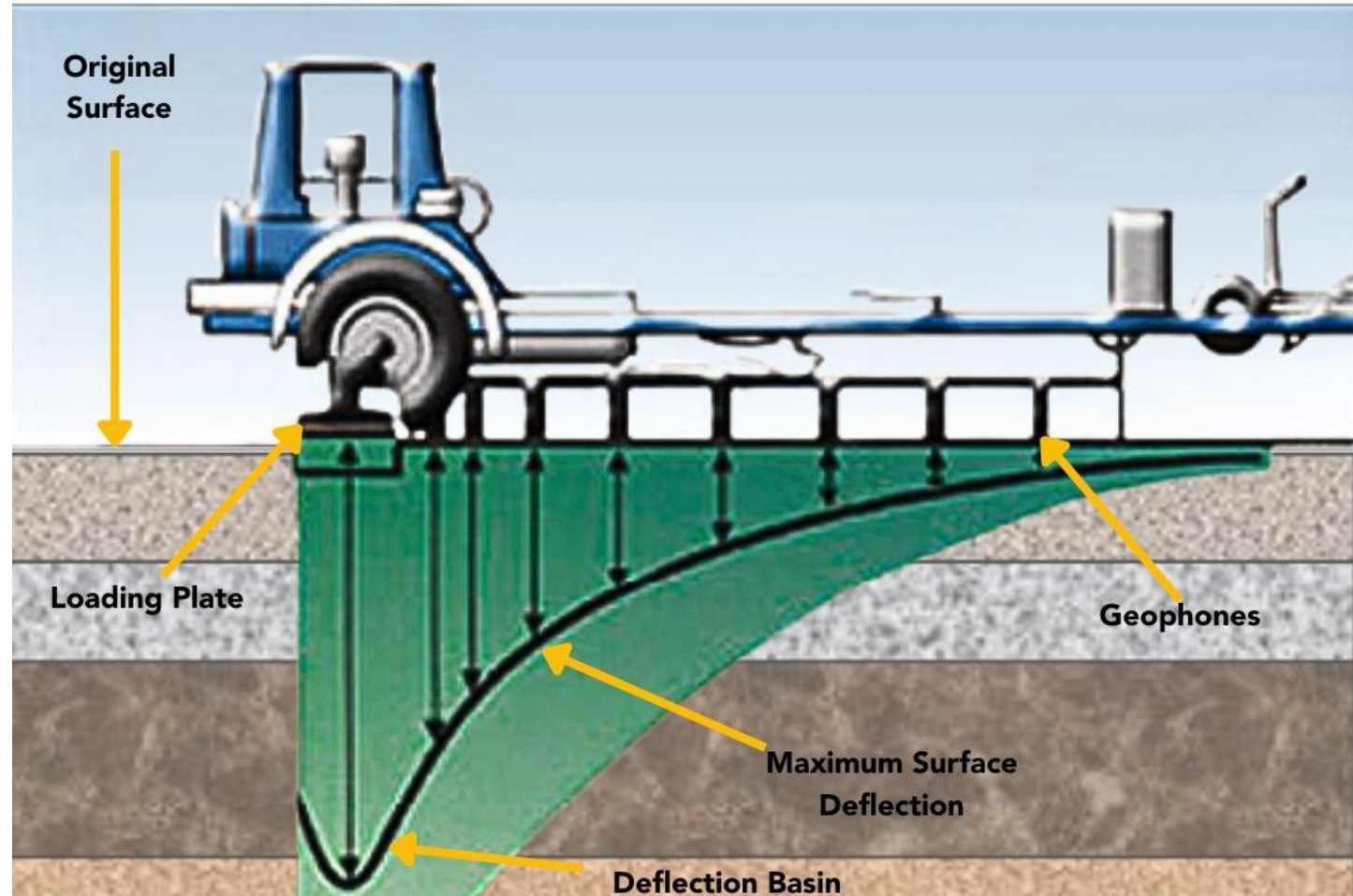


# Structural Capacity and Pavement Response

- Falling Weight Deflectometer (FWD)
- Non-destructive testing
- Measures the deflection of the pavement surface
- Understand pavement structure behaviour



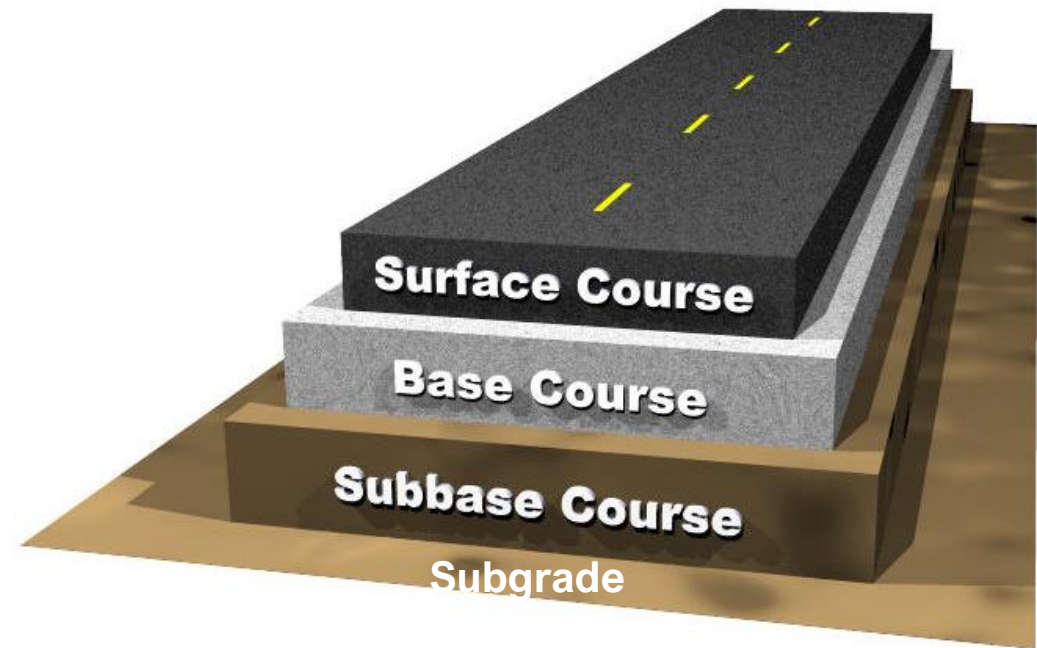
# Structural Capacity and Pavement Response



ParklandGeo

# Structural Capacity and Pavement Response

- Instrumentation to monitor pavement response with loading
  - Strain gauges
  - Pressure cells
  - Temperature probes
- Tension
  - In asphalt layers
  - Bottom of asphalt layers
- Pressure
  - Top of granular



[Pavementinteractive.com](http://Pavementinteractive.com)

# Temperature and Pavement Response

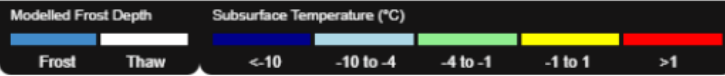
NR-47 Muskoka Falls on  
Region: MTO Northeastern Region MTO SLA

Forecasts | RWIS | Nearest L

Temperature Moisture SLR/WWP

Current Conditions Camera Obs/Fost SLA Metadi

Subsurface temperature



Subsurface Temperature

Modelled Frost Depth

| Sensor Depth (cm) | Feb 19 | Feb 20 | Feb 21 | Feb 22 | Feb 23 | Feb 24 | Feb 25 | Feb 26 | Feb 27 | Feb 28 | Feb 29 | Mar 1 | Mar 2 | Mar 3 | Mar 4 | Mar 5 | Mar 6 | Mar 7 | Mar 8 | Mar 9 | Mar 10 |
|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| 5                 | -1.6   | -1.6   | -1.2   | 0.3    | 0.2    | -0.5   | -0.2   | 0.3    | 1.4    | 3.6    | -0.3   | -0.4  | 1.7   | 4.2   |       |       |       |       |       |       |        |
| 5                 | -1.9   | -1.9   | -1.1   | 0.5    | 0.1    | -0.5   | -0.2   | 0.4    | 1.9    | 3.3    | -0.4   | -0.3  | 1.6   | 4.4   |       |       |       |       |       |       |        |
| 15                | -1.1   | -1.2   | -1.1   | -0.4   | -0.2   | -0.2   | -0.7   | -0.3   | -0.2   | 2.2    | 0.2    | -0.2  | 0.3   | 2.7   |       |       |       |       |       |       |        |
| 15                | 3.0    | 3.0    | 3.0    | 2.8    | 2.7    | 3.0    | 2.7    | 2.7    | 2.7    | 2.7    | 2.6    | 2.7   | 2.7   | 2.7   |       |       |       |       |       |       |        |
| 30                | 0.3    | 0.2    | -0.2   | -0.1   | 0.2    | 0.3    | 0.3    | 0.3    | 0.3    | 1.1    | 1.0    | 0.7   | 0.7   | 1.7   |       |       |       |       |       |       |        |
| 40                | 0.4    | 0.3    | 0.0    | -0.1   | 0.2    | 0.3    | 0.3    | 0.3    | 0.3    | 0.7    | 1.1    | 0.8   | 0.7   | 1.5   |       |       |       |       |       |       |        |
| 45                | 0.7    | 0.6    | 0.4    | 0.2    | 0.4    | 0.5    | 0.6    | 0.6    | 0.6    | 0.8    | 1.2    | 1.0   | 0.9   | 1.5   |       |       |       |       |       |       |        |
| 55                | 1.0    | 1.0    | 0.8    | 0.5    | 0.7    | 0.9    | 0.9    | 0.9    | 1.0    | 1.0    | 1.5    | 1.3   | 1.2   | 1.7   |       |       |       |       |       |       |        |
| 61                | 1.3    | 1.2    | 1.0    | 0.8    | 0.9    | 1.0    | 1.1    | 1.2    | 1.2    | 1.1    | 1.6    | 1.5   | 1.4   | 1.7   |       |       |       |       |       |       |        |
| 74                | 1.6    | 1.6    | 1.4    | 1.0    | 1.1    | 1.3    | 1.4    | 1.5    | 1.5    | 1.4    | 1.8    | 1.7   | 1.6   | 1.9   |       |       |       |       |       |       |        |
| 88                | 2.1    | 2.1    | 1.9    | 1.5    | 1.5    | 1.7    | 1.8    | 1.9    | 1.9    | 1.8    | 2.0    | 2.1   | 2.0   | 2.2   |       |       |       |       |       |       |        |
| 100               | 2.4    | 2.4    | 2.3    | 1.9    | 1.9    | 2.0    | 2.1    | 2.1    | 2.1    | 2.1    | 2.1    | 2.3   | 2.2   | 2.3   |       |       |       |       |       |       |        |
| 113               | 2.7    | 2.7    | 2.7    | 2.4    | 2.3    | 2.4    | 2.4    | 2.4    | 2.4    | 2.4    | 2.4    | 2.5   | 2.5   | 2.5   |       |       |       |       |       |       |        |
| 122               | 3.0    | 3.0    | 3.0    | 2.8    | 2.7    | 2.7    | 2.7    | 2.7    | 2.7    | 2.6    | 2.6    | 2.7   | 2.7   | 2.7   |       |       |       |       |       |       |        |
| 130               | 3.3    | 3.3    | 3.3    | 3.1    | 3.0    | 3.0    | 3.0    | 3.0    | 3.0    | 3.0    | 2.9    | 2.9   | 2.9   | 3.0   |       |       |       |       |       |       |        |

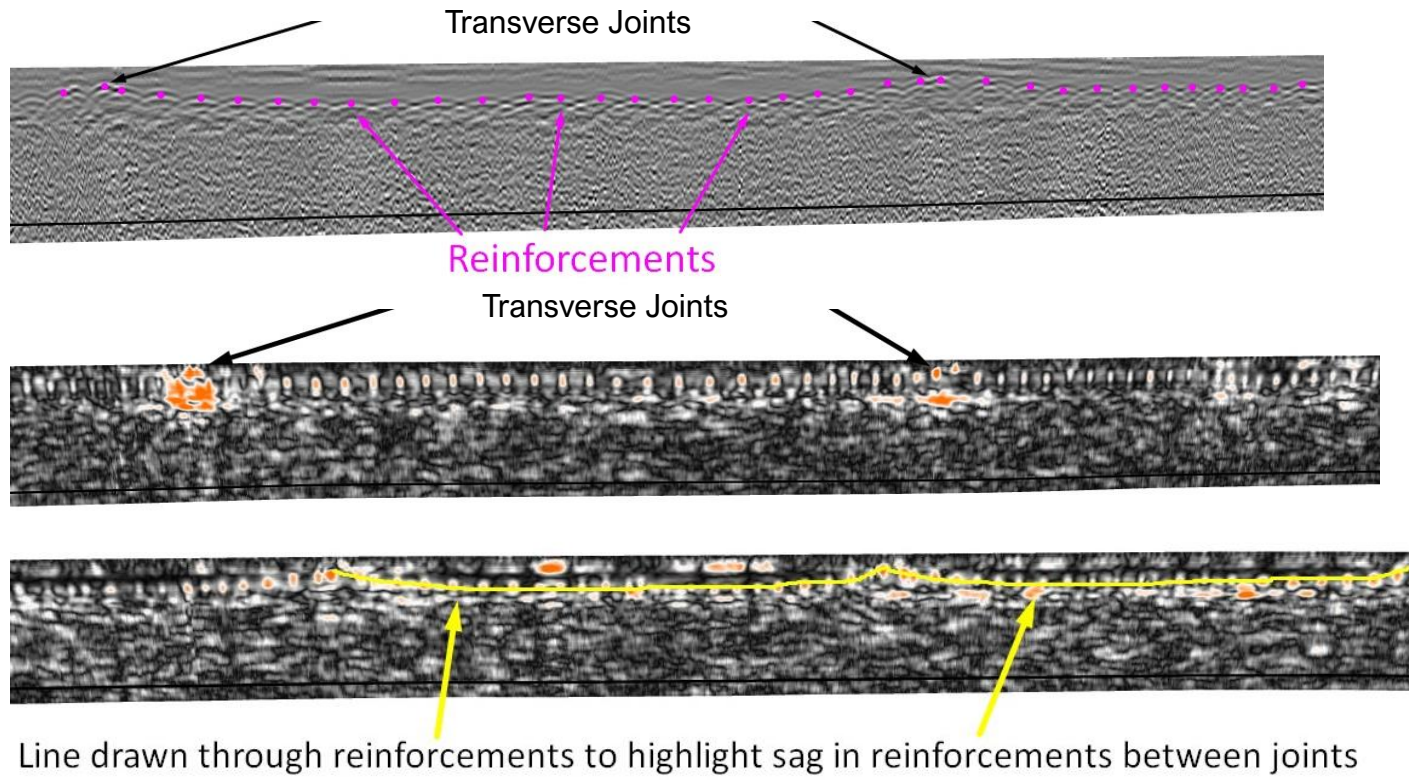
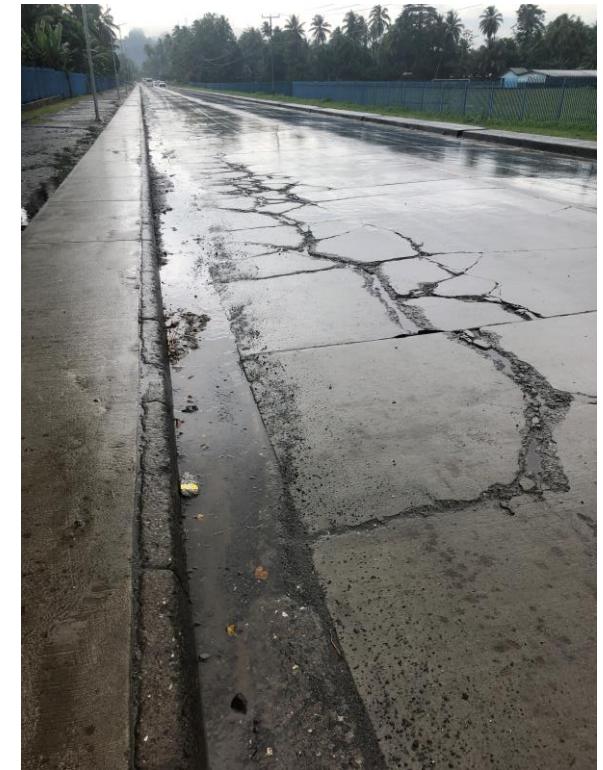
# Existing Pavement Structure

- Boreholes
- **Ground Penetrating Radar (GPR)**
  - Non-destructive testing
  - Provide surface layer thickness, voids, inconsistency



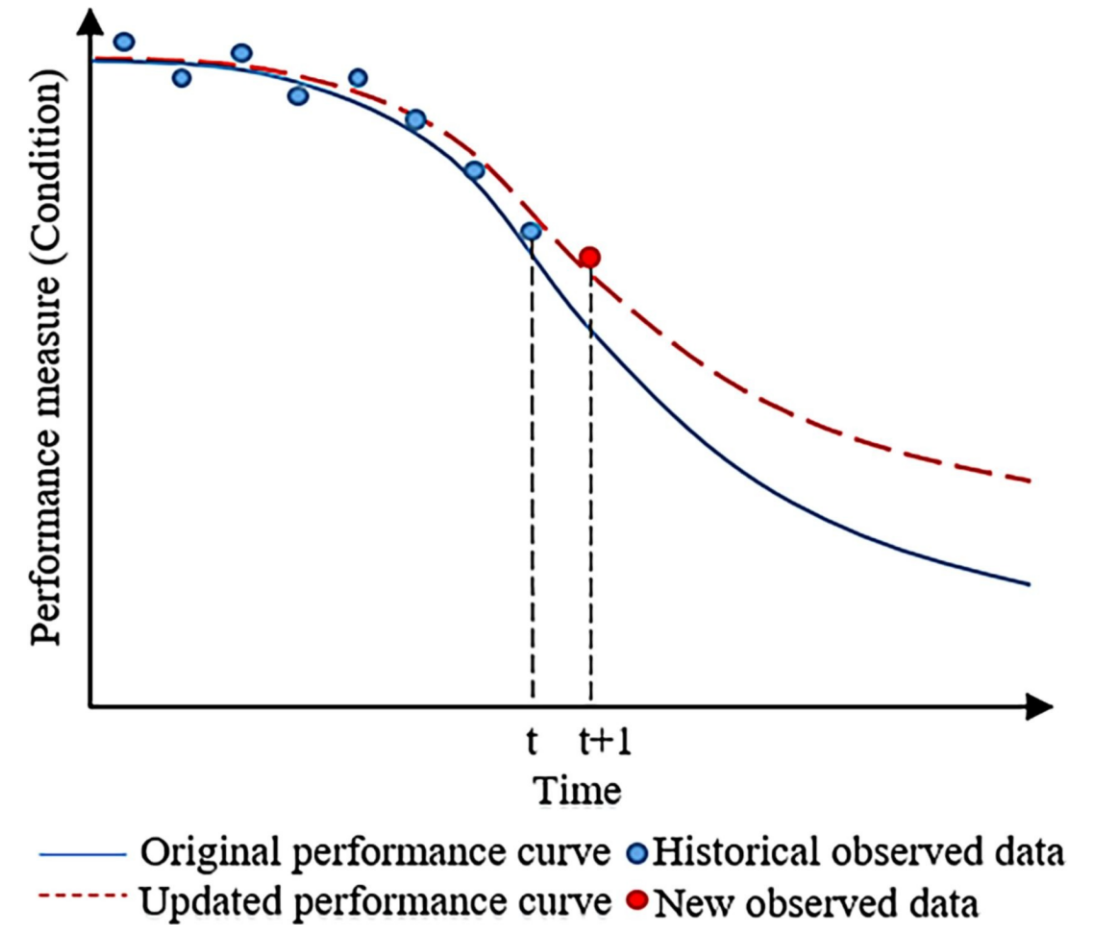
# Existing Pavement Structure

- Ground Penetrating Radar (GPR) – failed concrete pavement



# Pavement Performance Prediction

- Ability to predict pavement performance based on data



A review on empirical methods of pavement performance modeling, 2022, Aihui Hu, Qiang Bai, Lin Chen, Siyuan Meng, Qihui Li, Zhiman Xu

# Maintenance and Treatments

- The correct treatment for the pavement section
- Pavement performance factors should be consideration
- Treatment to address observed performance
- Proactive when feasible
  - Crack sealing
  - Pothole repair, patching



# Conclusion

- Data is very powerful
- Need to understand the question before we can look for answers
- Collect the correct type of data

Thank you

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