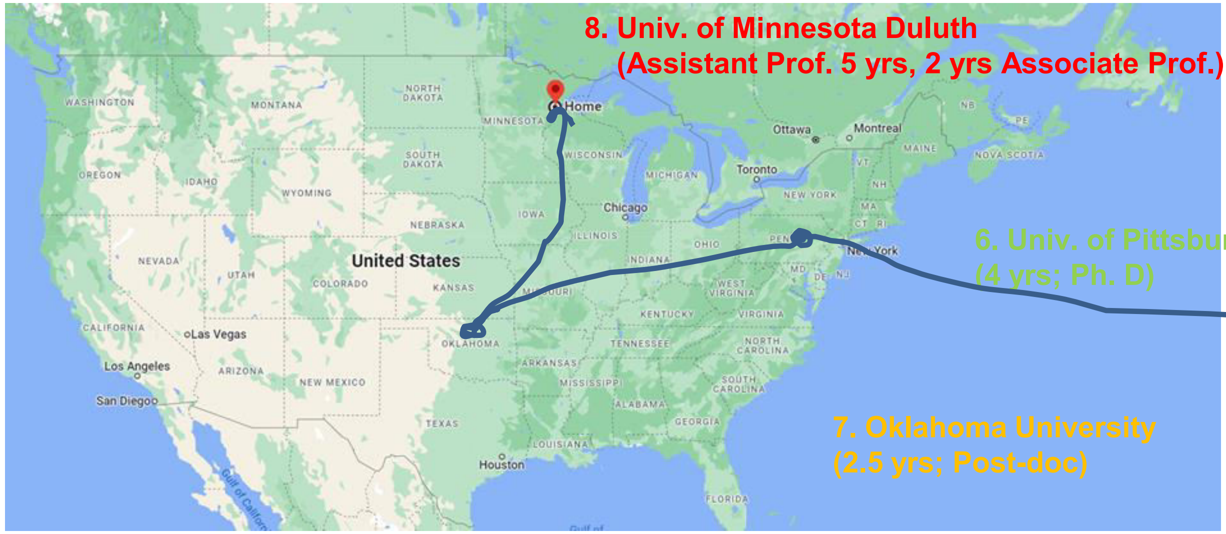
INNOVATIONS IN TECHNOLOGIES, MATERIALS, AND DESIGNS FOR LONG-LASTING LOW-VOLUME ROADS

Manik Barman, Ph. D.

Associate Professor, University of Minnesota Duluth, Minnesota, USA

Wednesday, August 3, 2022

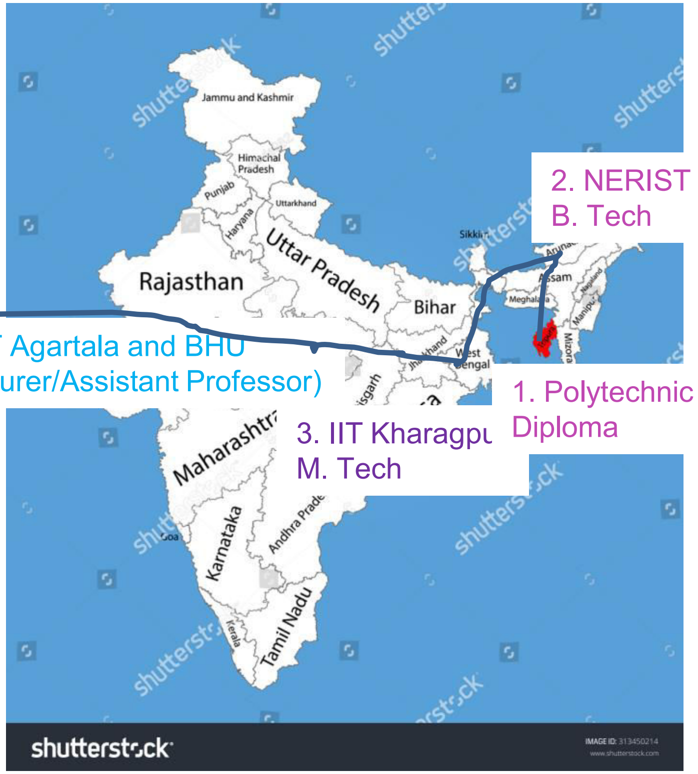
About Me



Now lives in Minnesota, USA

4. & 5. NIT Agartala and BHU
(4 yrs Lecturer/Assistant Professor)

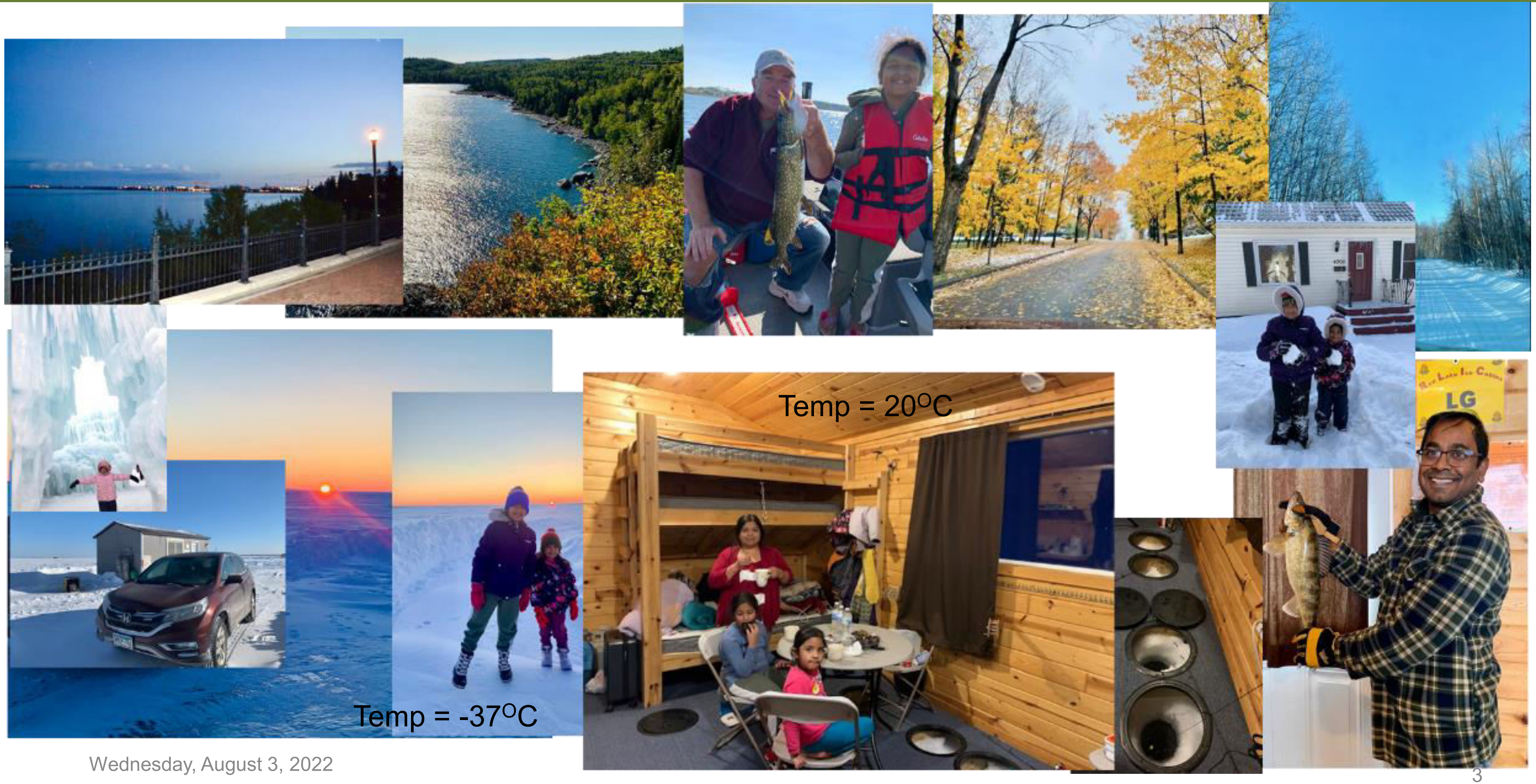
STA Member
PMGSY



Originally from Tripura, India

UMD University Campus

About Duluth and Minnesota



Low Volume Roads

Low-volume Road

Traffic < 400 ADT (Mn MUTCD, 2018)

High-volume Road

Traffic > 18,000 ADT (MnDOT, 2018)

Differences in Pavement Distresses

Low-volume Roads

Block/multiple Cracking

Pothole (moisture damage)

Thermal Cracking

Raveling

High-volume Roads

Thermal Cracking

Top-down Fatigue Cracking

Bottom-up Fatigue Cracking

Rutting

Hard Facts Related to Low Volume Roads

We do not focus on their unique distresses and challenges

We do not make long lasting pavements; give less importance

But as the funding will not come often, I think we need to make long-lasting pavements

So bringing Innovation is smartness!

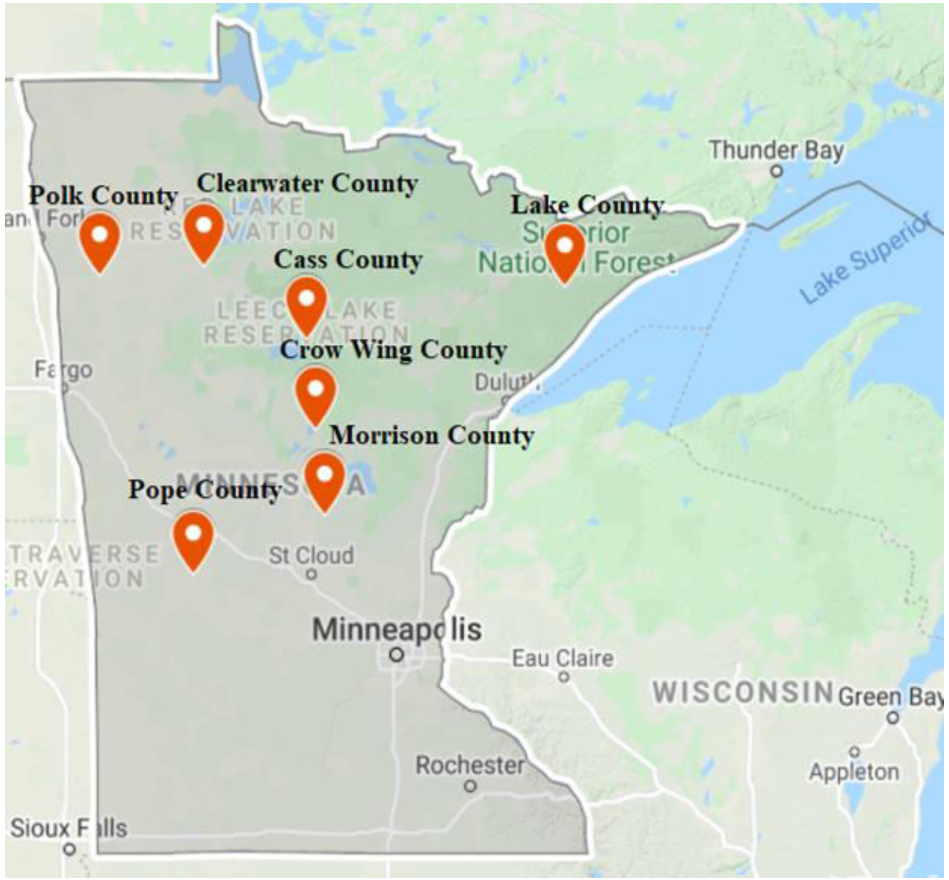
Two Examples of Innovations We Can Consider:

1: Intelligent Compaction of Low-volume Asphalt (Bituminous) Roads

2: Fiber Reinforced Ultra-thin and Thin Concrete Pavements for Low-volume Roads for Cold Climate Areas

1. Intelligent Compaction of Asphalt Roads

Low-volume Road Asphalt Density Study

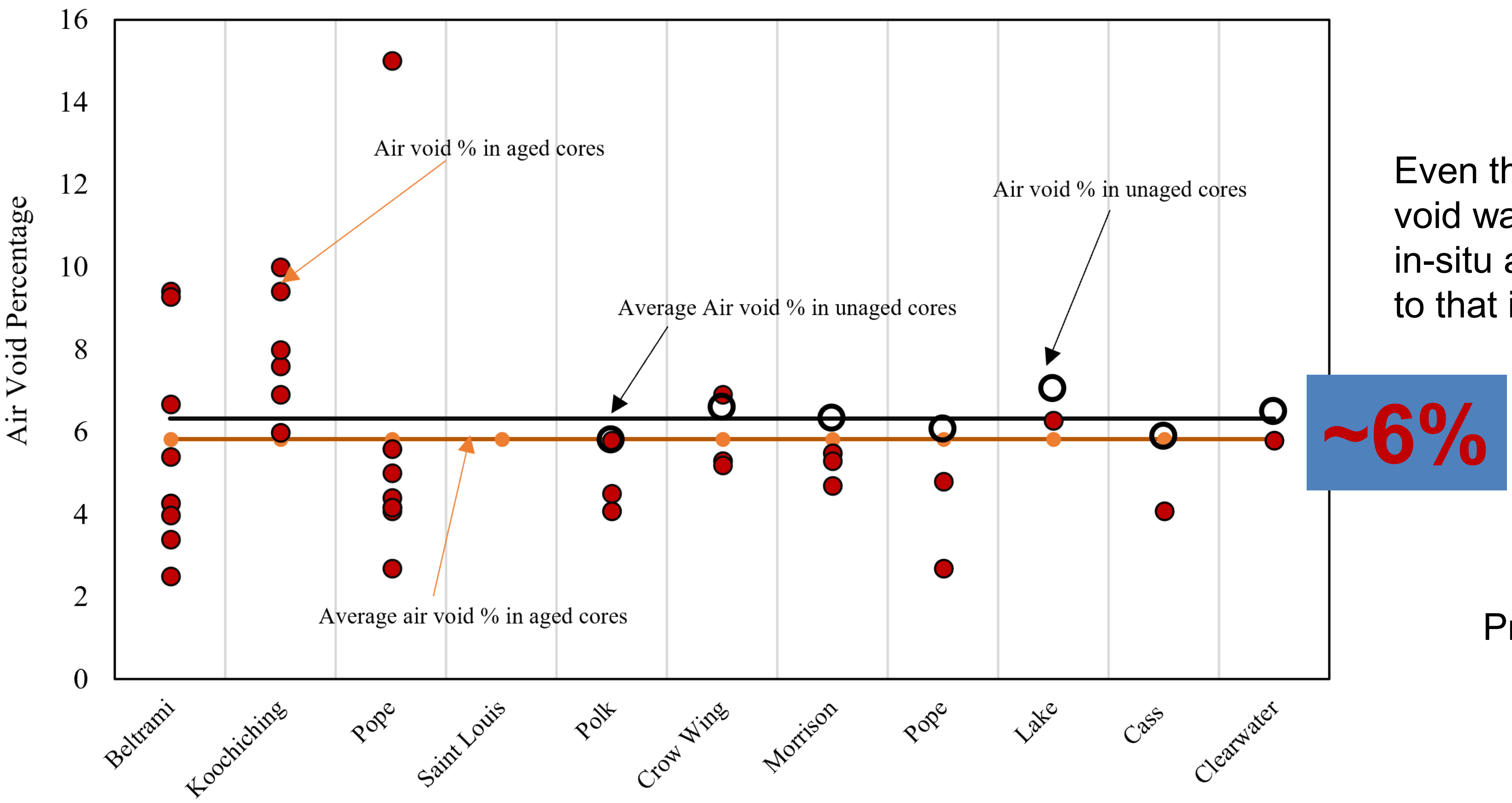


Data Set 1: Core data from 14 projects in 7 counties

Data Set 2: Core data from 11 projects in 4 counties

Cores from 25 projects, 11 counties

In-Situ Air Voids in Low-Volume Asphalt Roads



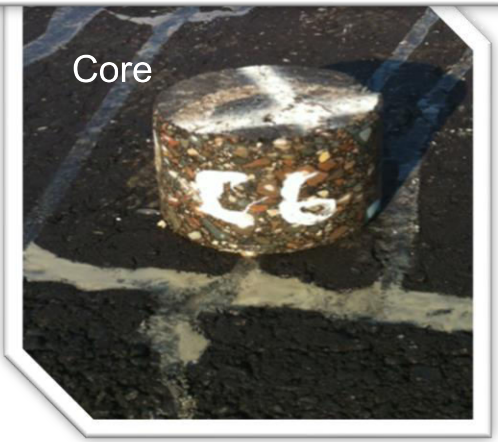
Even though the design air void was 3 to 4%, the in-situ air voids does not reach to that in their lifetime.

Premature distresses

Note: Relative Density (%) = 100 - Air Voids

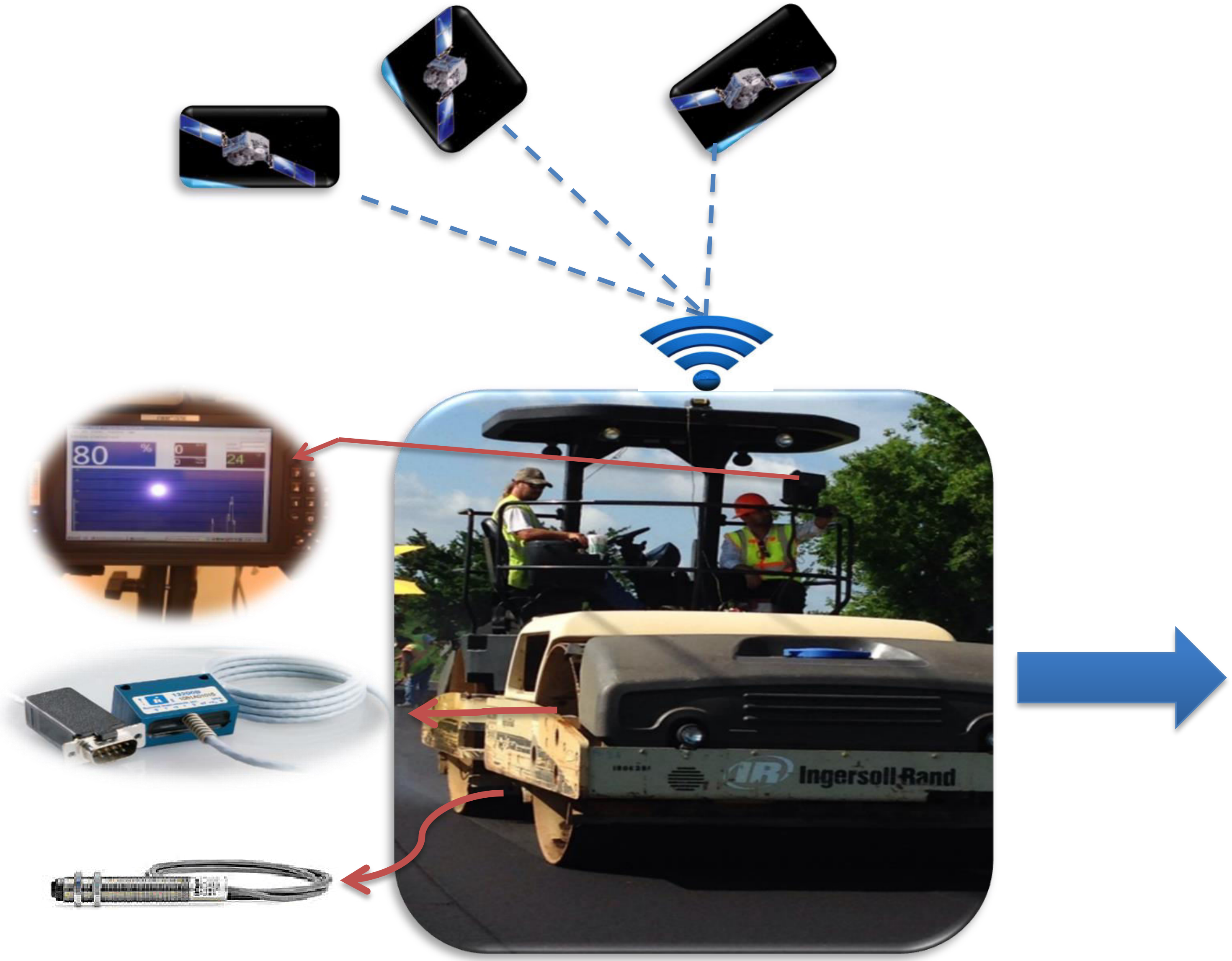
Intelligent Compaction can be game changer!

Traditional Asphalt Compaction



- **Post compaction QC**
- **Random check**
- **Under-compacted spots not detected and remediated**

Intelligent Compaction (IC)



- Real-time QC
- Covers entire area
- Provides geo-referenced color coded strip chart
- Identifies under/over-compacted spots
- Provides chance to fix under compacted areas

Commercial IC Rollers

Ammann/Case

Caterpillar

Dynapac

Bomag America

Sakai America

Commercial IC Roller: Volvo's Density Directly

This IC Technology was developed based on Oklahoma University's research (Commuri, et al.)

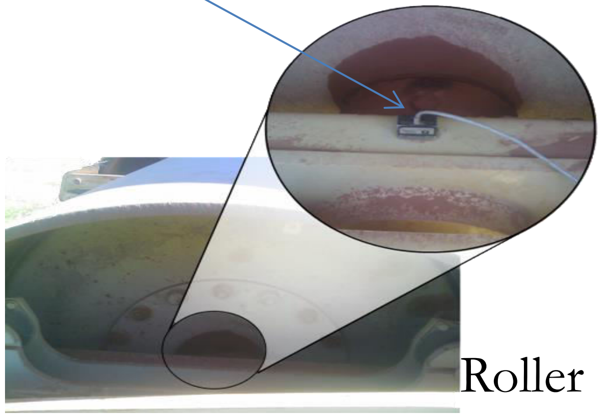
Independently tested and proven

Density Direct was developed and tested as part of the FHWA Highways for LIFE Technology Partnerships Program. The technology was used on various full-depth and overlay asphalt pavement projects and later evaluated by independent users at sites throughout the country. The results were overseen by University of Oklahoma researchers and showed that Density Direct calculations were proven to be within 1.5 percent of core samples every time at 180 test locations.

Brochure: Volvo IC with Density Directy

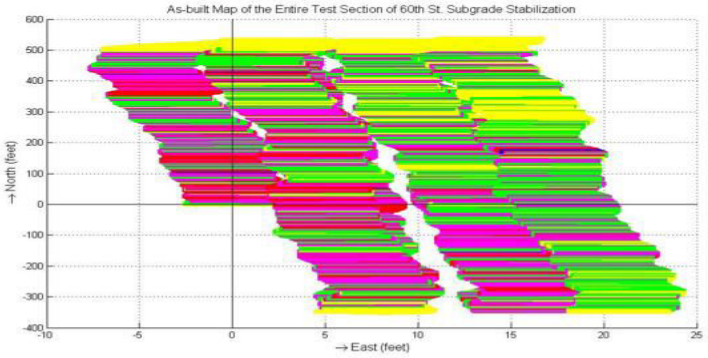
OU-ICA's Working Principle

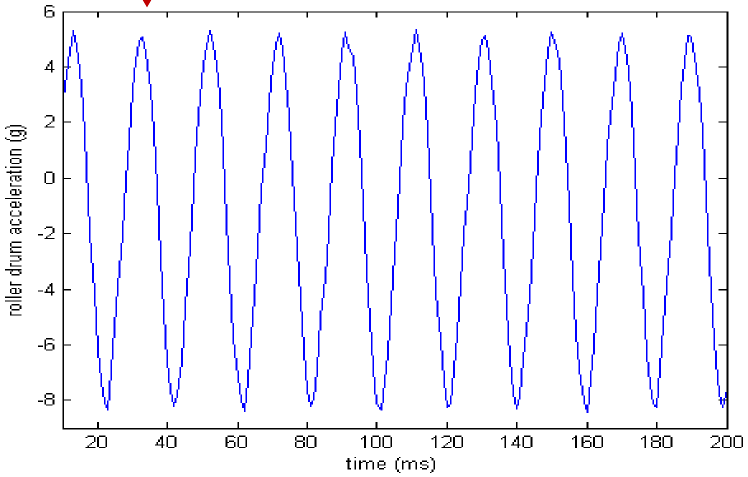
Accelerometer



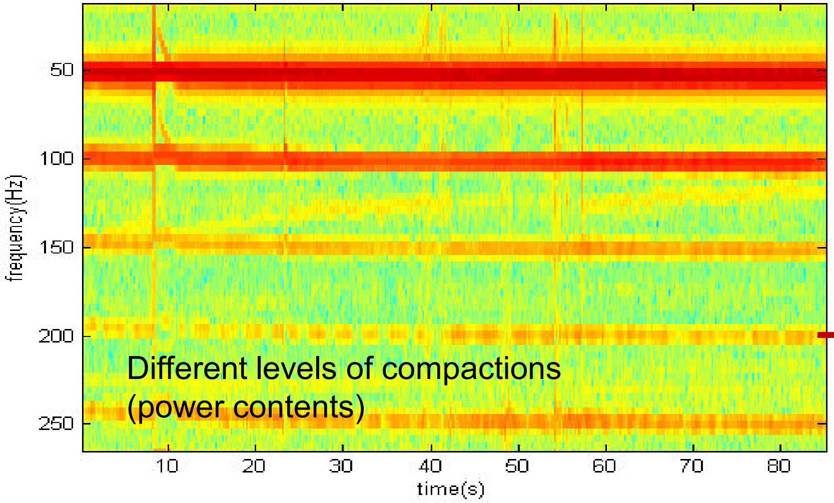
Roller

As-built map for Density/M_r/E*





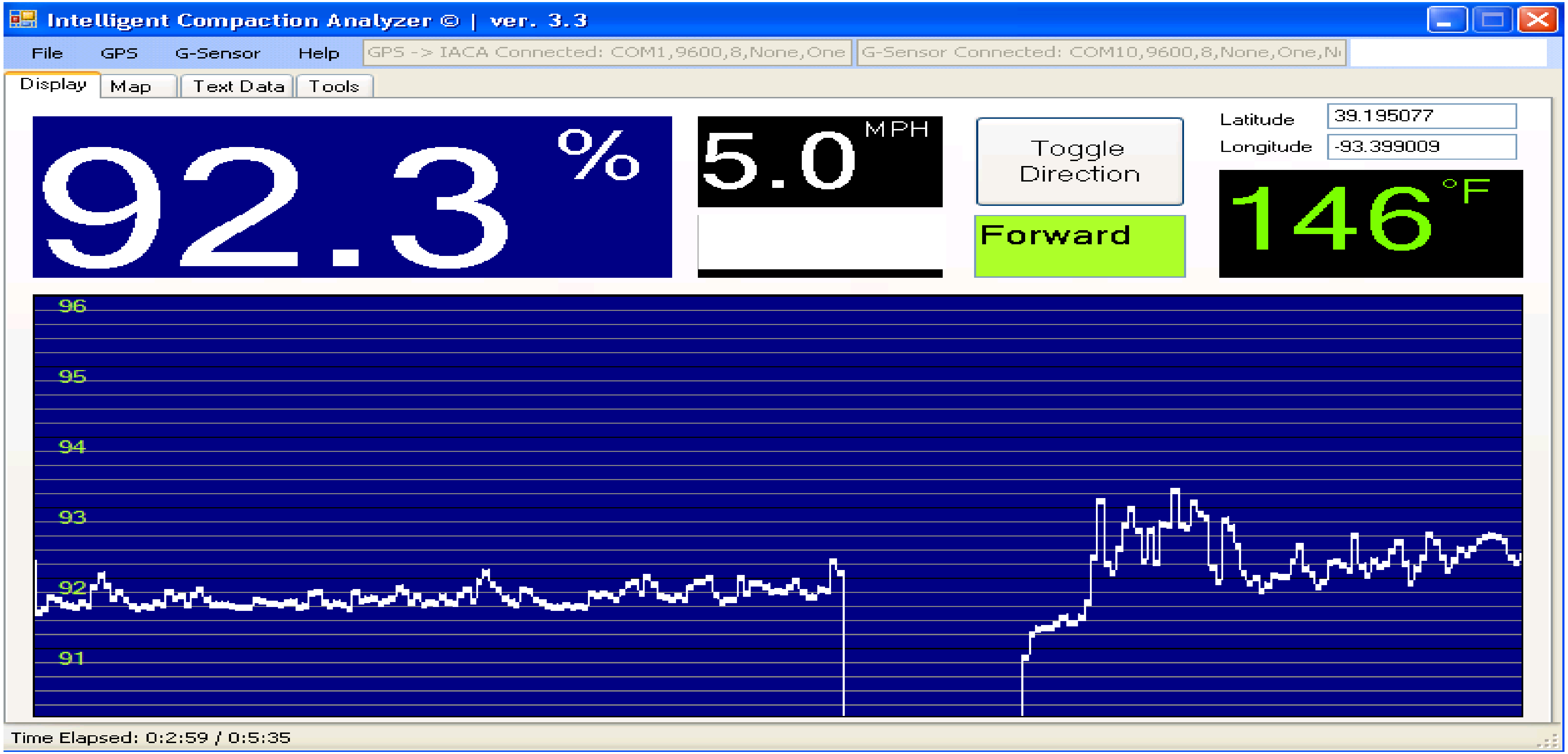
Fast Fourier Transform (FFT)



Calibration (Artificial Neural Network (ANN))

ICA = Intelligent Compaction Analyzer

Real-time Density Measurement



A Case study: ICA in Improving the Compaction

ICA compaction at Acme Road, Shawnee, Oklahoma, USA

(a) Base layer

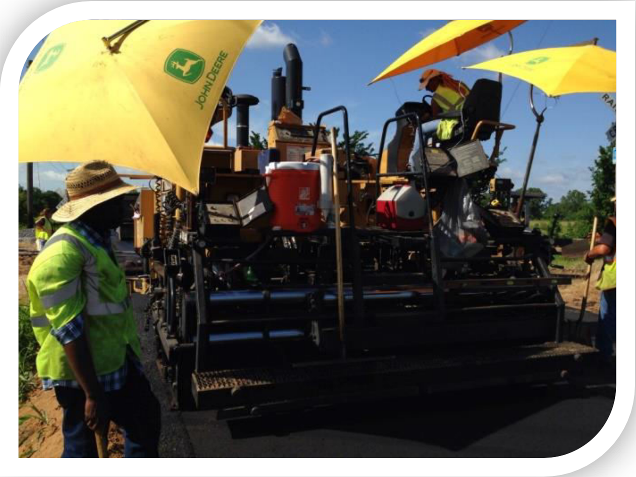
(b) Surface layer

Asphalt Material Details

Properties of asphalt mixtures in Acme Road Project

Parameters	Base layer	Surface Layer
Nominal maximum aggregate size	25.4 mm	12.5 mm
Los Angeles abrasion (%)	23.7%	23.4%
Effective specific gravity of aggregates	2.707	2.693
Type of asphalt binder	PG 64-22	
Proportion of RAP in the asphalt mix	25%	35%
Specific gravity of asphalt binder	1.010	
Asphalt binder content	4.0% (total); 3.0% (virgin)	4.7% (total); 3.5% (virgin)
Maximum theoretical specific gravity of asphalt mix	2.535	2.495
Voids in mineral aggregates	13.6%	15.2%

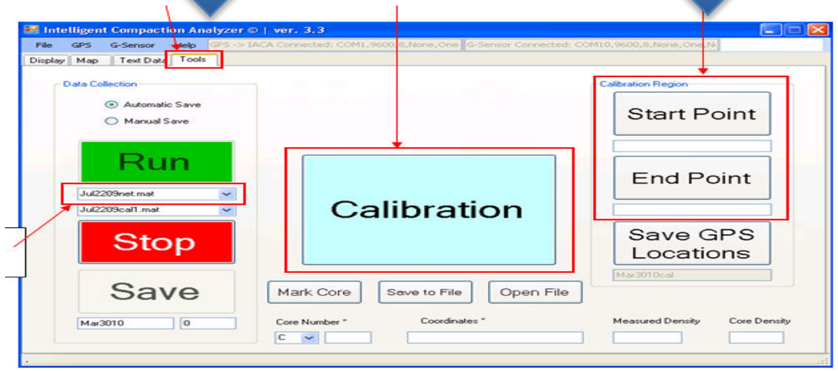
Calibration of ICA



Record roller vibration at the very first pass (laydown density)

Record roller vibrations at other successive passes (intermediate and target densities)

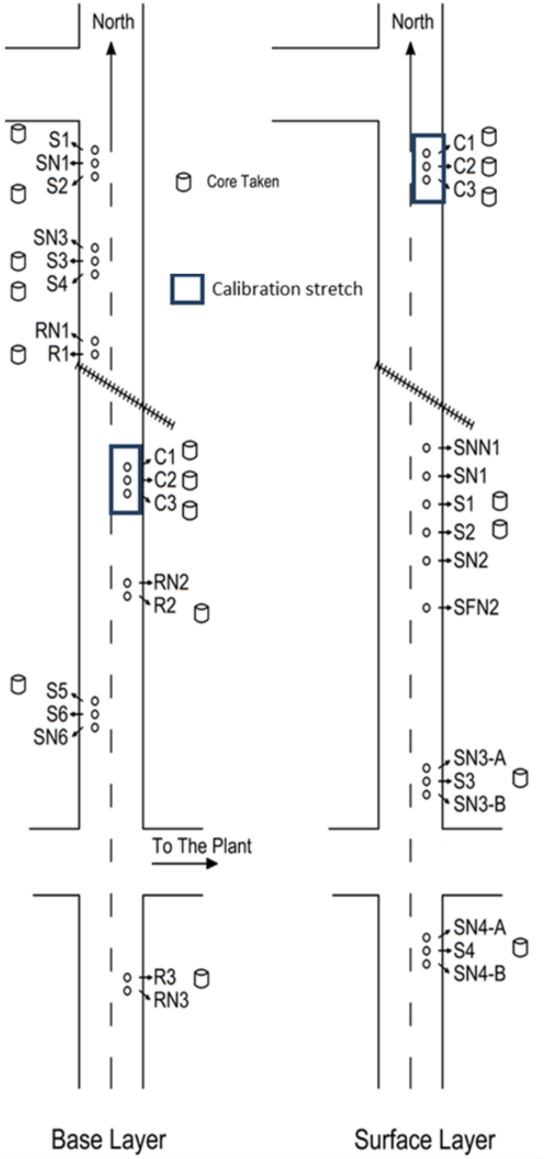
Core density



Preliminary calibration

Final calibration

Soft-spot Identification and Improvement



SX= Under- compacted spots;

SNX and RNX = additional tests were conducted on these spots (data not included in this paper)

X = numbers, 1, 2, 3, etc.

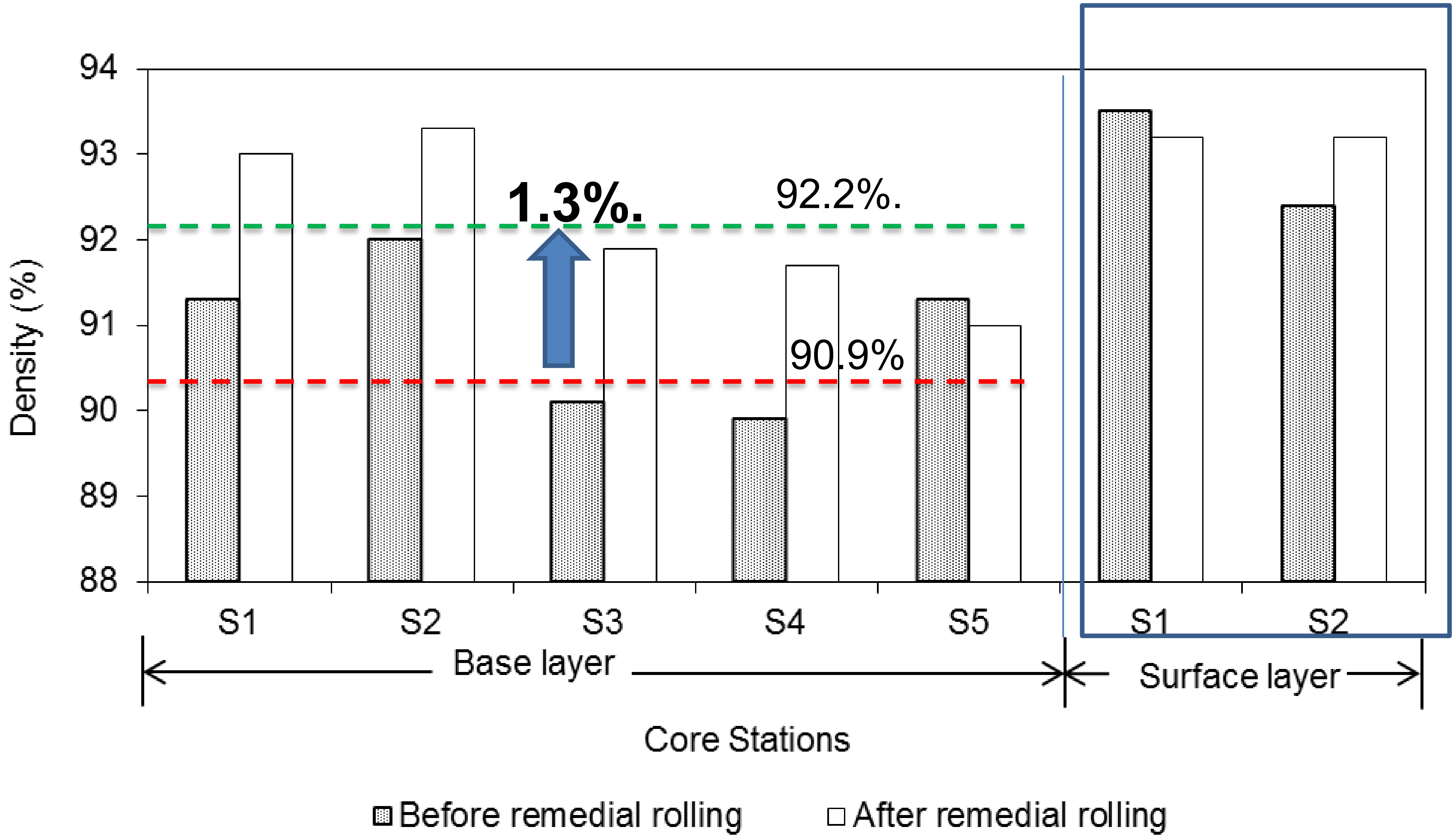
Base Layer

- 6 under-compacted spots (S1 to S6)
- 3 additional roller passes on S1 to S4
- 1 additional pass on S5
- No additional pass on S6

Surface Layer

- 4 under-compacted spots (S1 to S4)
- 3 additional roller passes on S1 and S2
- No additional pass on S3 and S4

Improvement in Density



Conclusions: 1. Intelligent Compaction

- The ICA can be used in real-time monitoring of compaction quality of asphalt layers;
- The accuracy of the ICA estimates are suitable for quality control checks;
- The as-built color-coded strip charts can be used for identifying and remediating under-compacted spots;
- Destructive tests such as core extraction can be avoided;
- Under-compacted spots can be improved with additional roller passes
- As-built color-coded strip charts can be used in pavement management system or future rehabilitation works.

2. Fiber Reinforced Ultra-thin and Thin Concrete Pavements

First Concrete Paved Roads in USA

Duluth, MN
1909-1910

First Concrete Road in India

first concrete pavement in India

All | Images | News | Videos | Maps | More | Tools

About 7,020,000 results (0.55 seconds)

The first concrete road in India was built just over a hundred years ago; in **early 1914 to** be precise, in the city then known as Madras (now Chennai). It was constructed outside the Municipality office, and the builder had guaranteed that it would last for at least 10 years.

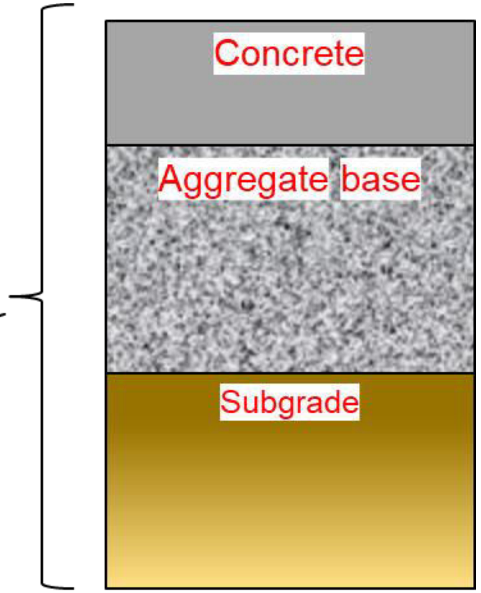
Concrete Pavement Where I grew up in India

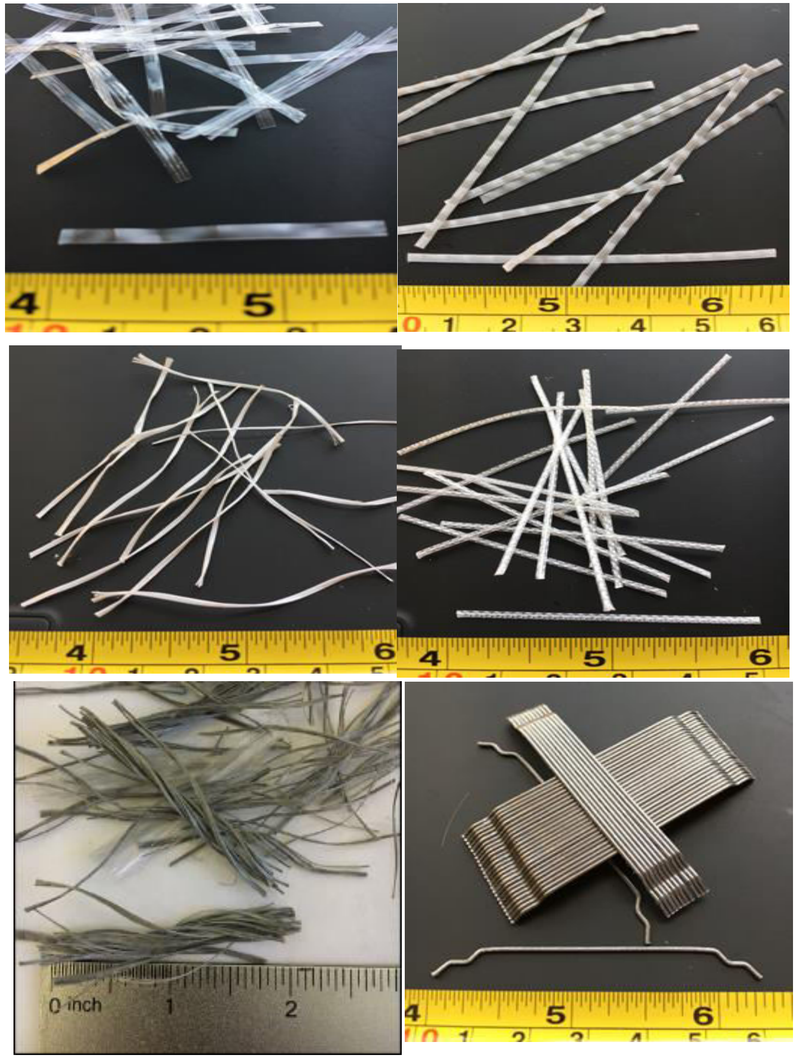
Age: Not known,

but

the road was constructed before the independence

Ultra-thin and Thin FRC Pavements





- Slab thickness = 3” to 4” for ultra-thin
  = 4” to 6” for thin
- Slab size = 6’ x 6’
- Base = unstabilized agg. layer
- No dowel bars
- Intended for low volume roads

A field Study to Answer to the Following Key Questions

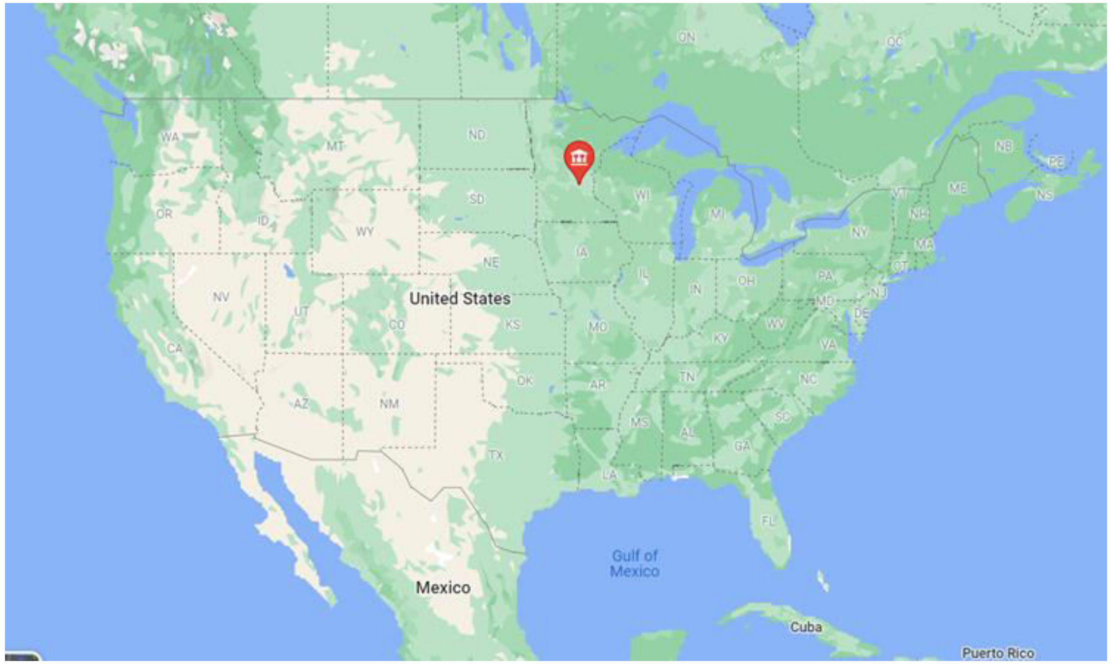
1. Are 3” and 4” thick concrete pavements feasible?

2. Do fibers mitigate fatigue cracks and joint faulting in ultra-thin and thin pavements? If so, then what is fiber dosage?

3. Can we construct thin concrete overlays with wider slabs when we use macro fibers?

4. What are the influence of fibers to the pavement responses?

Field Test Cells at MnROAD Location



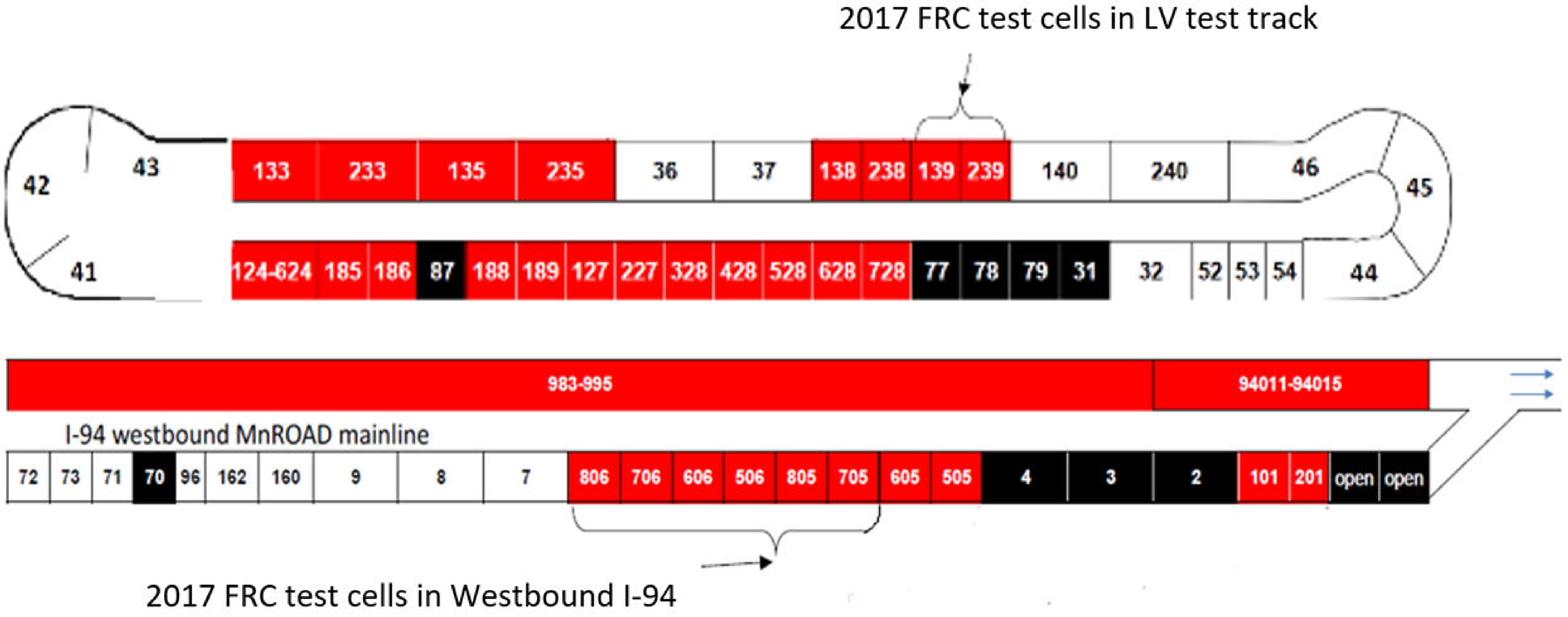
- MnROAD is a pavement test facility owned and operated by MnDOT and located on westbound I-94, northwest of Minneapolis metropolitan area, Minnesota.

- World's largest winter weather road research test sections.

MnDOT,2018

NRRA-MnROAD FRC Test Cells

7 FRC Cells and 1 PCC Cell



All the cells are designed for low volume roads

MnDOT,2018

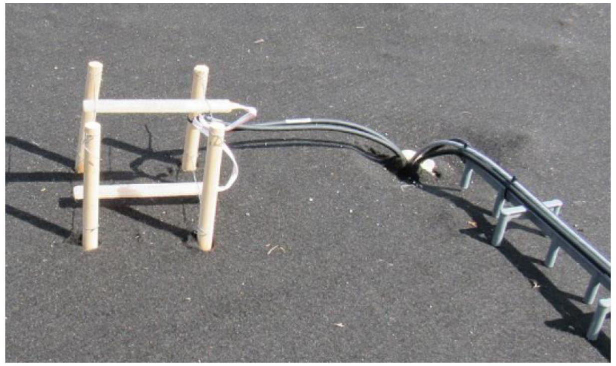
Cell Descriptions

Cell number	Length (ft)	Pavement/ overlay Ty	Underlying layer	Type of concrete/ fiber	Panel size W ft x L ft	Panel thickness (inch)
506	144	Thin pav gr			6 x 6	5; 6*
606*	138			)		
706				)		
806						
139	270	Ultra-thin on g			6 x 6	3
239	273	Ultra-thin on g			6 x 6	4
705	144	Thin un ove		)	Driving: 14 x 12 Passing:13 x 12 12 x 12	5
805	124				Driving: 6 x 12 and 8 x 12 Passing:6 x 12 and 7 x 12	5

Conc. Pavement on Gravel

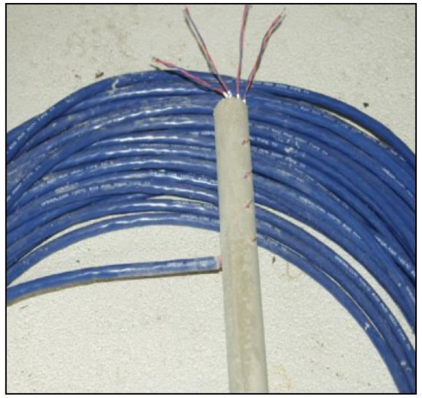
Conc. overlay

Different High-tech Sensors and Field Tests

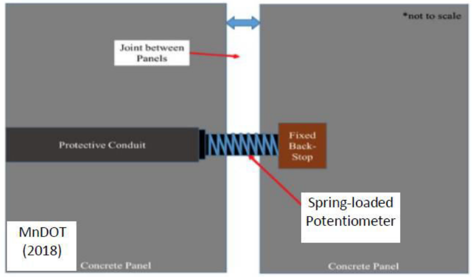


Dynamic strain gauge

Environmental strain sensor



Thermocouple



Joint opening Sensor

Falling Weight Deflectometer

Georgia fault meter

Wu and Ai (2011)

MnDOT's Pathway Services, Inc. Digital Inspection Vehicle (DIV)

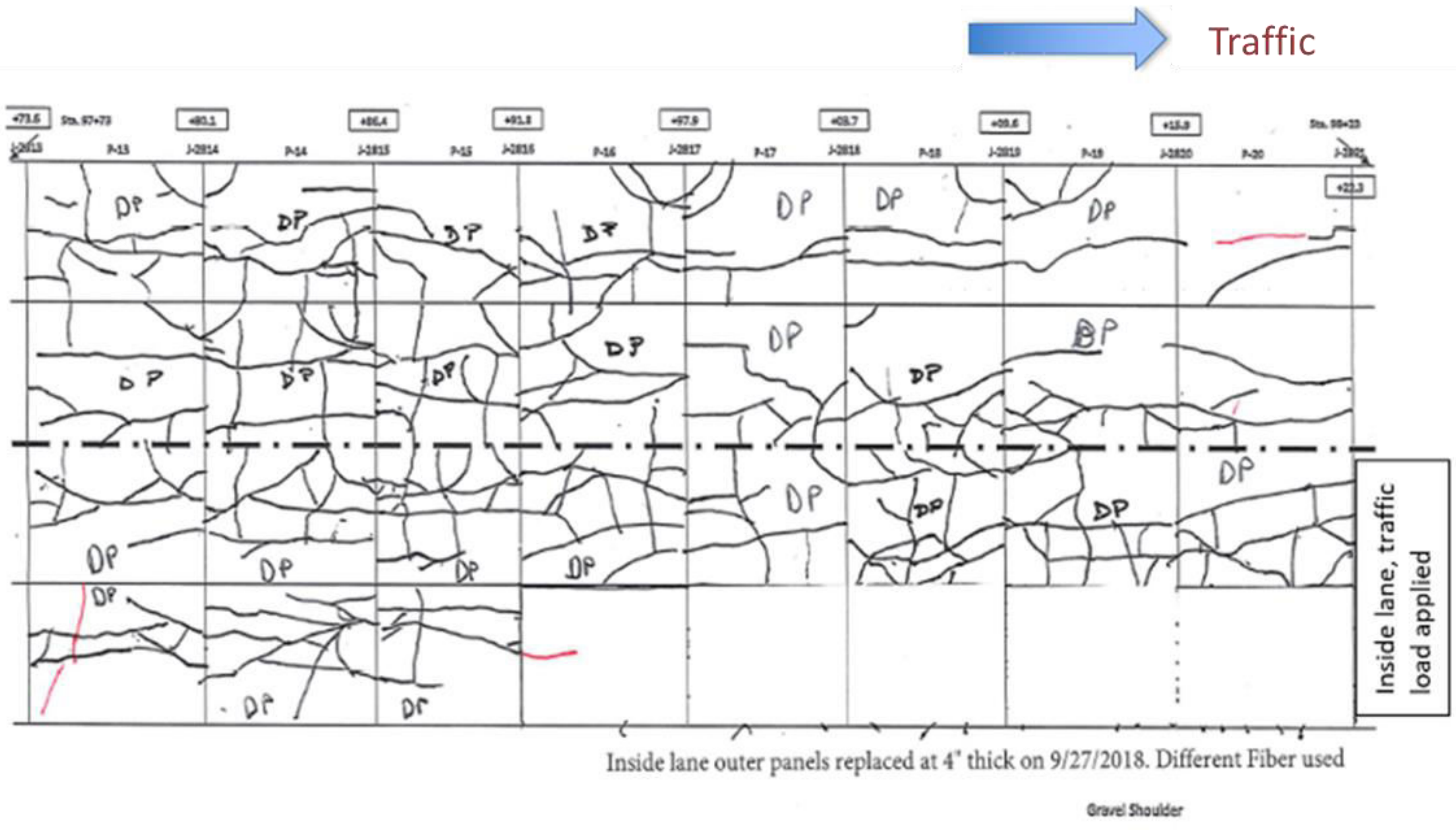
Observations: Fatigue Cracks in Cell 139 (3” slab on 6” base)

@35,000 ESALs

Only inner lane is loaded

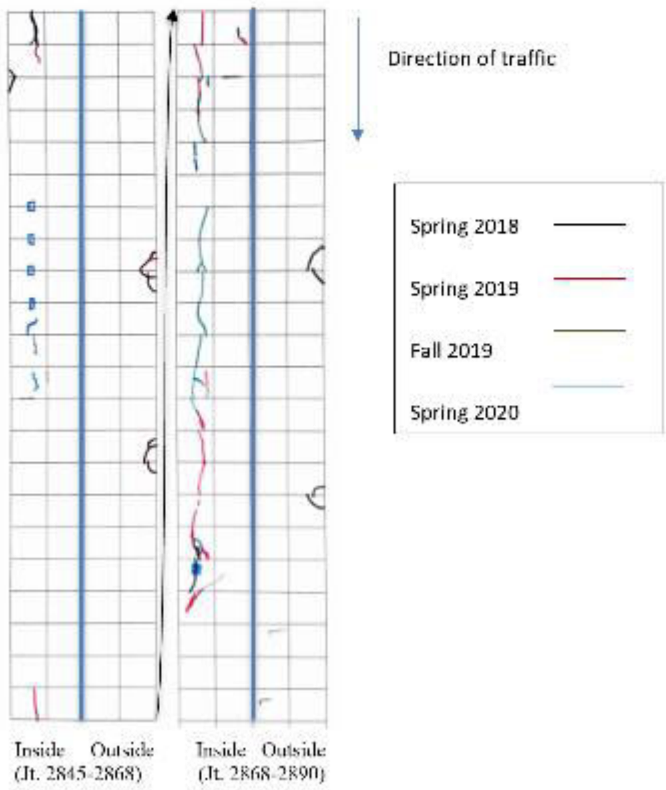
@ 63,000 ESALs

Observations: Fatigue Cracks in Cell 139 (3” slab on 6” base)



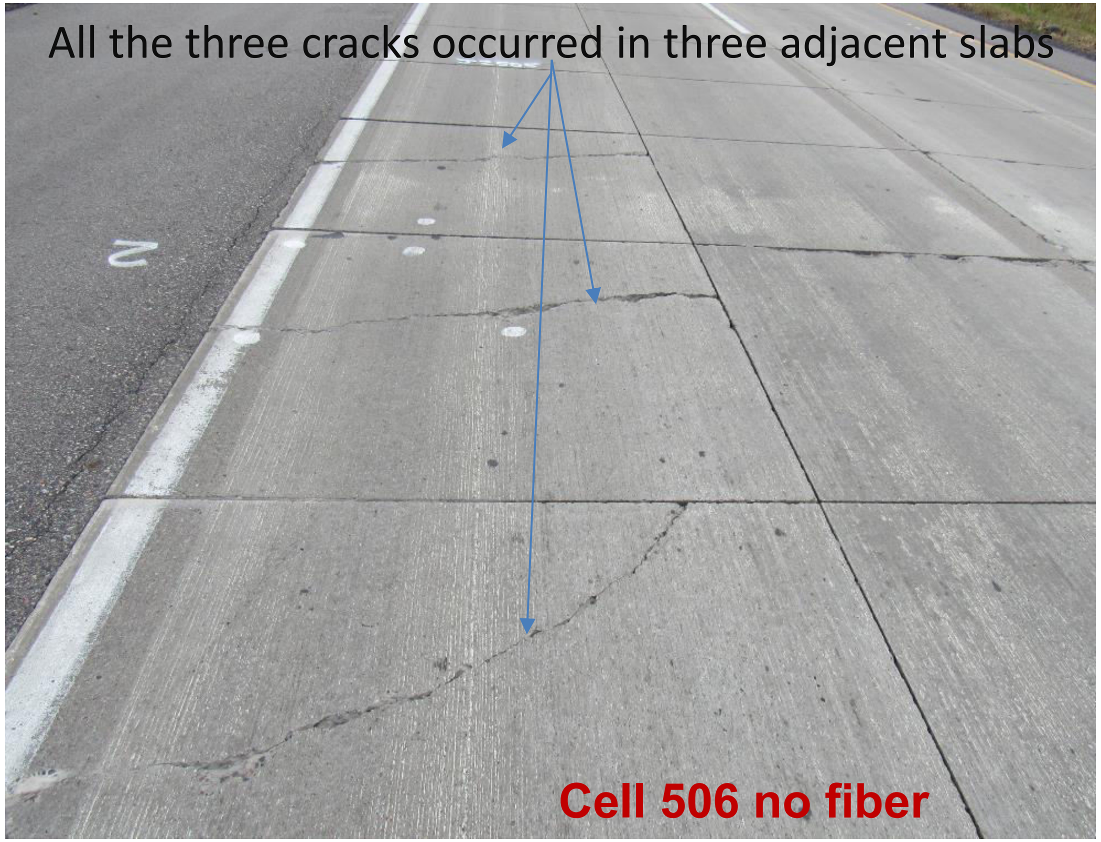
More than 75% slabs cracked by December 2019 (114,000 ESALs)

Observations: Fatigue Cracks in Cell 239 (4” slab on 6” base)



20% slabs cracked by March 2020 (145,000 ESALs << 1 million ESALs)

Observations: Fatigue Cracks in Cell 506 (5” slab on 11” base)



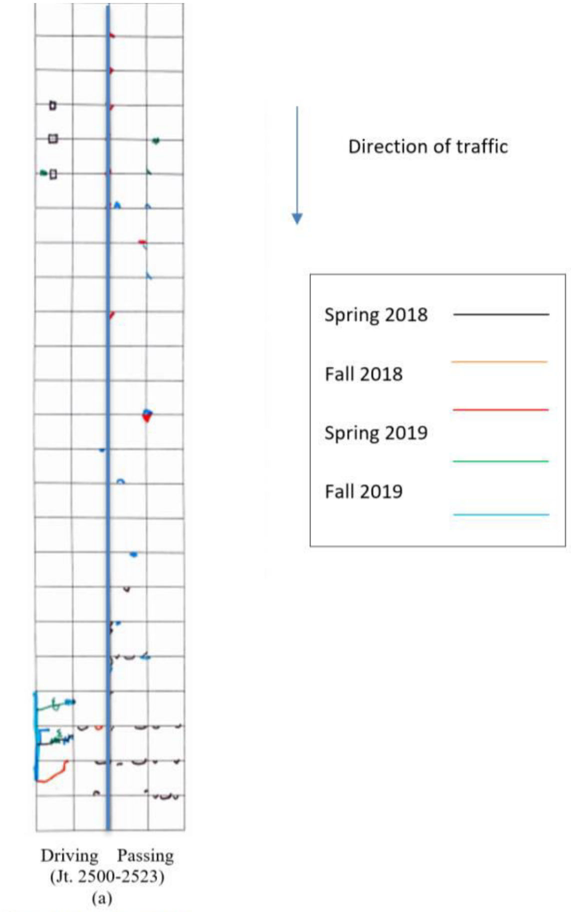


Figure 3-14: Distress Ma|

Only 2% slabs in Cell 506 cracked by summer 2020 (@2.8 million ESALs)

Fatigue Cracks in Cell 606, 706 and 806 (5 &6" slab on 11" base)

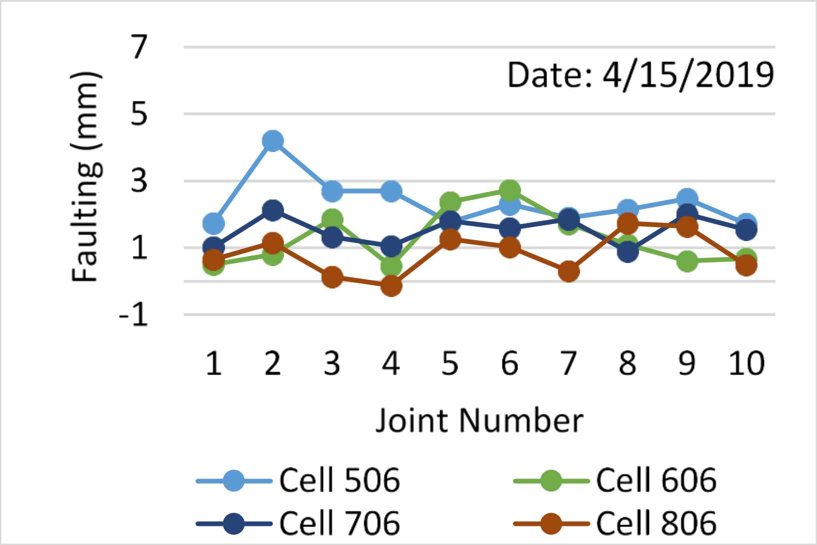
Cell 606, 706 and 806 did <u>NOT</u> experience any crack until @2.8 million ESALs

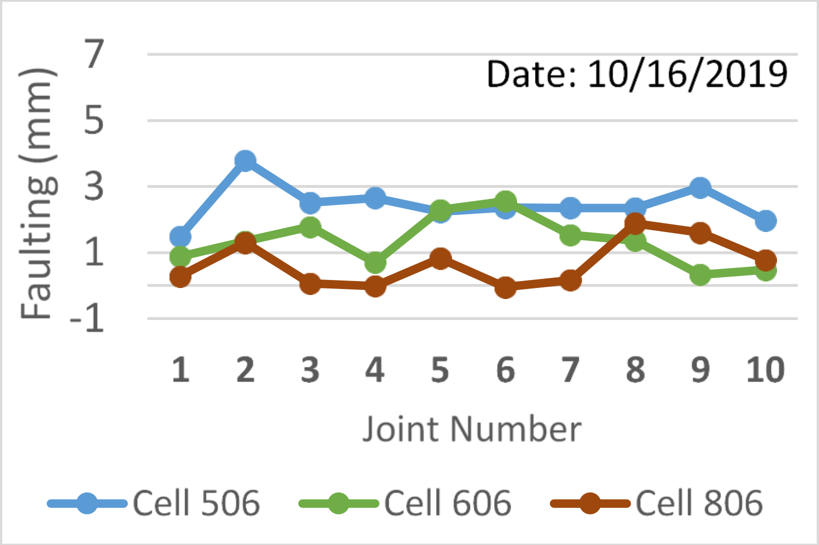
> typical low volume design traffic

Transverse Joint Faulting

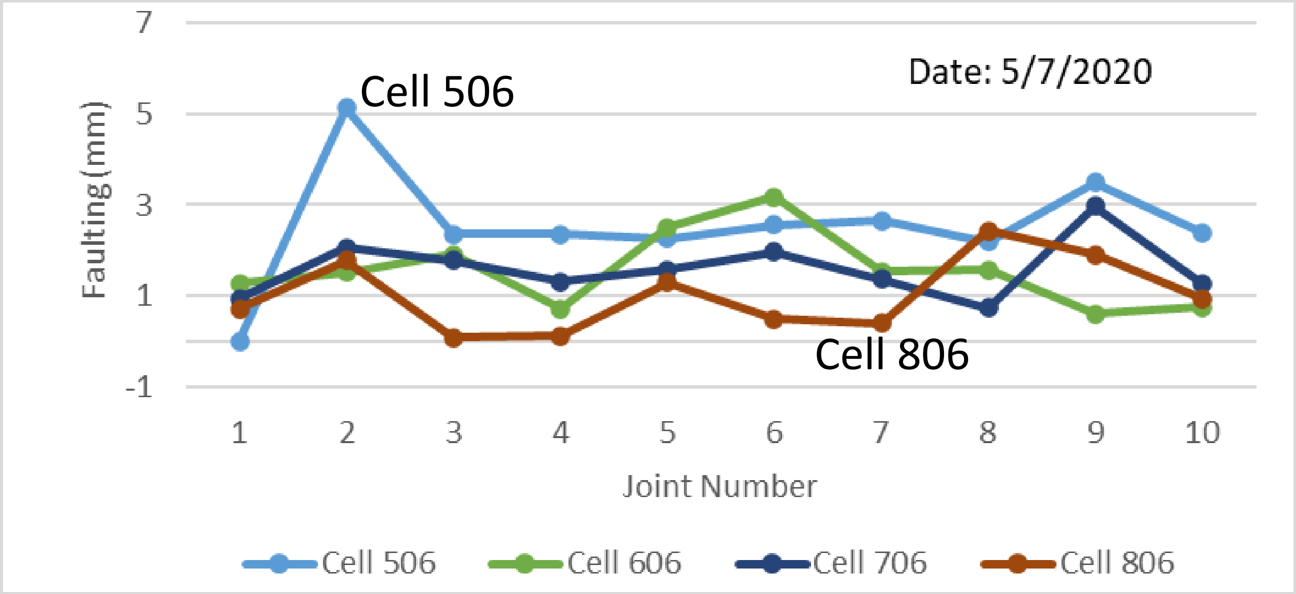
Faulting

Transverse Joint Faulting

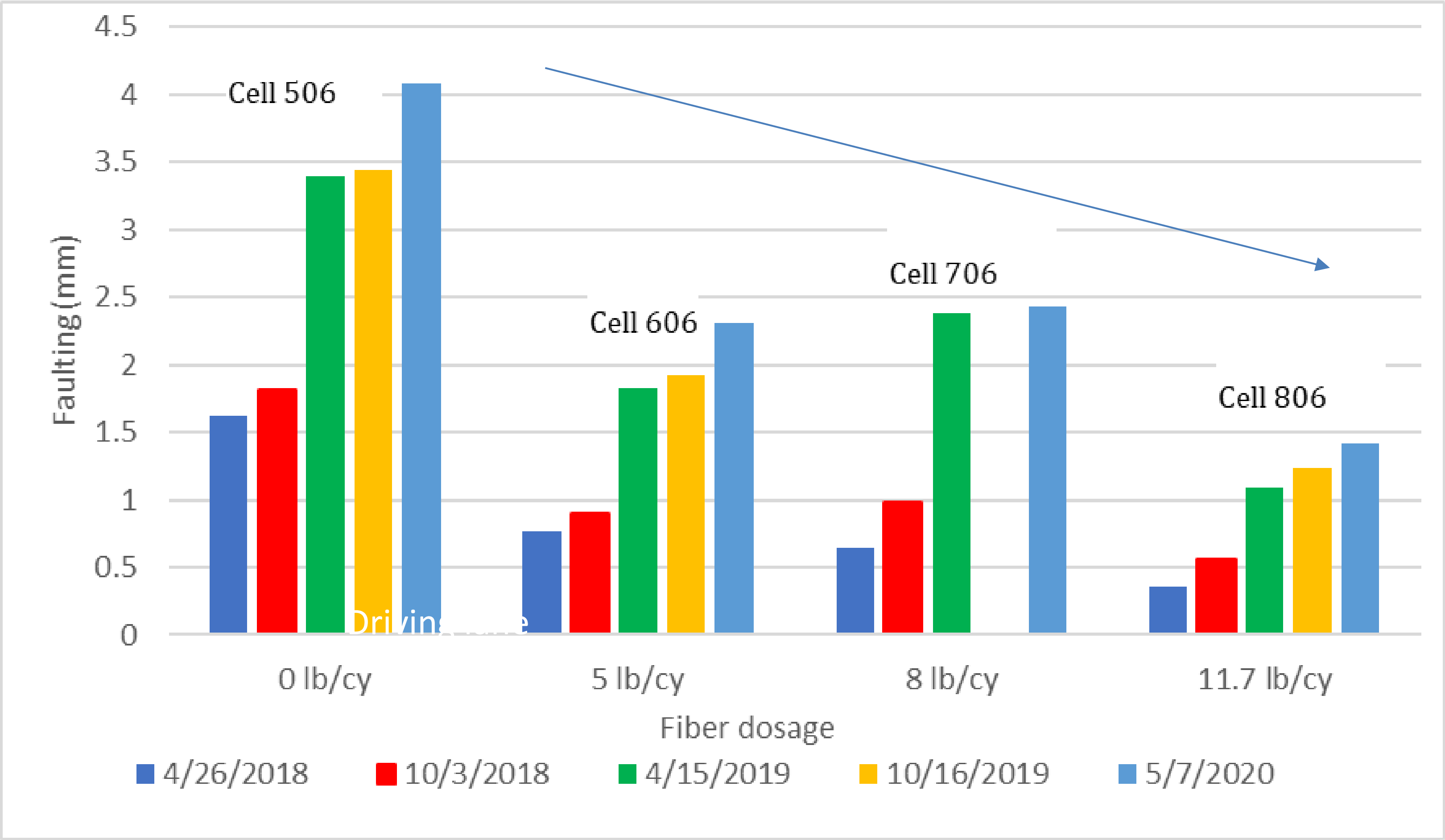




Cell 506 (no fiber) cell- **highest faulting**
Cell 606: 5 lb/cy fiber
Cell 706: 8 lb/cy fiber
Cell 806: 11.7 lb/cy fiber- **least faulting**



Joint Faulting Summary



Cell 806, 11.7 lb/cy fiber shown the lowest faulting

Conclusions: Ultra thin and Thin FRC Pavements

- **3” slab is too thin on a 6-inch gravel base; they may fail before the anticipated design life irrespective of fibers’ inclusion or not.**

- **Cell 239 (4”) has performed better than Cell 139, but more than 20% slabs cracked. Fibers helped holding the cracked slabs.**

- **Longitudinal fatigue cracks is the dominating distress in the ultra-thin and thin cells.**

- **With regards to the fatigue cracking in thin cells, only Cell 506 (no fibers) experienced 3 cracks; it is hard to quantify the contribution of fibers in mitigating fatigue cracks from this study.**

- **Cell 606, 706 and 806 showed less faulting than Cell 506 (no fiber).**

- **Thin (5” to 6”) pavements on relatively strong base layers seem to be a safe design with respect to the fatigue cracking for the low volume roads (~ 2 million design ESALs). Fibers can reduce the faulting and keep the riding quality until the design period, but the plain concrete pavements may not offer the same.**

Acknowledgement

- Oklahoma Transportation Center (OkTC), Oklahoma City, OK
- Volvo Construction Equipment (VCE), Shippensburg, PA
- Oklahoma Department of Transportation (ODOT), Oklahoma City, OK,
- Southern Plain Transportation Center, Norman, OK
- Haskell Lemon Construction Co., Oklahoma City, OK,
- Silver Star Construction Company, Moore, OK
- Minnesota Department of Transportation (MnDOT)
- National Road Research Alliance (NRRA)
- Student and staff of the University of Oklahoma and University of Minnesota

Questions?

mbarman@d.umn.edu