

# Determining Pavement Design Criteria for Recycled Aggregate Base and Large Stone Subbase

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Haluk Sinan Coban

Tuncer Edil

William Likos

Junxing Zheng

Halil Ceylan

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**MnDOT Project TPF-5(341)**

Monthly Meeting

December 10, 2019

# RESEARCH TEAM

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## Michigan State University

- Principal Investigator – **Bora Cetin**  
*Assistant Professor – Department of Civil and Environmental Engineering*

## Iowa State University

- Principal Investigator – **Halil Ceylan**  
*Professor – Department of Civil, Construction & Environmental Engineering*
- Co-Principal Investigator – **Ashley Buss**  
*Assistant Professor – Department of Civil, Construction & Environmental Engineering*
- Co-Principal Investigator – **Junxing Zheng**  
*Assistant Professor – Department of Civil, Construction & Environmental Engineering*
- Research Personnel – **Haluk Sinan Coban**  
*PhD Candidate – Department of Civil, Construction & Environmental Engineering*

## University of Wisconsin-Madison

- Co-Principal Investigator – **William Likos**  
*Professor – Department of Civil and Environmental Engineering*
- Co-Principal Investigator – **Tuncer B. Edil**  
*Professor Emeritus – Department of Civil and Environmental Engineering*

# AGENCY MEMBERS

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- MnDOT
- Caltrans
- MDOT
- IDOT
- LRRB
- MoDOT
- WisDOT
- NDDOT
- Iowa DOT

# ASSOCIATE MEMBERS

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- Aggregate & Ready Mix of MN
- Asphalt Pavement Alliance (APA)
- Braun Intertec
- Infracore
- Diamond Surface Inc.
- Flint Hills Resources
- International Grooving & Grinding Association (IGGA)
- Midstate Reclamation & Trucking
- MN Asphalt Pavement Association
- Minnesota State University - Mankato
- National Concrete Pavement Technology Center
- Roadscanners
- University of Minnesota - Duluth
- University of New Hampshire
- Mathy Construction Company
- Michigan Tech Transportation Institute (MTTI)
- University of Minnesota
- National Center for Asphalt Technology (NCAT) at Auburn University
- GSE Environmental
- Helix Steel
- Ingios Geotechnics
- WSB
- Cargill
- PITT Swanson Engineering
- University of California Pavement Research Center
- Collaborative Aggregates LLC
- American Engineering Testing, Inc.
- Center for Transportation Infrastructure Systems (CTIS)
- Asphalt Recycling & Reclaiming Association (ARRA)
- First State Tire Recycling
- BASF Corporation
- Upper Great Plains Transportation Institute at North Dakota State University
- 3M
- Pavia Systems, Inc.
- All States Materials Group
- Payne & Dolan, Inc.
- Caterpillar
- The Dow Chemical Company
- The Transtec Group
- Testquip LLC
- Hardrives, Inc.
- Husky Energy
- Asphalt Materials & Pavements Program (AMPP)
- Concrete Paving Association of MN (CPAM)
- MOBA Mobile Automation
- Geophysical Survey Systems
- Leica Geosystems
- University of St. Thomas
- Trimble

# OUTLINE

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- Follow-up
- Test cells & materials
- Tasks 5 & 6

# FOLLOW-UP

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- **Task 1** – Literature review and recommendations
- **Task 2** – Tech transfer “state of practice”
- **Task 3** – Construction monitoring and reporting
- **Task 4** – Laboratory testing
- **Task 5** – Performance monitoring and reporting
- **Task 6** – Instrumentation
- **Task 7** – Pavement design criteria
- **Task 8 & 9** – Draft/final report

Green – Completed  
Red – In Progress

# TEST CELLS

Recycled Aggregate Base				Large Stone Subbase		Large Stone Subbase with Geosynthetics				
185	186	188	189	127	227	328	428	528	628	728
3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave	3.5 in Superpave
12 in Coarse RCA	12 in Fine RCA	12 in Limestone	12 in RCA+RAP	6 in Class 6 Aggregate	6 in Class 6 Aggregate	6 in Class 5Q Aggregate	6 in Class 5Q Aggregate	6 in Class 5Q Aggregate	6 in Class 5Q Aggregate	6 in Class 5Q Aggregate
3.5 in S. Granular Borrow	3.5 in S. Granular Borrow	3.5 in S. Granular Borrow	3.5 in S. Granular Borrow	18 in LSSB (1 lift)	18 in LSSB (1 lift)	9 in LSSB	9 in LSSB	9 in LSSB	9 in LSSB	9 in LSSB
Sand	Sand	Clay Loam	Clay Loam			TX	TX+GT	BX+GT	BX	
				Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam

S. Granular Borrow = Select Granular Borrow

TX = Triaxial Geogrid  
 BX = Biaxial Geogrid  
 GT = Nonwoven Geotextile

# MATERIALS

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Sand Subgrade



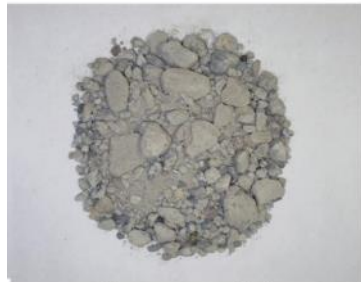
Clay Loam



Select Granular Borrow



LSSB



Coarse RCA



Fine RCA



Limestone



RCA+RAP



Class 6 Aggregate



Class 5Q Aggregate

1 in (25.4 mm)



# TASKS 5 & 6

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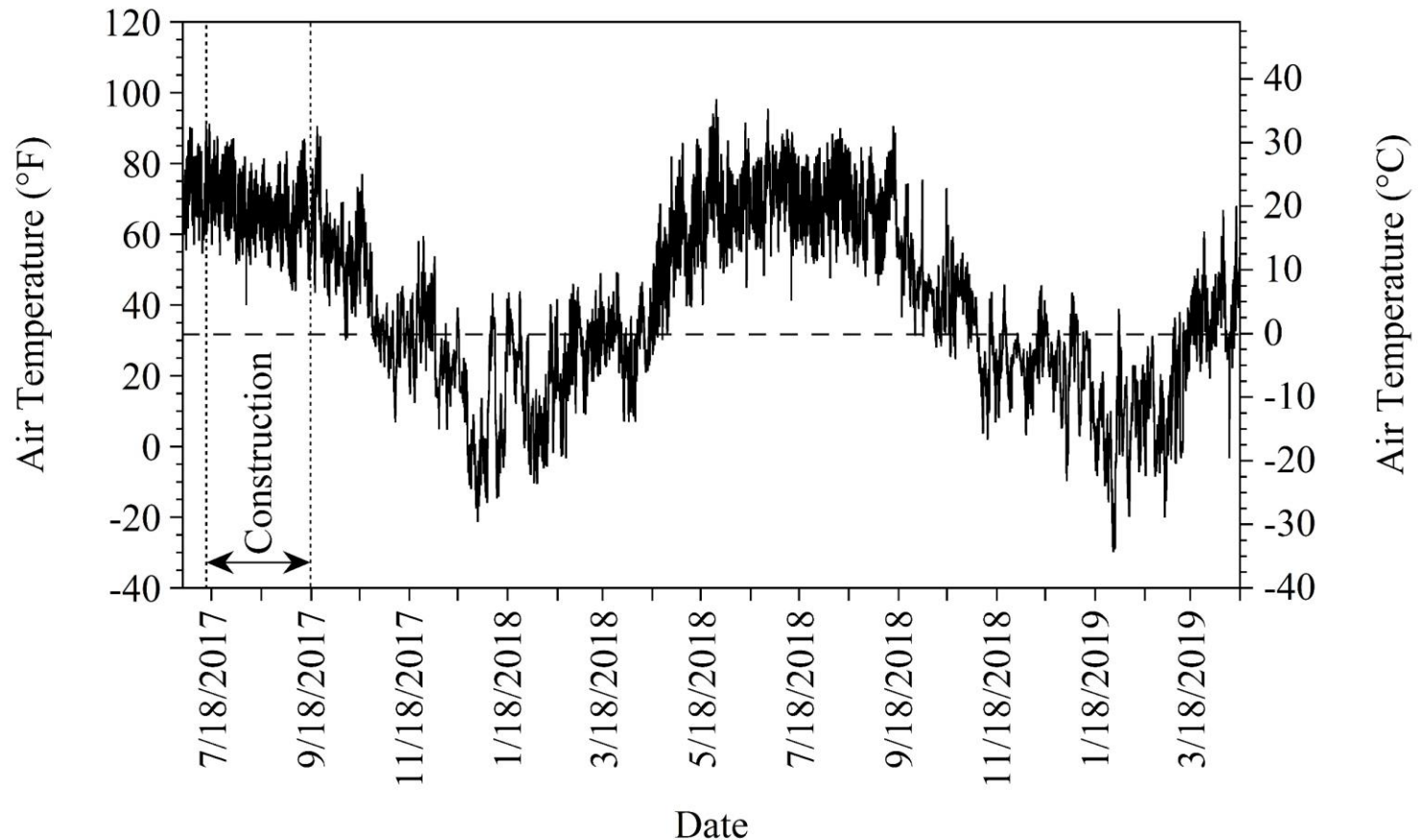
- Falling weight deflectometer (FWD)
- Frost monitoring
- International roughness index (IRI)
- Rutting
- Environmental monitoring
  - Weather data
  - Temperature sensors
  - Moisture sensors

Green – Completed  
Red – In Progress

# TASKS 5 & 6

## Weather Data

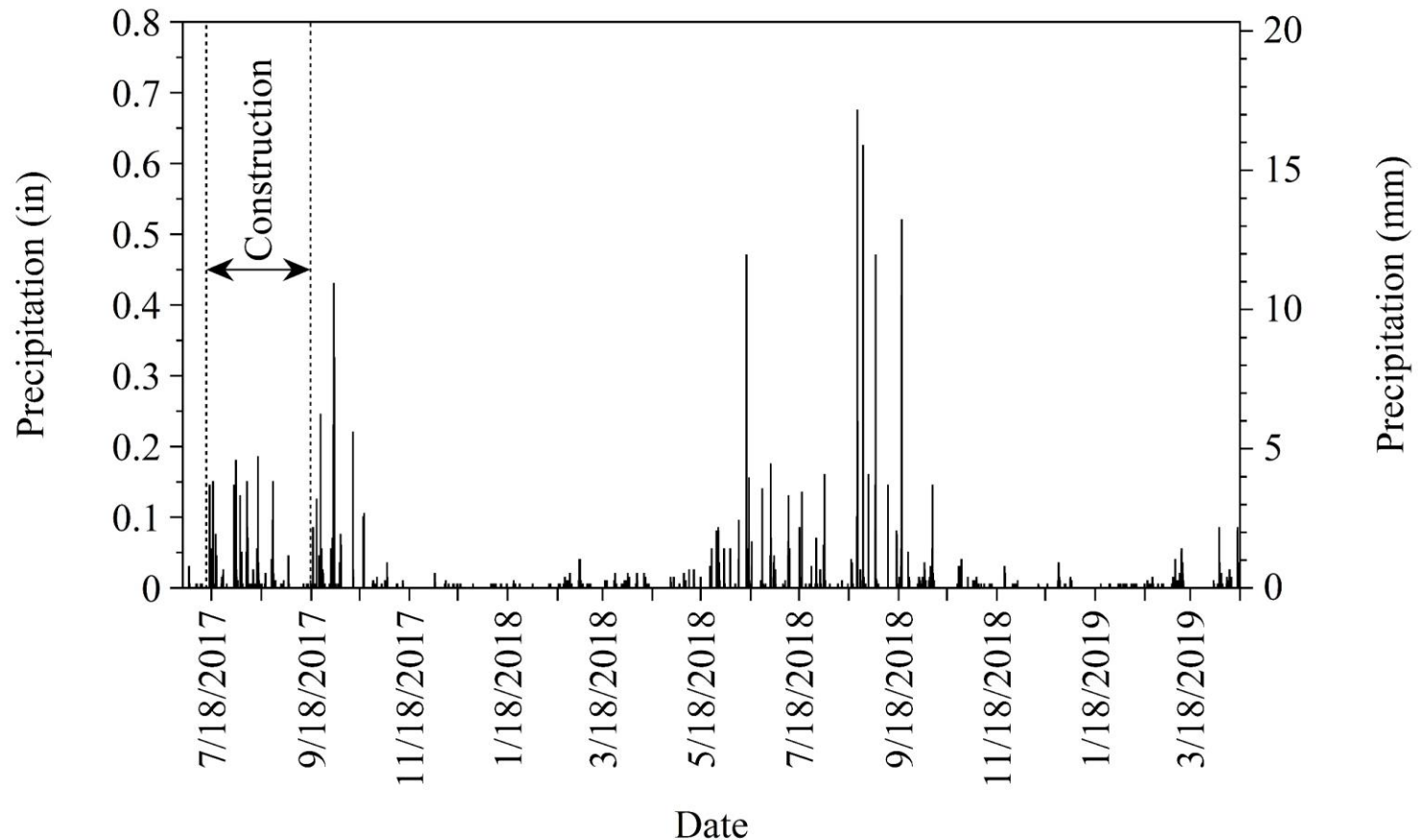
- Air temperature



# TASKS 5 & 6

## Weather Data

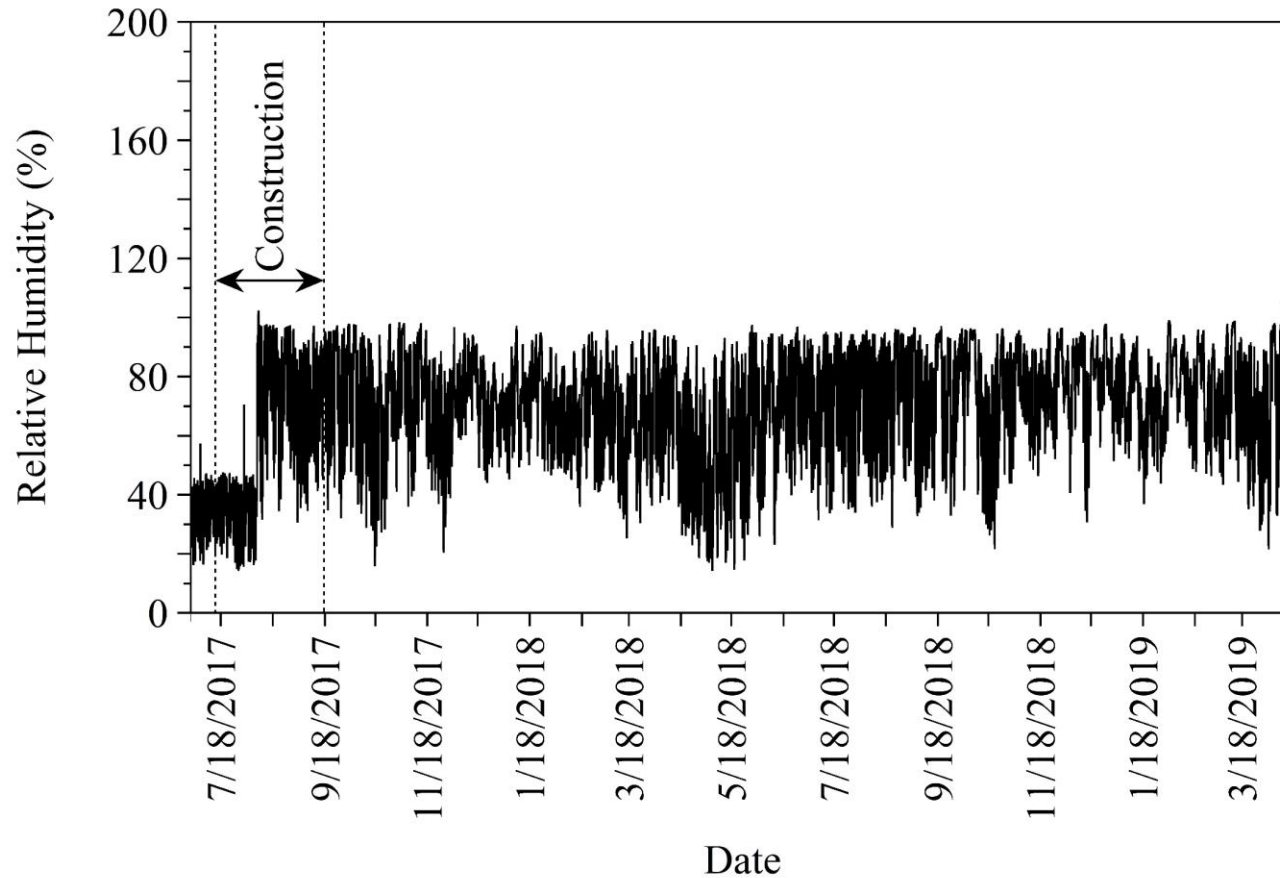
- Precipitation



# TASKS 5 & 6

## Weather Data

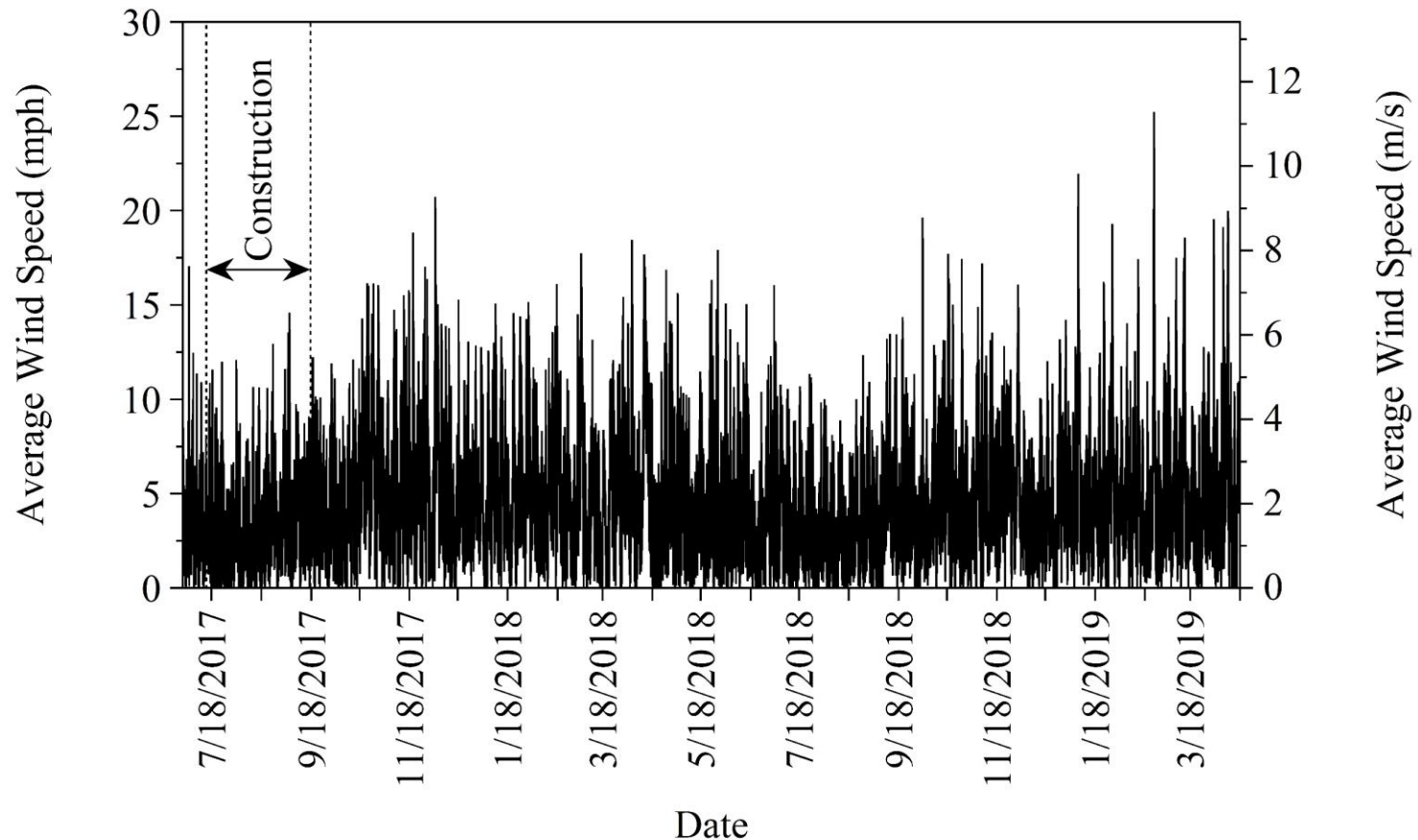
- Relative humidity



# TASKS 5 & 6

## Weather Data

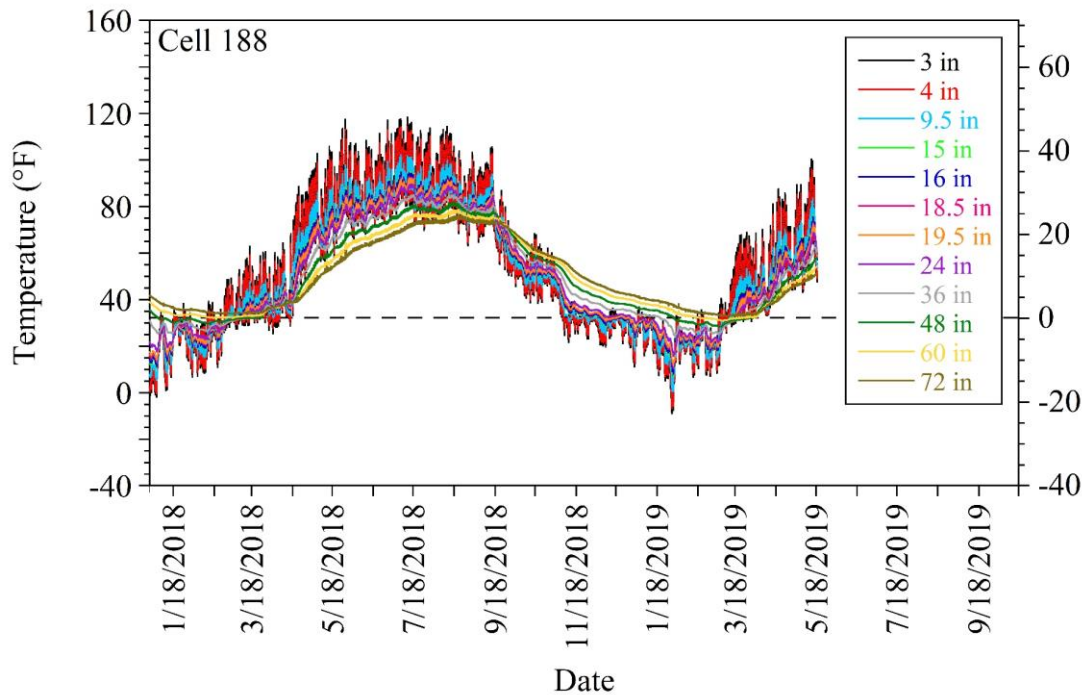
- Average wind speed



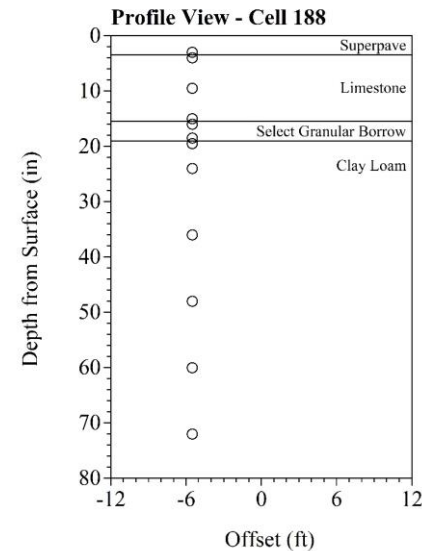
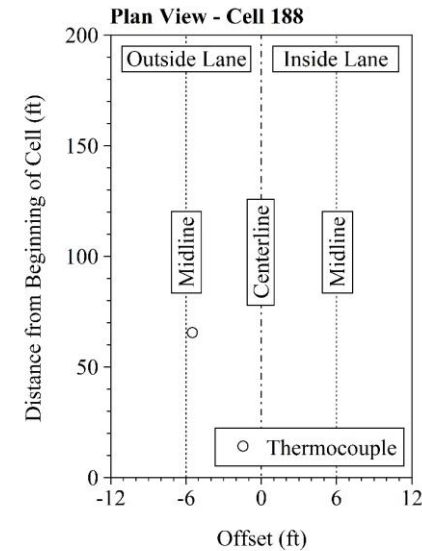
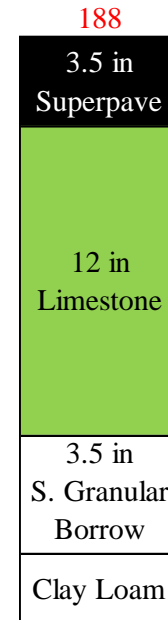
# TASKS 5 & 6

## Sensor Monitoring

- Thermocouples



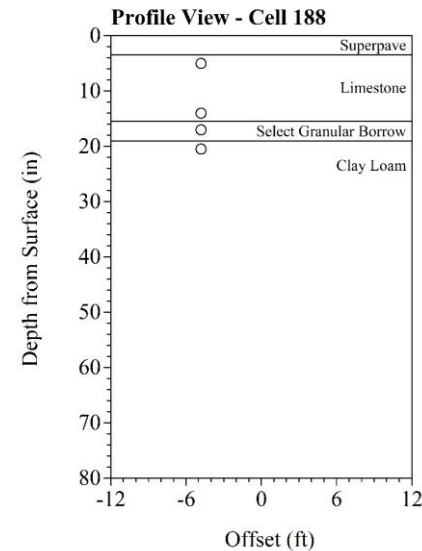
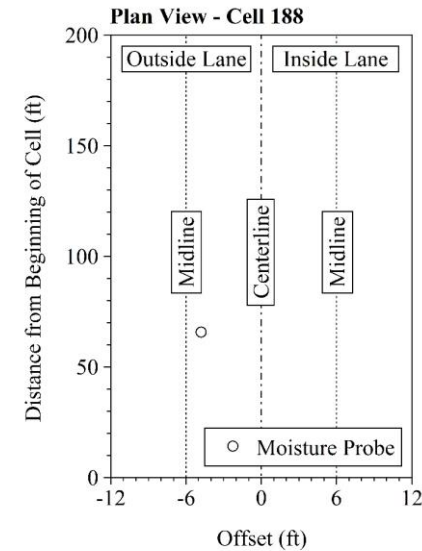
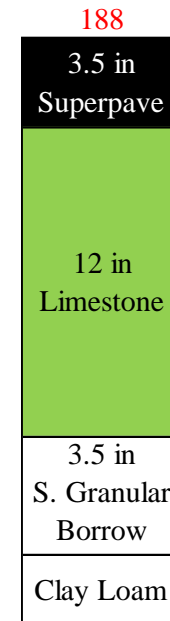
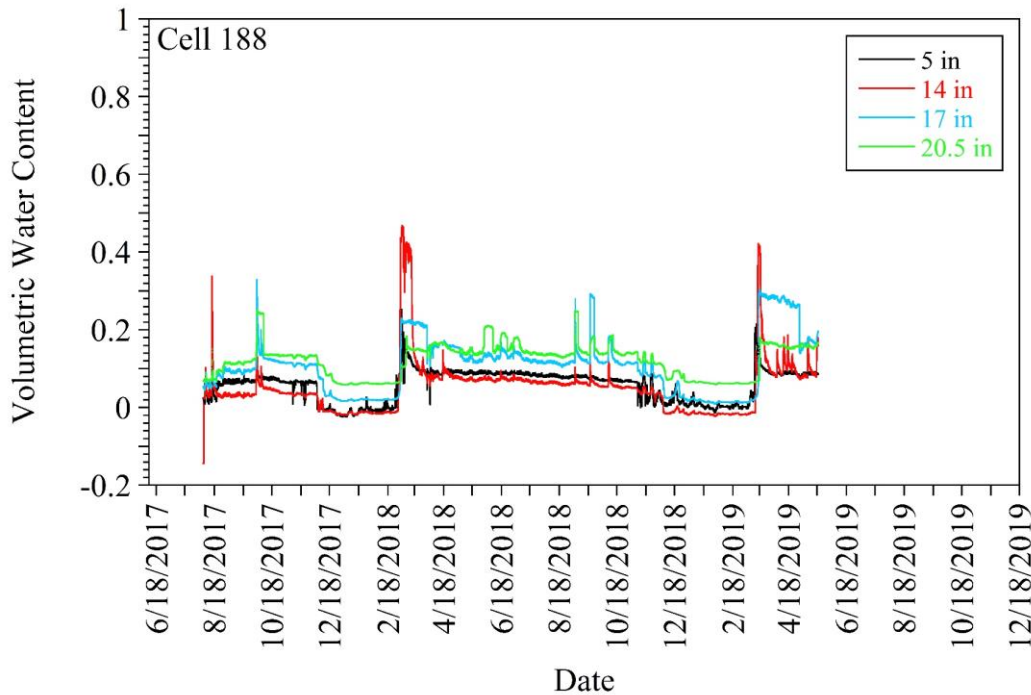
Temperature (°C)



# TASKS 5 & 6

## Sensor Monitoring

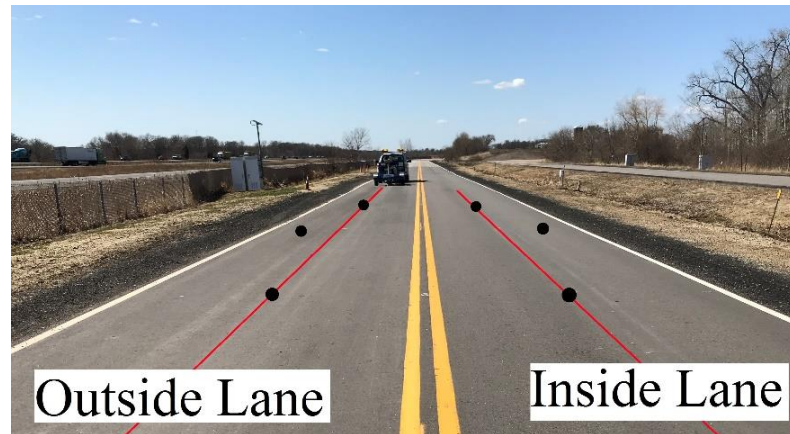
- Moisture probes



# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

Cell Number	Station	Test Points	OUTSIDE LANE (+)			INSIDE LANE (-)		
			OWP	MID	IWP	IWP	MID	OWP
185  12 in. Coarse RCA	16368	Start						
	16379	1	o					o
	16409	2		o			o	
	16439	3	o					o
	16469	4		o			o	
	16499	5	o					o
	16529	6		o			o	
	16559	7	o					o
	16569	End						



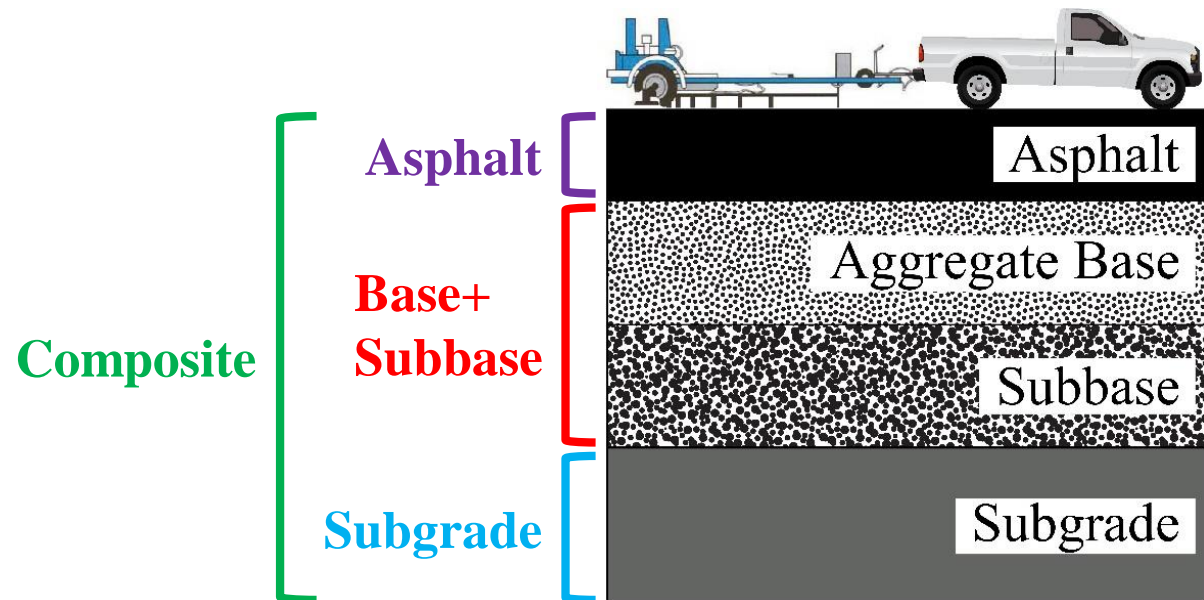
IWP = Inner wheel path  
 MID = Midlane  
 OWP = Outer wheel path



# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

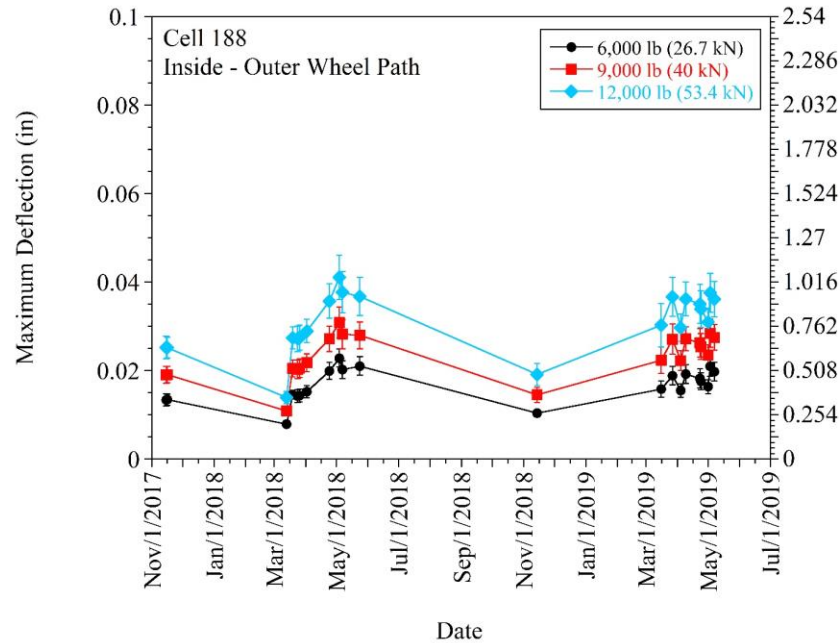
- After paving
- Composite analysis
- Layered analysis
  - Asphalt
  - Base+subbase
  - Subgrade



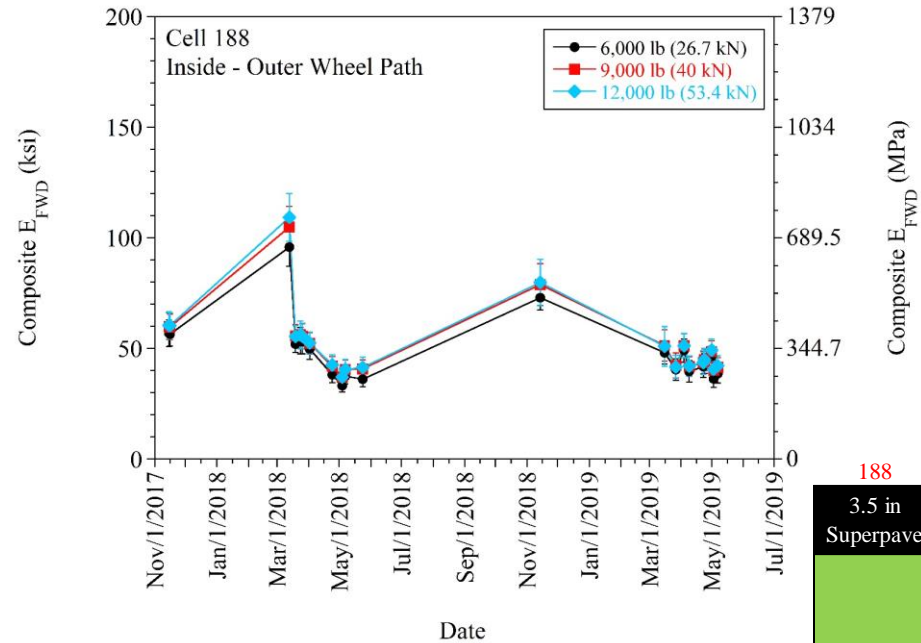
# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

Maximum deflection



Composite  $E_{FWD}$

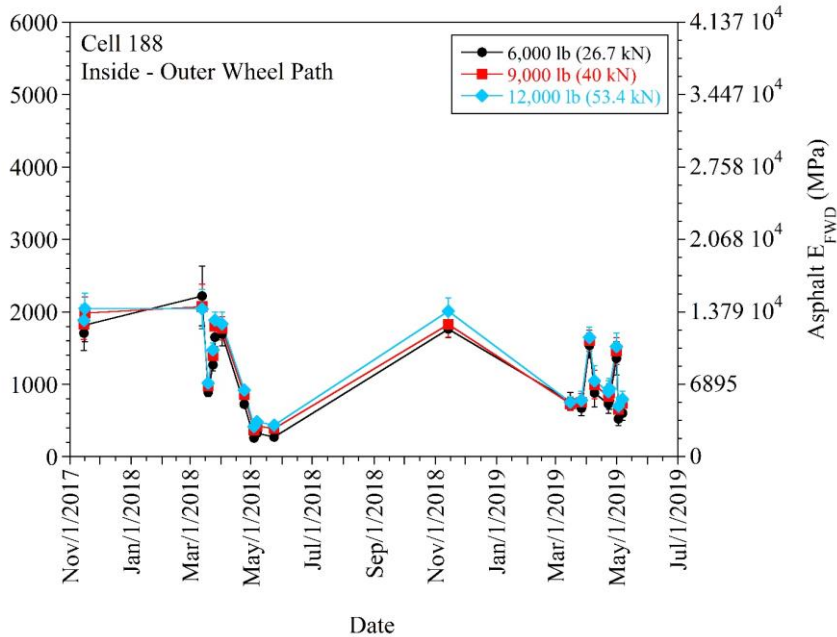


188
3.5 in Superpave
12 in Limestone
3.5 in S. Granular Borrow
Clay Loam

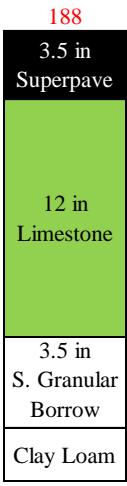
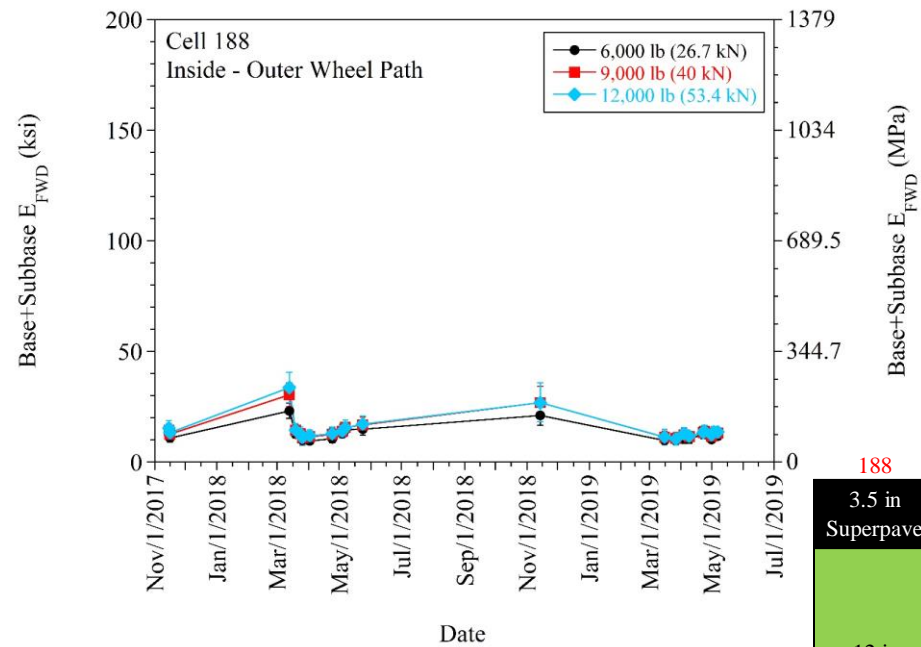
# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

### Asphalt $E_{FWD}$

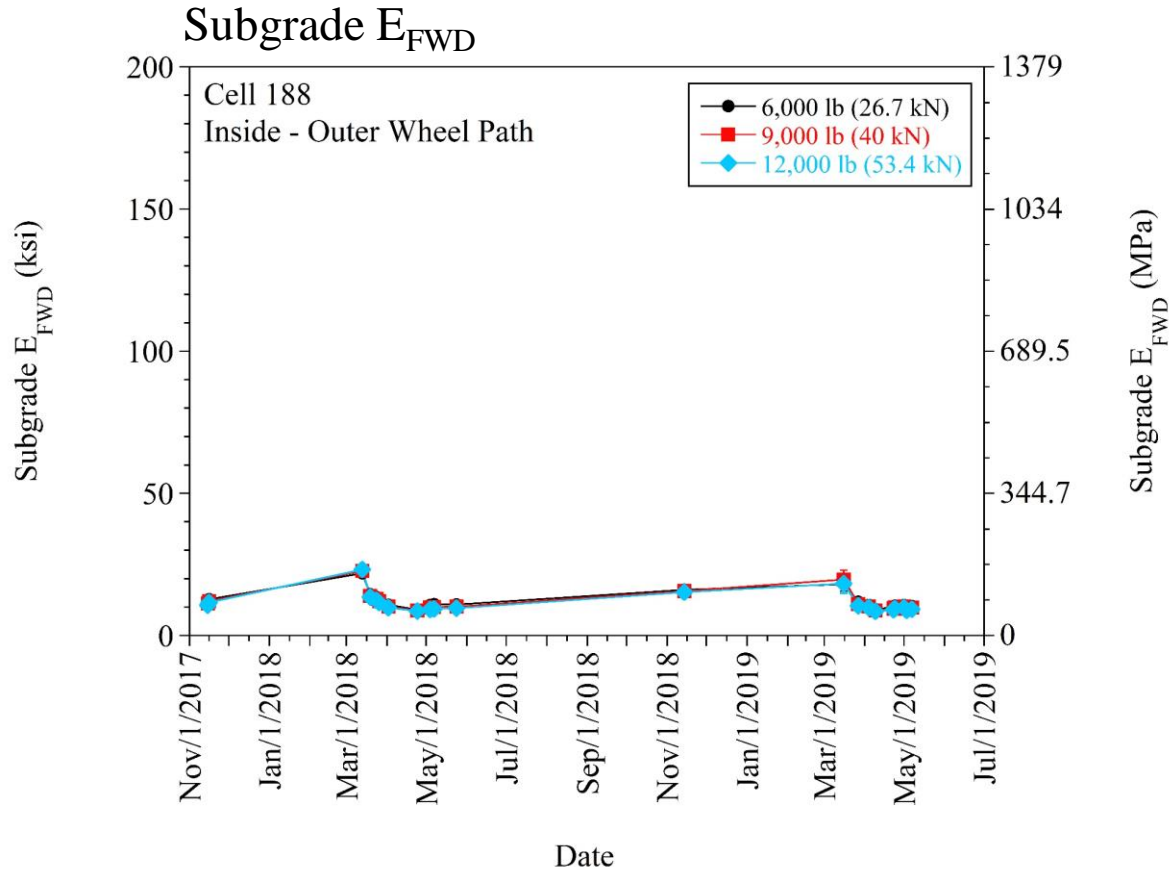


### Base+Subbase $E_{FWD}$



# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

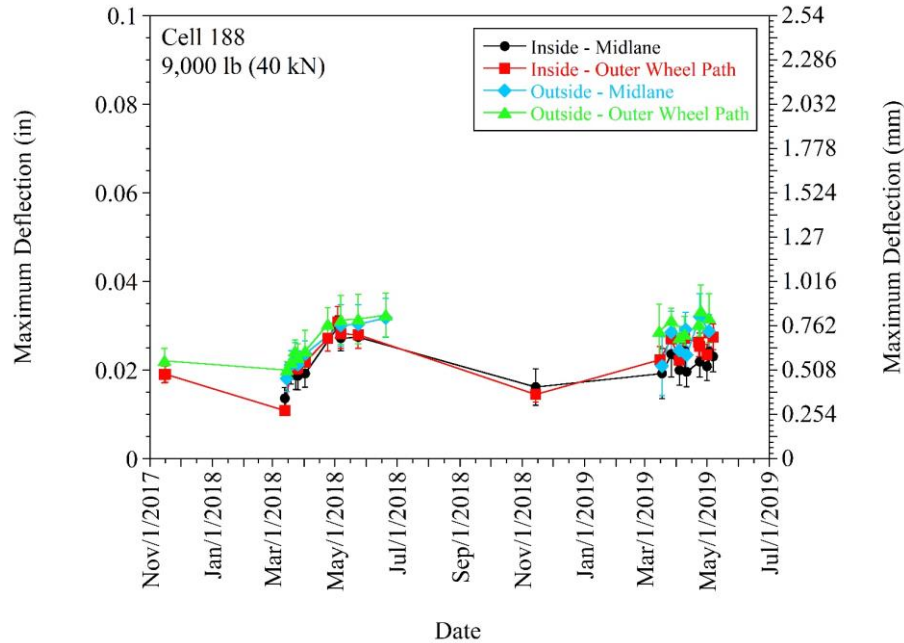


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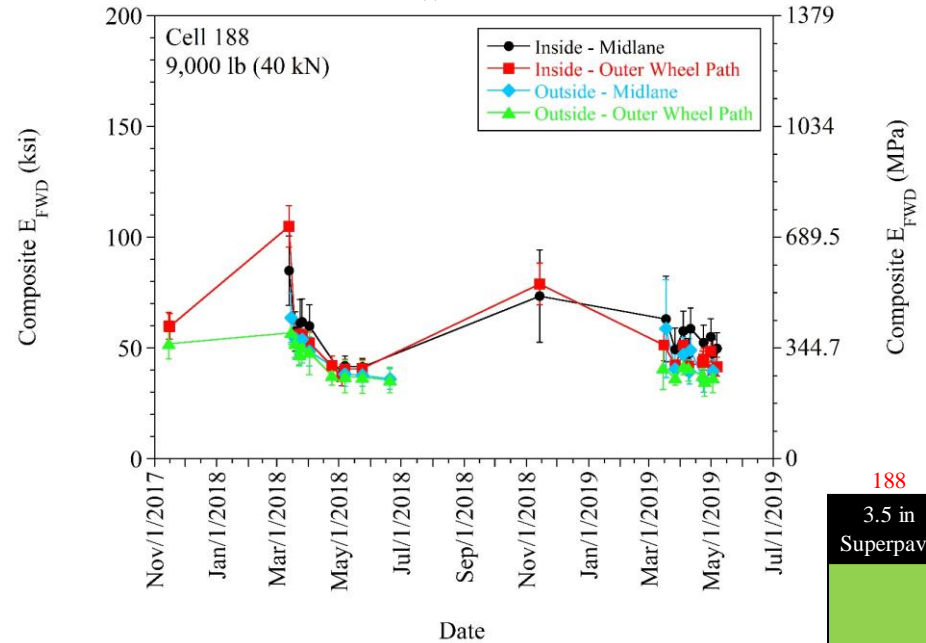
# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

### Maximum Deflection



### Composite $E_{FWD}$

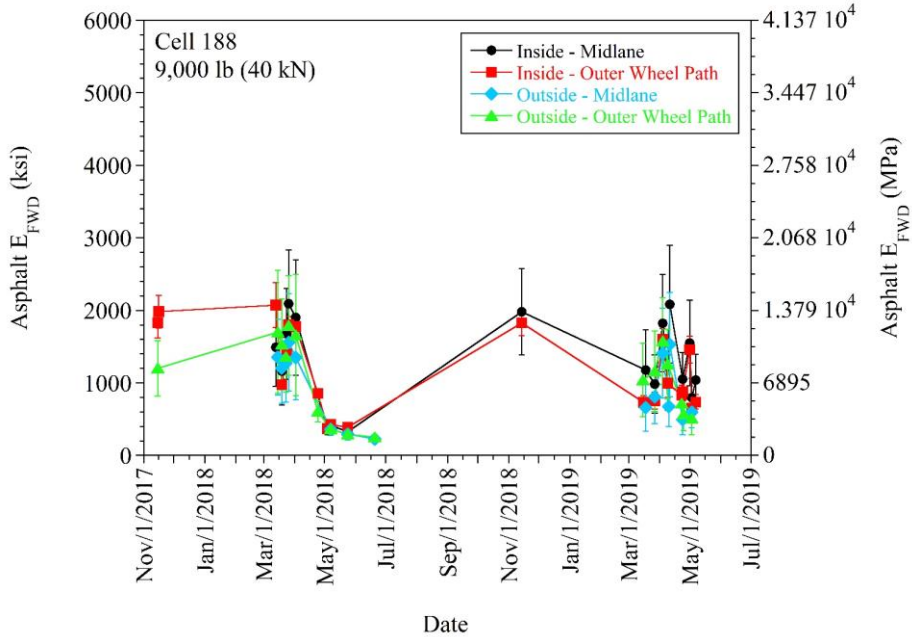


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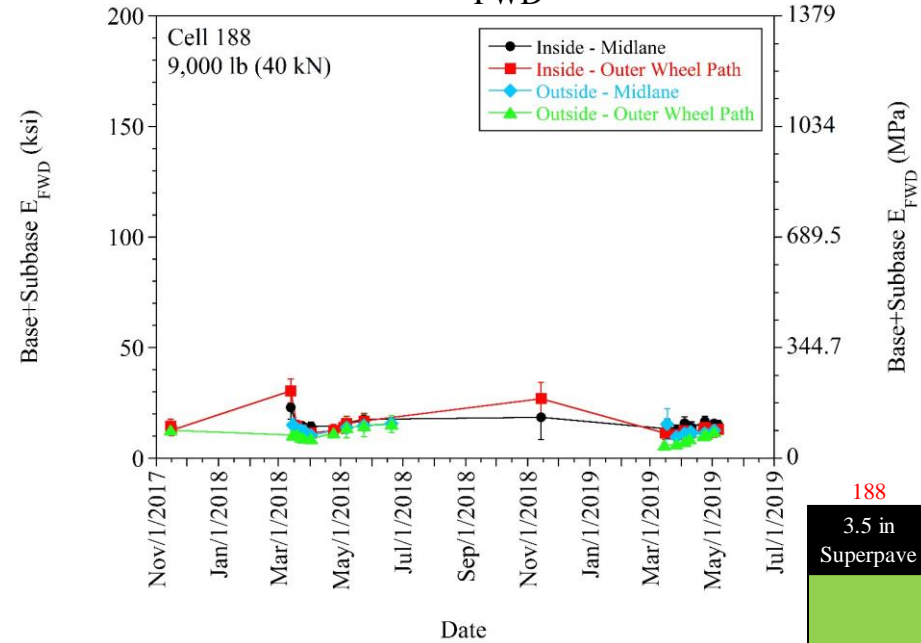
# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)

### Asphalt $E_{FWD}$



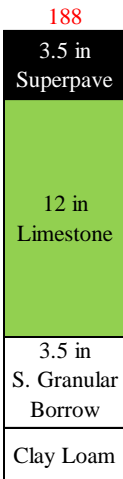
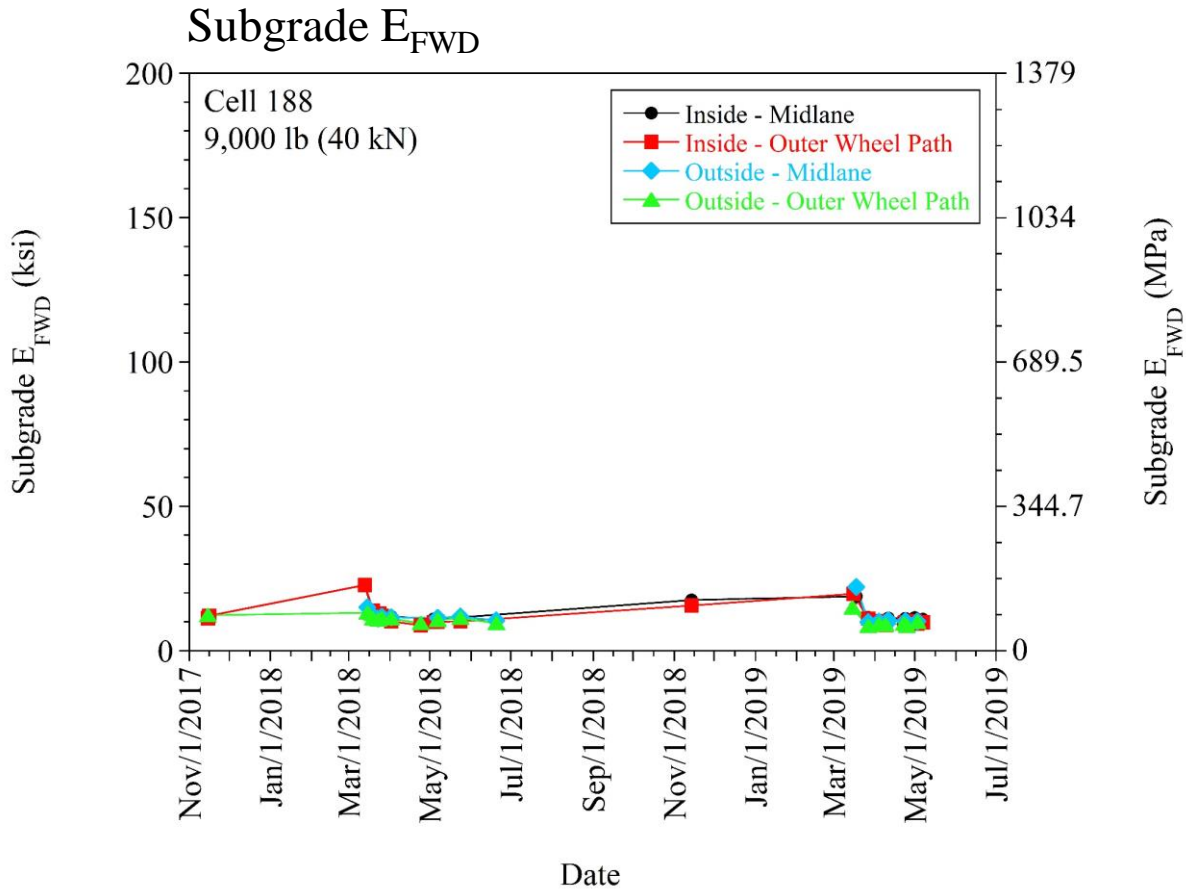
### Base+subbase $E_{FWD}$



188
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12 in Limestone
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Clay Loam

# TASKS 5 & 6

## Falling Weight Deflectometer (FWD)



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Thank You!

**QUESTIONS??**

IOWA STATE  
UNIVERSITY



MICHIGAN STATE  
UNIVERSITY



# TASKS 5 & 6

## Sensor Monitoring

- Moisture probes

MnROAD Model	Sensor	MnROAD Material	Calibration Equation
EW	TE	Generic (2006)	VWC= 0.00109 RAW - 0.629
		Sand	VWC= 0.0009 RAW - 0.4929
		Clay	VWC = 0.0009 RAW - 0.4693
		Select Granular	VWC = 0.0011 RAW - 0.6615
		Class-3	VWC = 0.0009 RAW - 0.5149
		Class-4	VWC = 0.0008 RAW - 0.4120
		Class-5	VWC = 0.0007 RAW - 0.3524
		Class-6	VWC = 0.0011 RAW - 0.6787
	5TE	Generic (2008)	VWC = 0.00109 RAW - 0.629
		Sand	VWC = 0.0004 RAW - 0.0780
		Clay	VWC = 0.0003 RAW - 0.0021
		Select Granular	VWC = 0.0005 RAW - 0.0908
		Class-3	VWC = 0.0004 RAW - 0.0481
		Class-4	VWC = 0.0004 RAW - 0.0520
		Class-5	VWC = 0.0003 RAW - 0.0239
Class-6		VWC = 0.0006 RAW - 0.1438	
	Class-7 (Reclaimed HMA)	VWC = 0.0006 RAW - 0.1358	

# SCHEDULE

TASKS	MONTHS																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33		
Task 1	█	█	█	█	█																														
Task 2						█	█	█	█																										
Task 3		█	█	█	█	█	█	█																											
Task 4		█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█															
Task 5		█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█										
Task 6		█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█									
Task 7																									█	█	█	█							
Task 8																												█	█	█	█	█			
Task 9																																█	█	█	