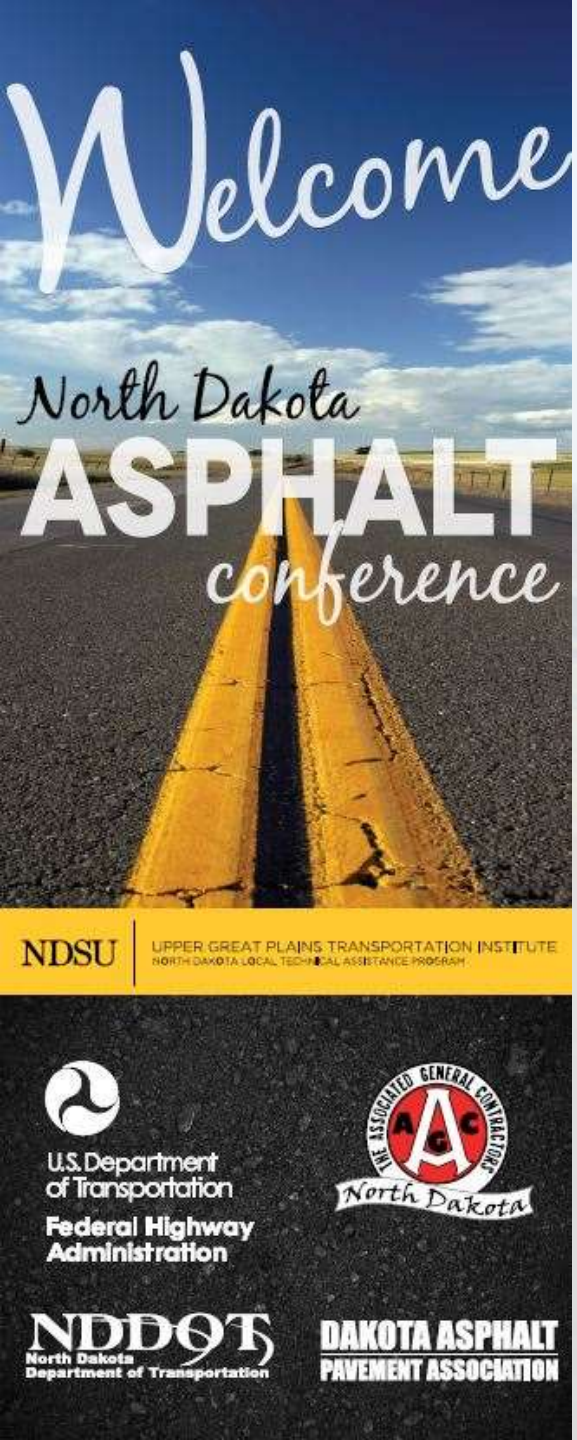


Using Thermal Imaging & IC Data for Quality Control

Presented by: Todd Mansell

CATERPILLAR®

What Problem are we Trying to Solve?

Owner: We are not realizing our design pavement life

- It's not design-related, it's construction-related!!
- The pavement is only as good as its weakest link
- We often give full acceptance when the pavement is not acceptable
- Current methods are "spot tests" – a moment in time and space

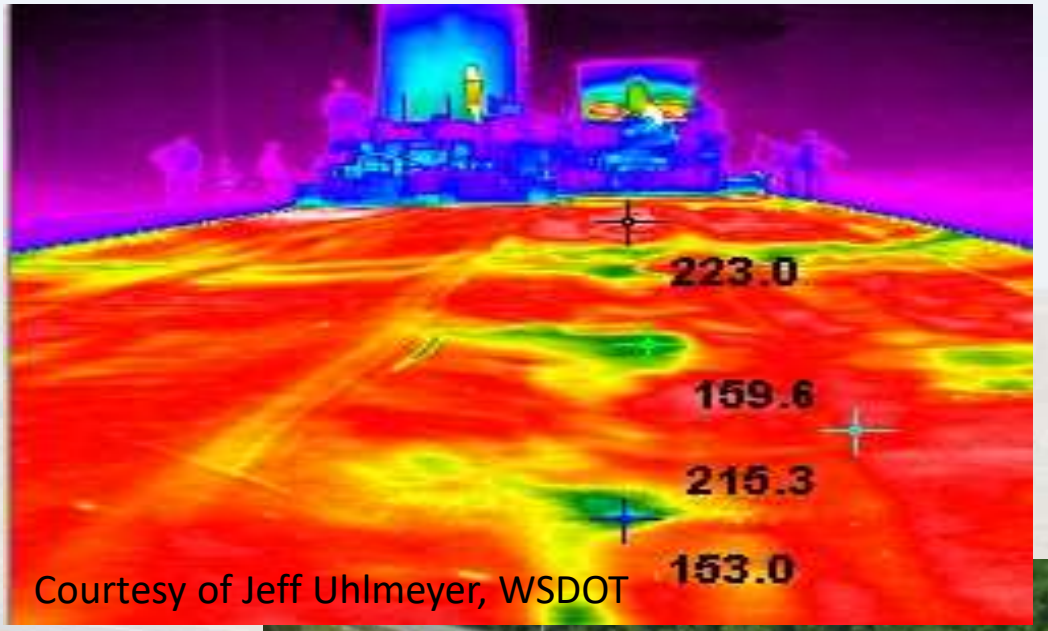
Contractor: We are not realizing our full incentive pay!!

- PWL specifications - consistency
- Efficiencies in process – fewest roller passes, quality, production
- Operator training for quality & efficiency
- Equipment condition/repair

Temperature Differentials = Density Differentials

Courtesy of Jeff Uhlmeyer, WSDOT

This....becomes....this....



Courtesy of Jeff Uhlmeyer, WSDOT

What Percentage Actually Gets Measured?

Applying technology will minimize risk

Thermal Imaging

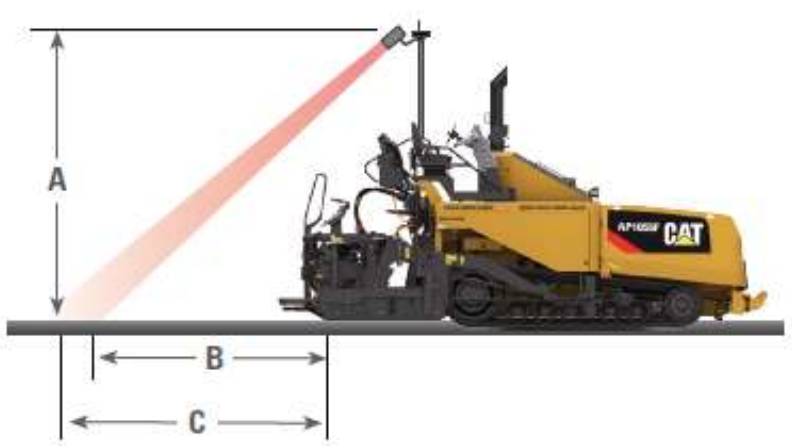
- Handheld thermal cameras
- Paver-Mounted Thermal Profiling (PMTP)

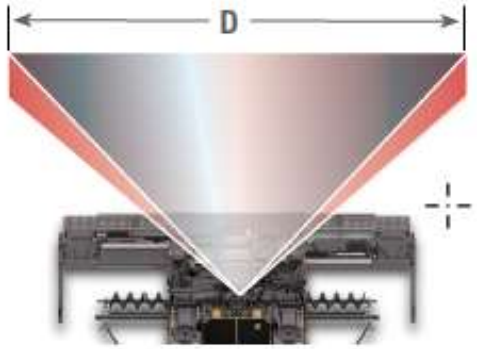
Paver-Mounted Thermal Profiling (PMTP)

- Continuous
- Real-time on paver
- Stationary infrared camera
- Variable width
- Compatible direct upload to Veta software

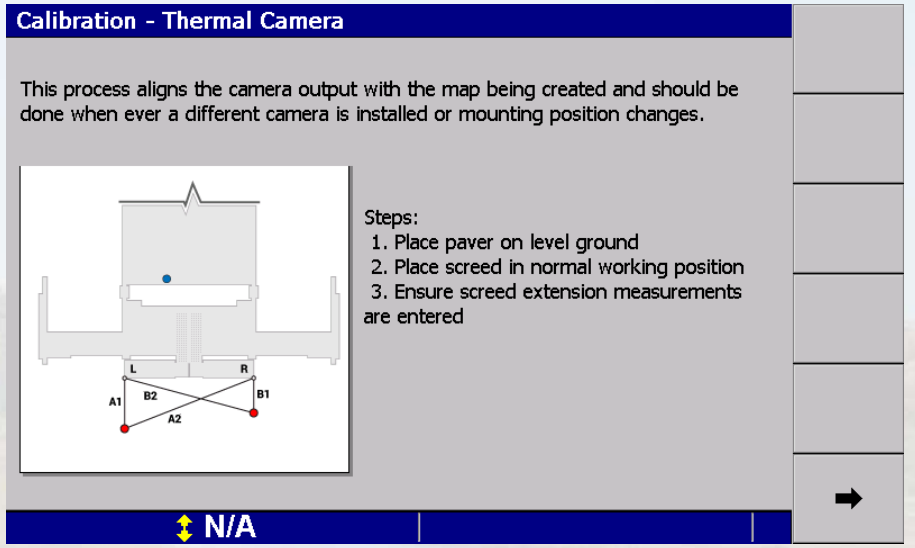
Caterpillar Thermal Mapping Product Spec

SPECIFICATIONS AND DIMENSIONS





TECHNICAL SPECIFICATIONS			
Temperature Mapping Range	60º - 200º C (141º - 392º F)		
Temperature Accuracy	±2º C or 2%		
DIMENSIONS			
Camera Eye Height	A	3.96 m	(13')
Maximum Camera Height	–	4.27 m	(14')
Minimum Camera Height	–	2.93 m	(9' 7")
Calibration Zone			
Distance from Screed Plate – Minimum	B	2.44 m	(8')
Distance from Screed Plate – Maximum	C	3.66 m	(12')
Maximum Mat Width	D	9.14 m	(30')



Thermal Mapping in Real-Time on the Paver


```
Cat Grade Control In-Field Report
=================================
Machine          :
Start Time       : 19:38:44
Start Date       : 2018/05/29
End Time         : 22:46:08
End Date         : 2018/05/29
Duration                 : 187 Minutes
Site Design      : I10 FLAT
UTM Zone         : 14 N
Start Station            :
End Station                        :
Total Area Covered       : 14387.9 FT²
Layer                              : 1

Target Temperature Variation Range: 25°F to 50°F
Temperature Percentages:
  0- 25°F:        45%
 25- 50°F:        21%
  >  50°F:        34%

High Temperature Variation Areas: (>50°F, 12.0 FT²)
   Northing       Easting Temperature Variation
1. 10759554.6   1760971.7        111°F
2. 10759553.4   1760975.1        103°F
3. 10759289.1   1761125.6         98°F
4. 10759559.0   1760963.9         94°F
5. 10759388.4   1761060.9         86°F
6. 10759499.9   1761009.6         85°F
7. 10759283.5   1761139.0         84°F
8. 10759628.2   1760928.2         81°F
9. 10759617.0   1760934.9         80°F
10. 10759188.7  1761200.4         80°F

Approval
=================================

Operator

Site Manager
Date
.................................

Third Party Inspector
Date
.................................
```

How Can Thermal Imaging Help with QC?

- Consistent mat temperatures = consistent compaction = better smoothness = extended pavement life

- Identify areas of improvement in process and equipment
  - Plant operations
  - Plant repairs
  - Transportation & handling of mix
    - Loading, transfer to paver, through the paver
  - Paving equipment setup & operation
  - Paving equipment repair

Components of IC Roller

Intelligent Compaction

- Pass count mapping
- Temperature monitoring
- ICMVs
- Accurate positioning

How Can IC Help with Quality Control?

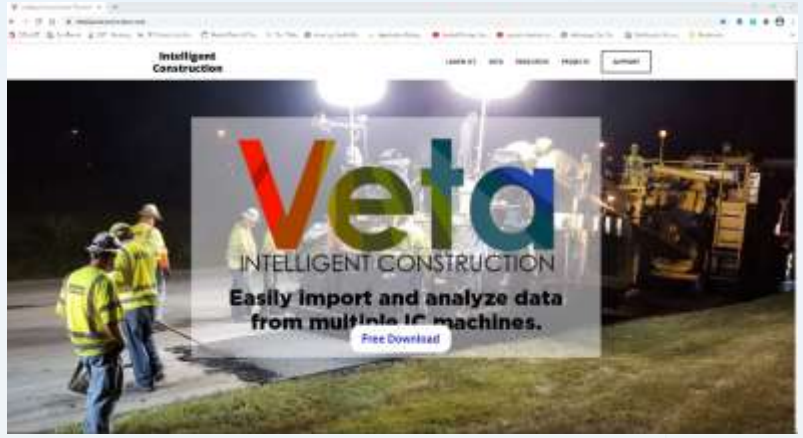
- Consistent pass count ⟶ uniform density (PWL)
- Rolling in temperature zones ⟶ uniform density (PWL)
- Intelligent Compaction Measurement Value (ICMV) ⟶ unproven
- *"Operator-assist"* tool for tracking rolling patterns
  - Vibration on/off
  - Length of roller pass relative to temperature zones
  - Night work
  - Overlap of longitudinal joints
  - Stopping at an angle to the mat, coverage/pattern
  - Identifying soft spots
- Safety - reduced field testing

Why These Technologies?

- Combining IC and Thermal data provides sufficient information to “drill down”, isolate and solve quality and efficiency problems anywhere in the paving process

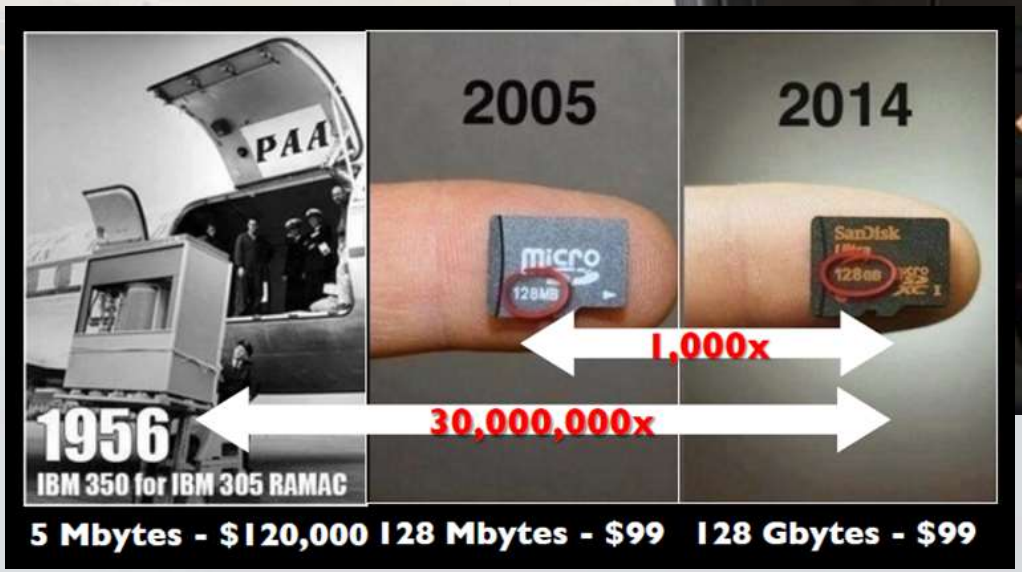
Why Now?

- Wireless data coverage expanding



- Wireless data transfer enables near real-time information

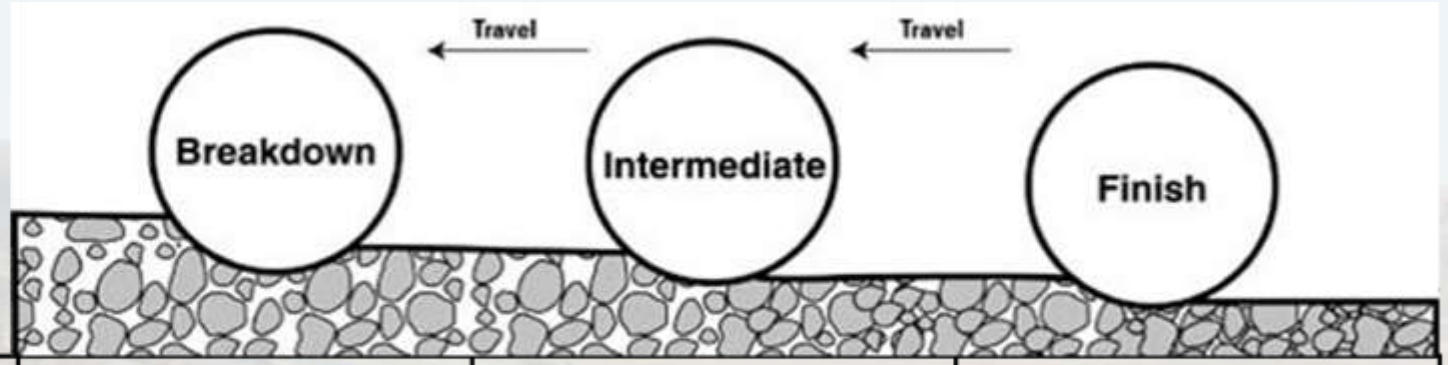
- Technology is becoming less expensive & easier to use (CANBus on equipment)



- Veta analysis software is universal

Examples of Using Thermal & IC for QC

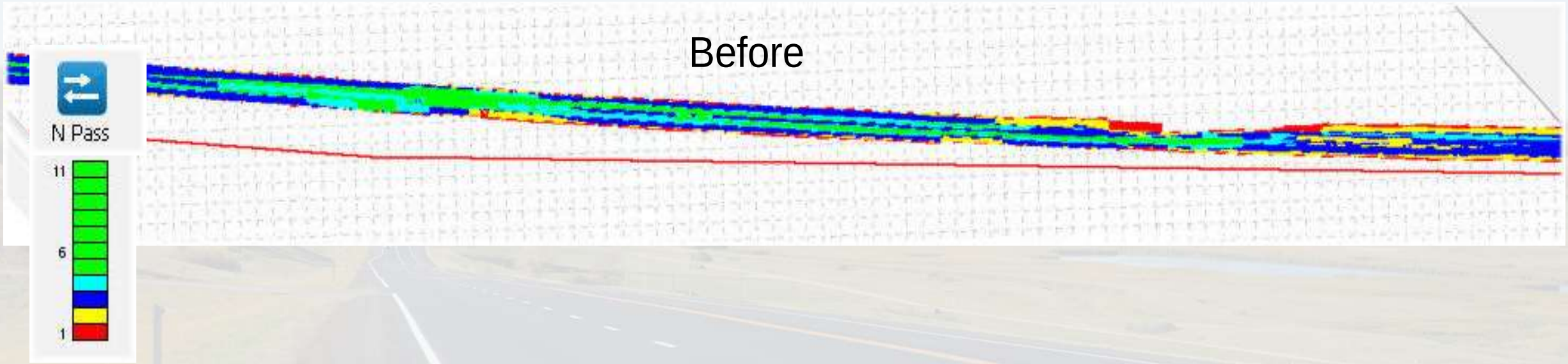
IC: Example of a Rolling Pattern

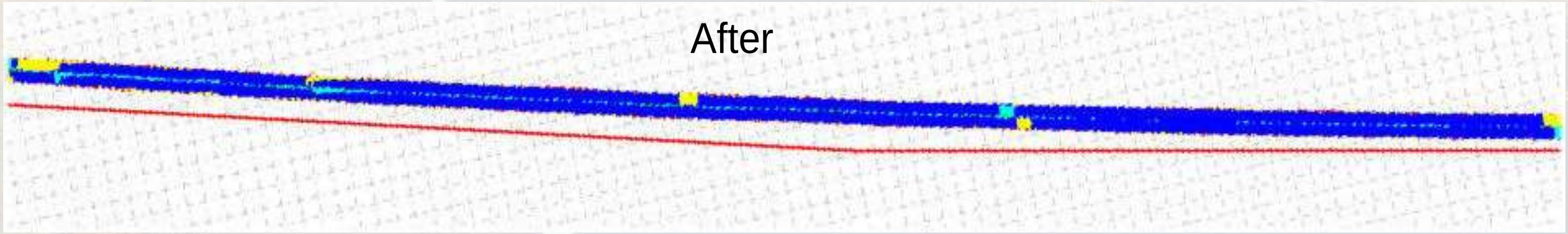


%TMD	90-92%	92-94%	94+ %
			
Temp	300-260˚F	260-200˚F	200-160˚F
Coverage	3	2	2 (1 vibe, 1 static)
Settings	High A, Low F	90 psi	Low A, static
	126 feet	200 feet	200 feet

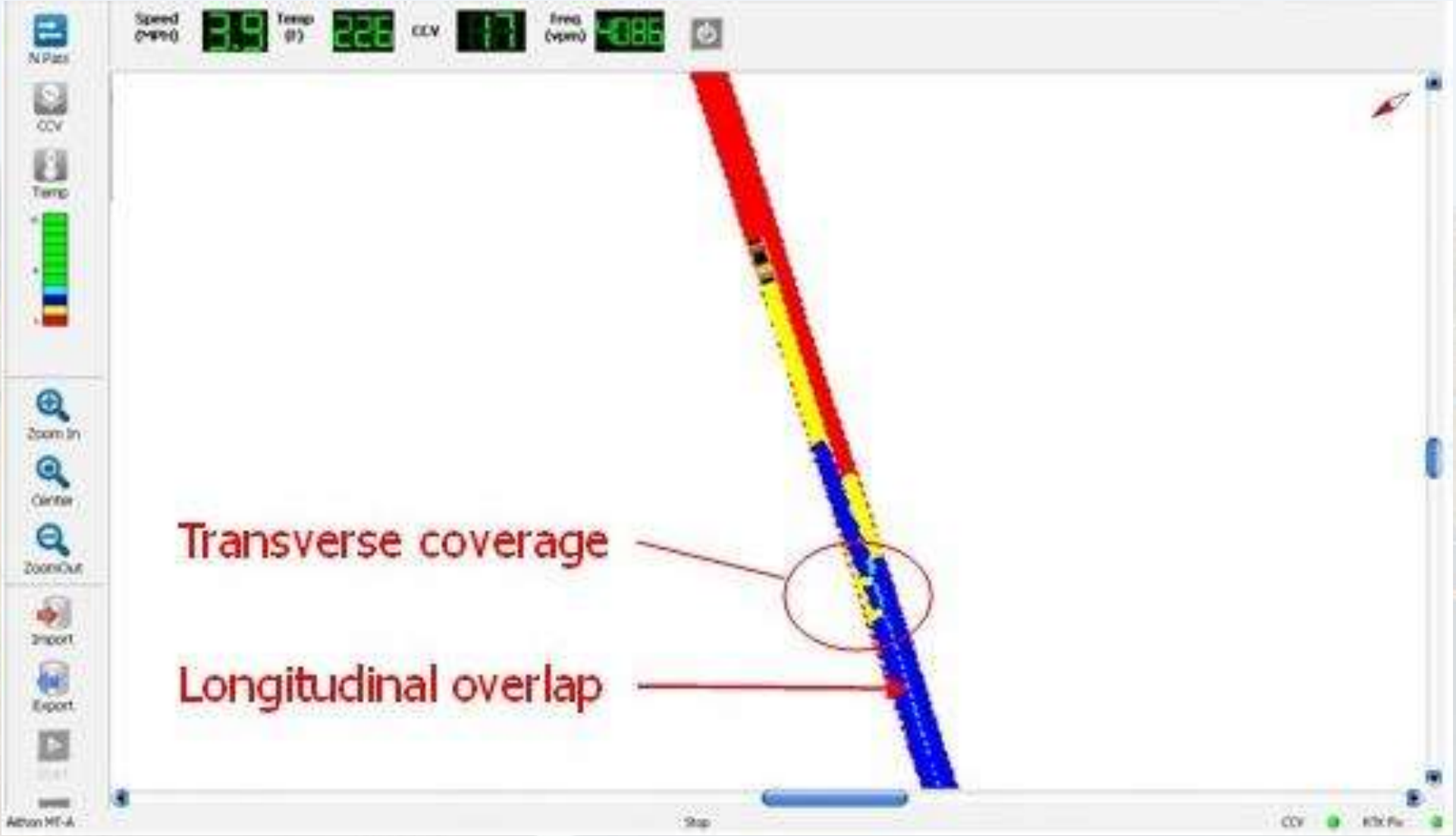
- Stay in established temperature zones
- Keep track pass counts
- Avoid Tender Zones
- Identify & troubleshoot “cold” mix
- Avoid “soft spots”
- See joint overlap

Before & After – Pass Count Consistency!!

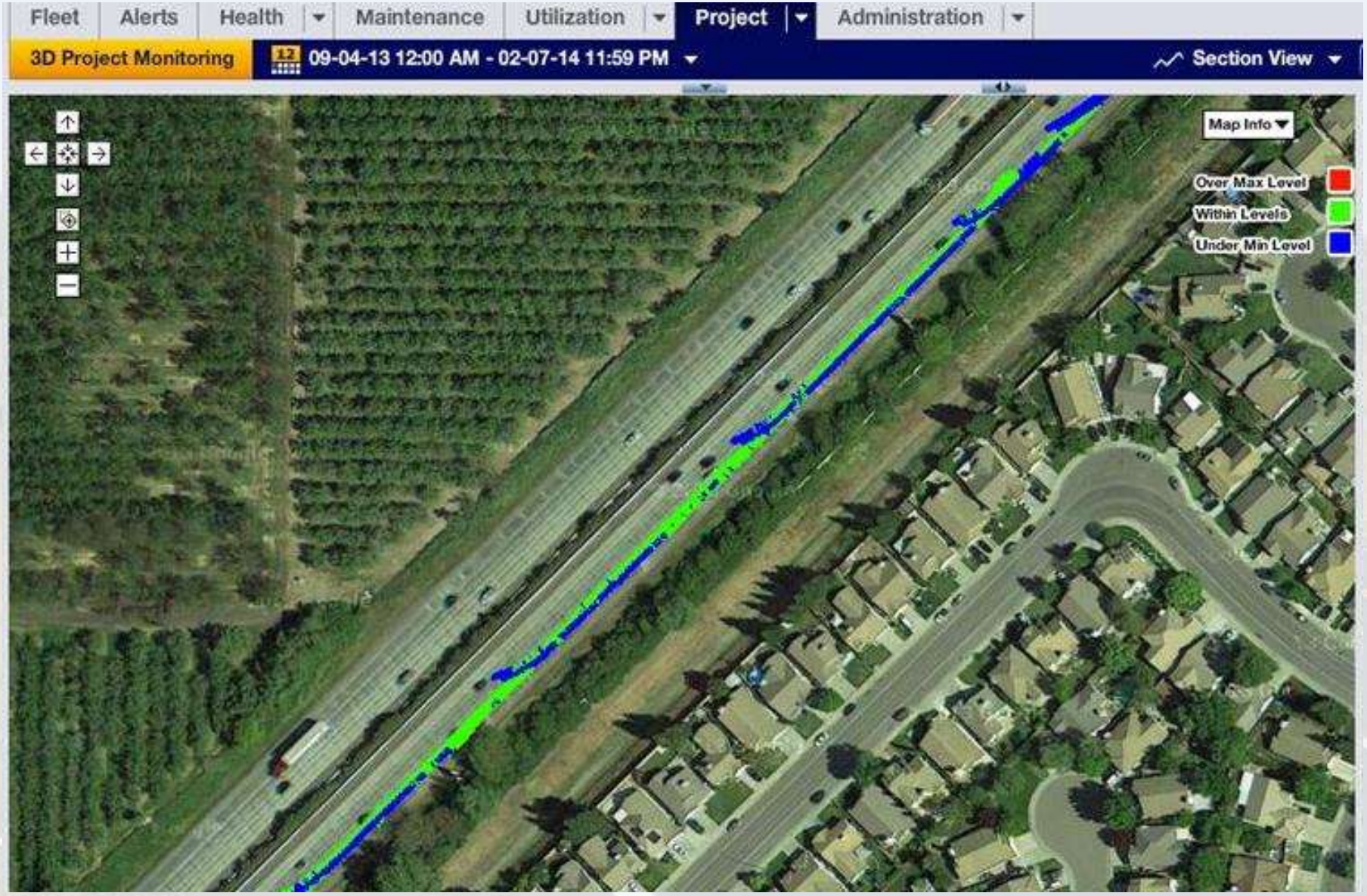




Transition zones, longitudinal joints

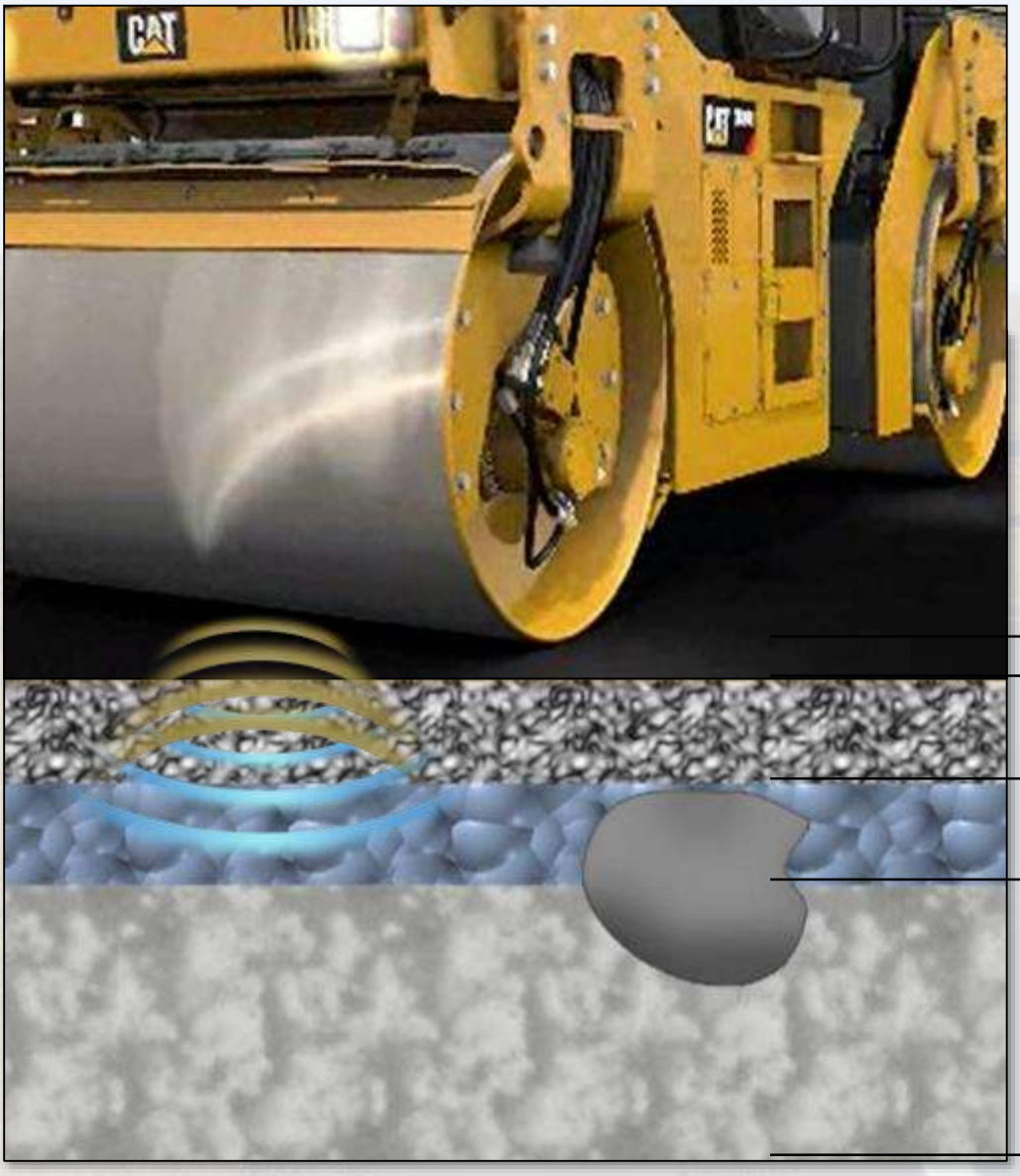


Temperature Challenges



Process control opportunity – you don't know what you don't know!!

Accelerometer measures deep…



- Accelerometer technology measures deeper than the freshly paved lift of asphalt
- CMV value is a *composite* measurement
- Affected by amplitude, speed, direction, etc.

ICMV (accelerometer value) – find soft spots / slabs

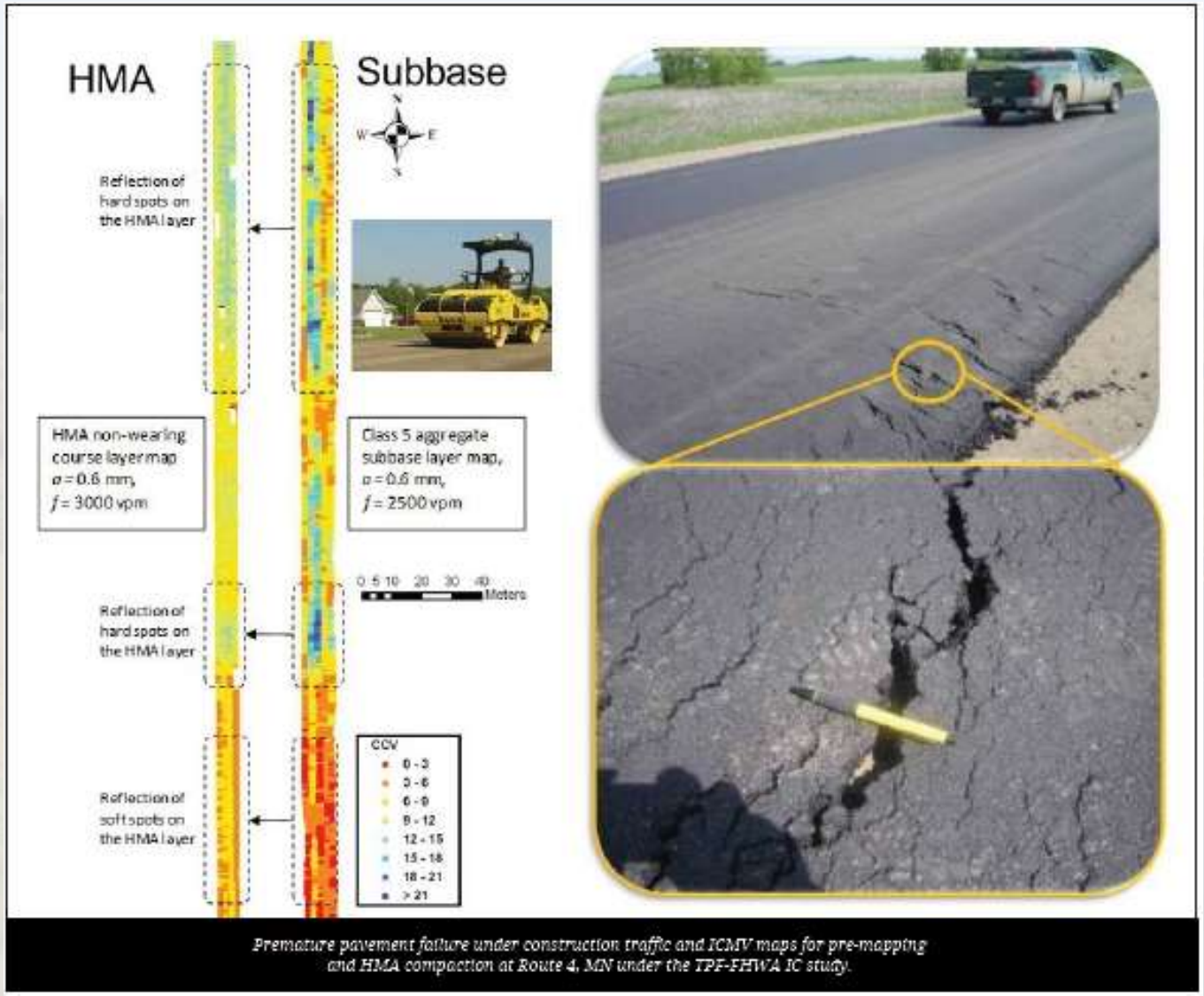
PCC Joints

Soft base

Pre-mapping to find soft areas

- Can be done in one pass
- ICMVs obtained to identify relative weak areas prior to paving
- Depth and extent of “soft spot” is difficult to identify

Pre-Mapping in MN



Premature pavement failure under construction traffic and ICMV maps for pre-mapping and HMA compaction at Route 4, MN under the TPF-FHWA IC study.

TECHNICAL BRIEF

U.S. Department of Transportation
Federal Highway Administration

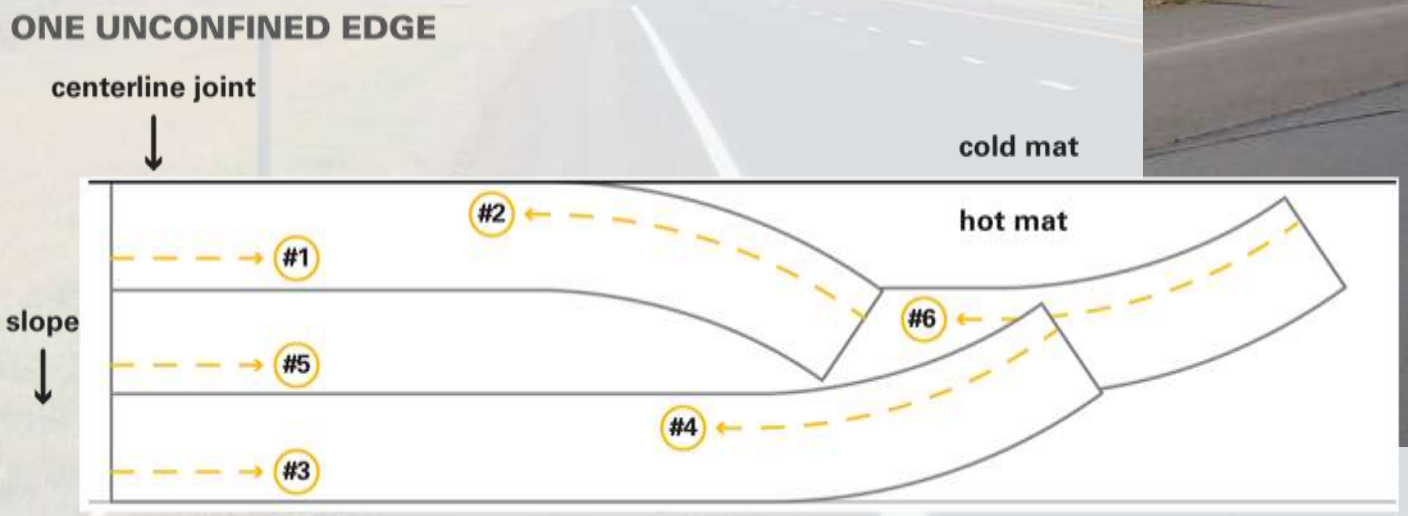
DEFINITION OF PRE-MAPPING

INTELLIGENT COMPACTION FOR PRE-MAPPING

TECHNICAL BRIEF

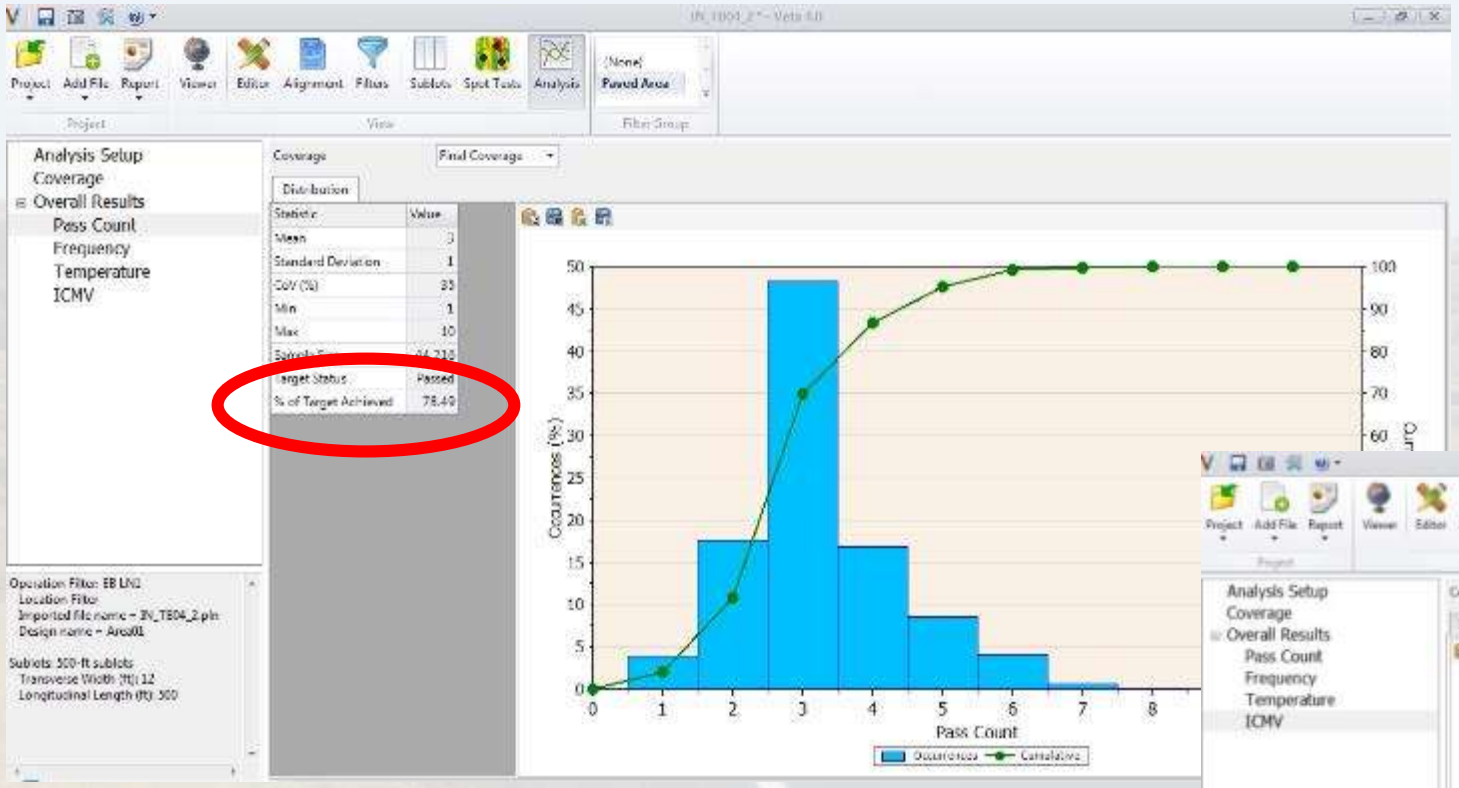
BACKGROUND

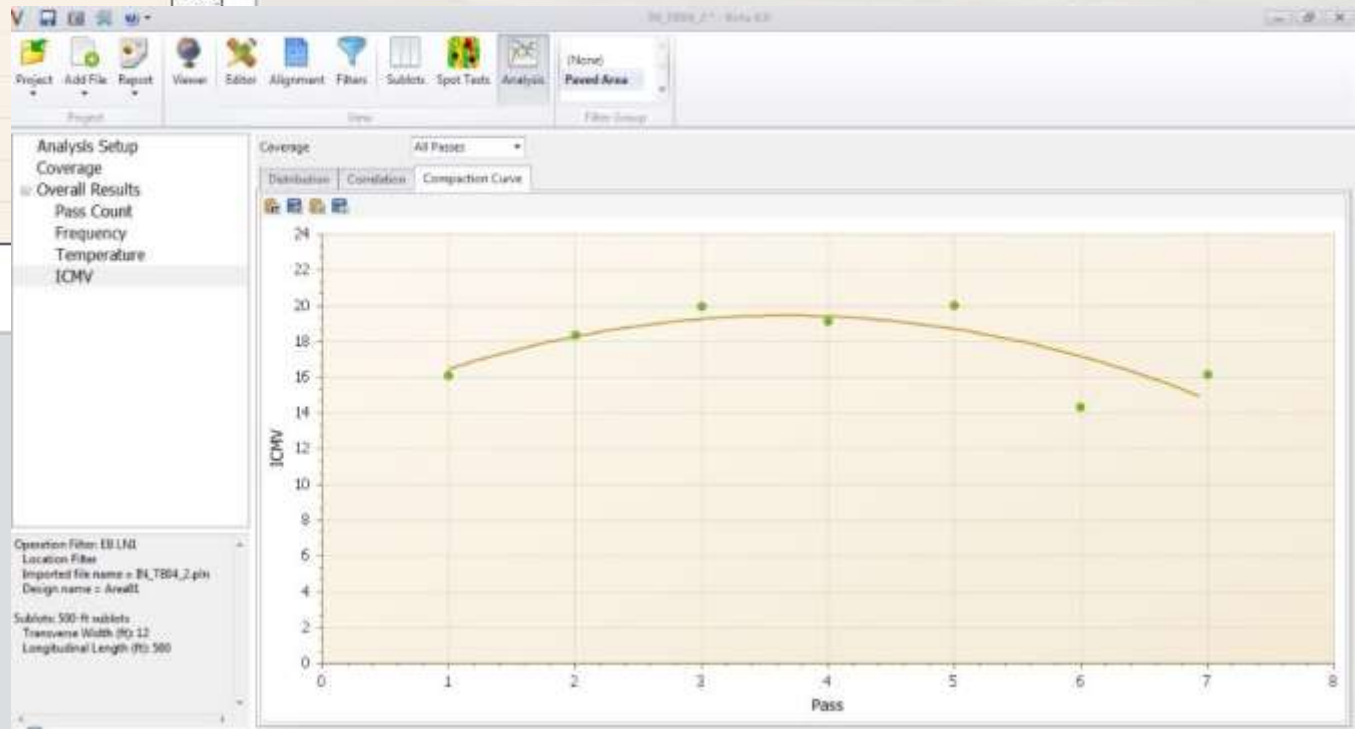
Rolling Pattern Training Tool



Roller Speed should be 10 - 14 ipf

Using VETA to Manage Pass Count & ICMV

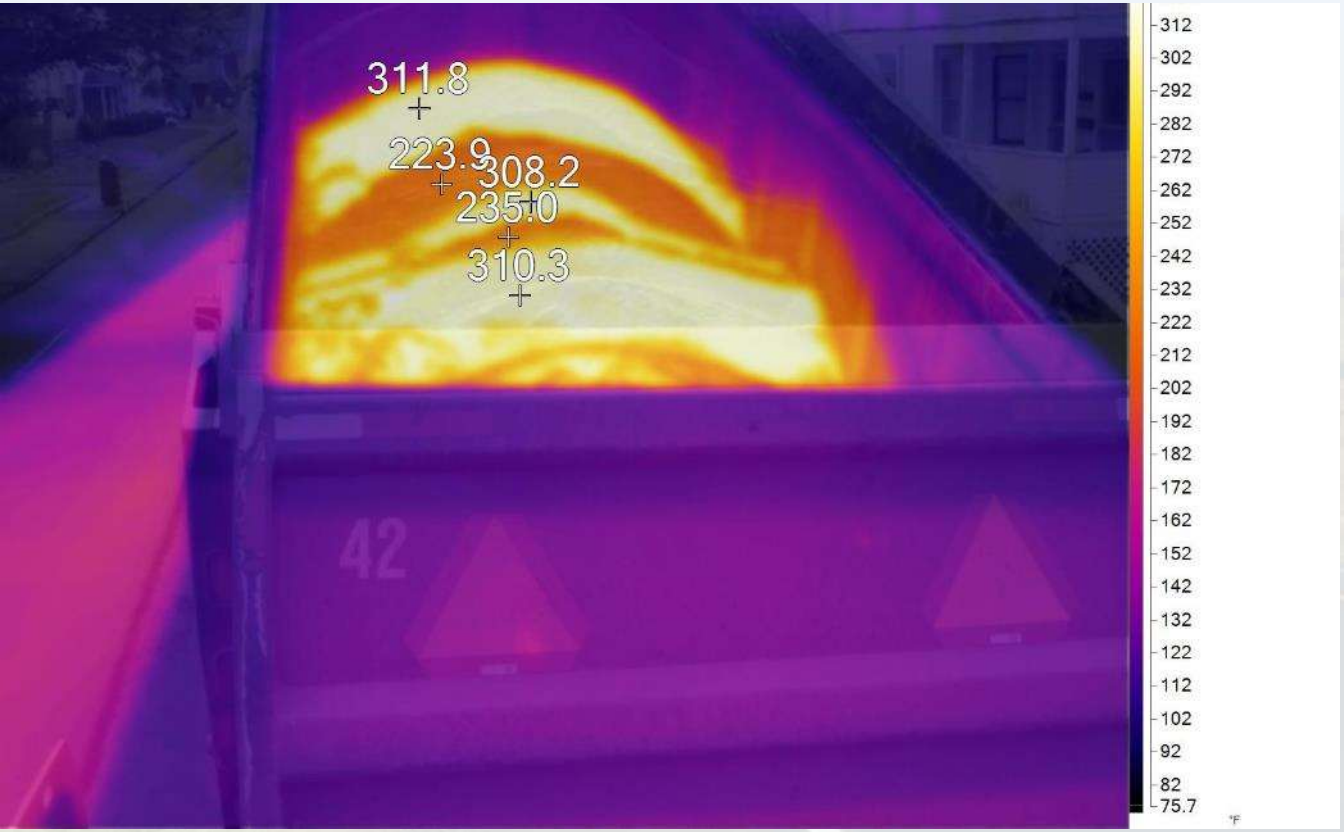




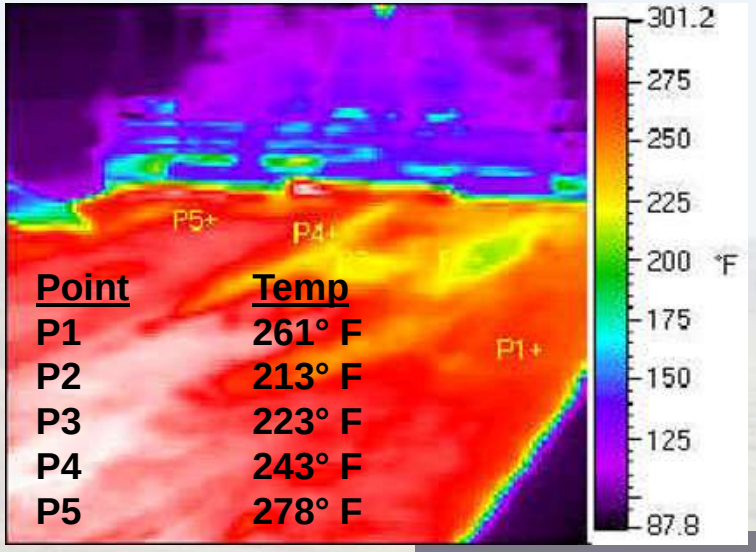
Thermal Patterns: What do they Mean?

- What temperature pattern am I seeing?
- What is this pattern telling me?
- What can I do to reduce temperature differentials?

Truck loadout



End dumping 4-Step Procedure

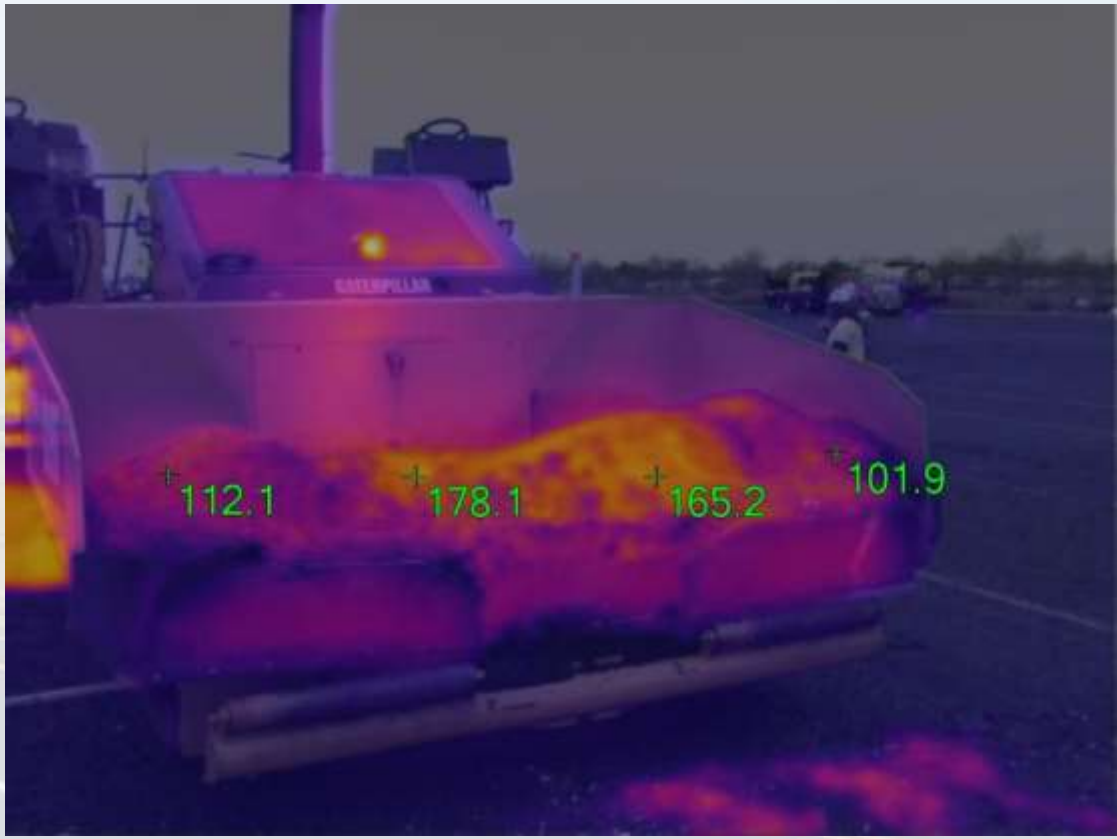


1. Pave at normal speed between trucks
2. Fold hopper wings every truck when allowed
3. Never pave out material in hopper
4. Cycle hopper wings when conveyors are still covered with mix

Segregation – End-of-load – Segregation in Hopper

- Large aggregate accumulates at sides of hopper
- Folding hopper wings
- Keep conveyors full during truck exchange

Paver Stop – hopper level

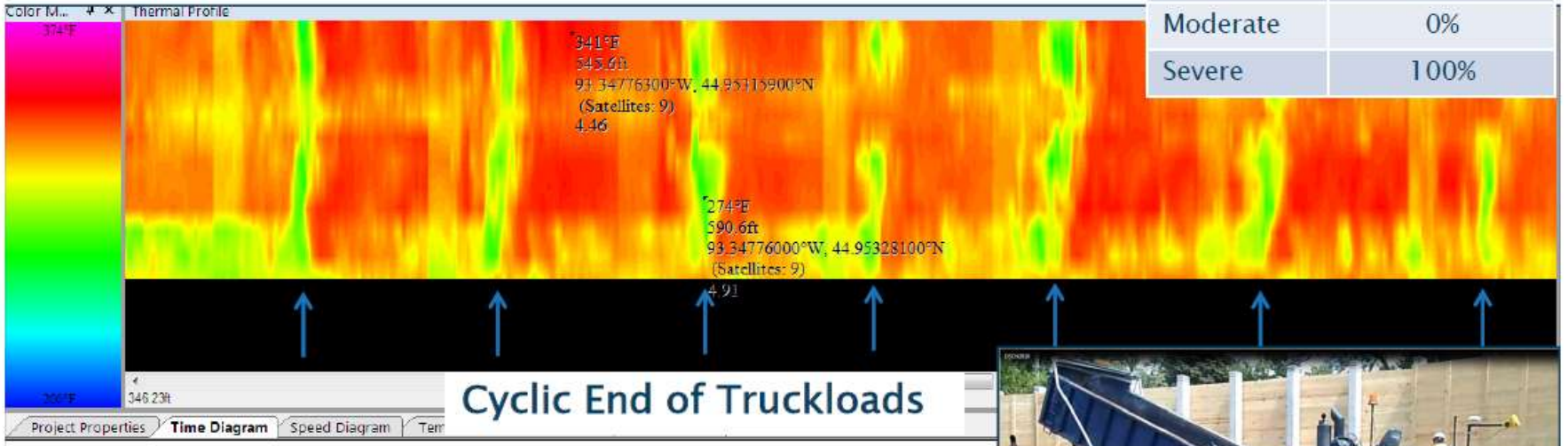


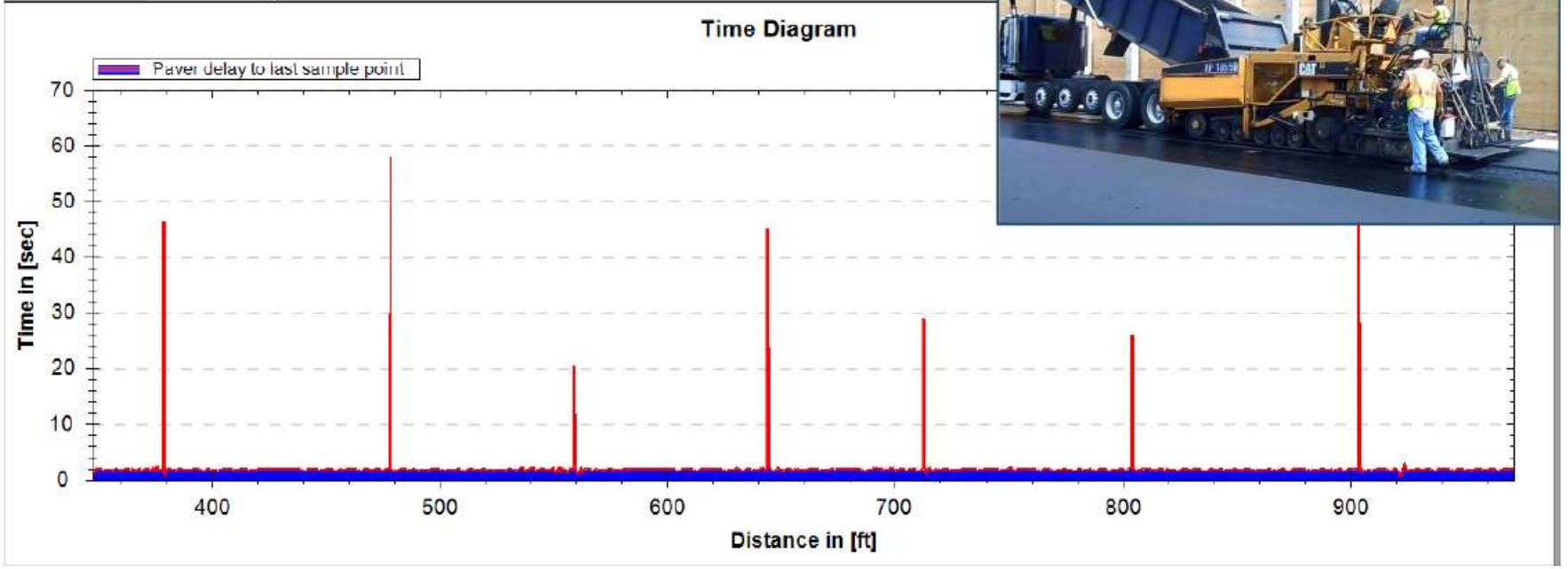
End dumping

Thermal Segregation – End Dump

Project C

Thermal Segregation Category	Percent of Sublots
Low	0%
Moderate	0%
Severe	100%





Courtesy of MnDOT

Silo Management

Hot on one side?

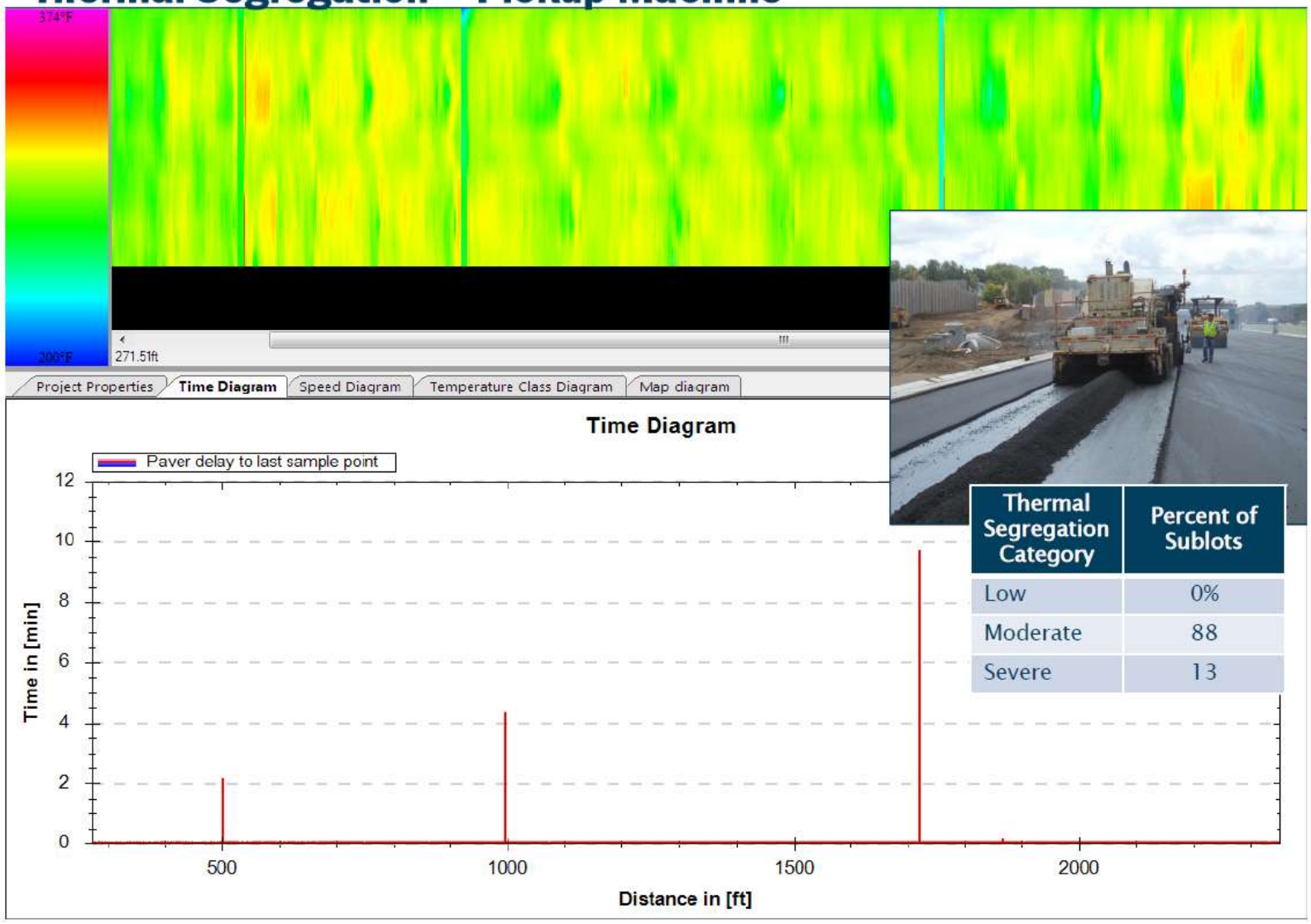
Plant Loadout

Plants

Pickup Machine (windrow elevator)

Project C (Cont.)

Thermal Segregation – Pickup Machine



Thermal Segregation Category	Percent of Sublots
Low	0%
Moderate	88
Severe	13

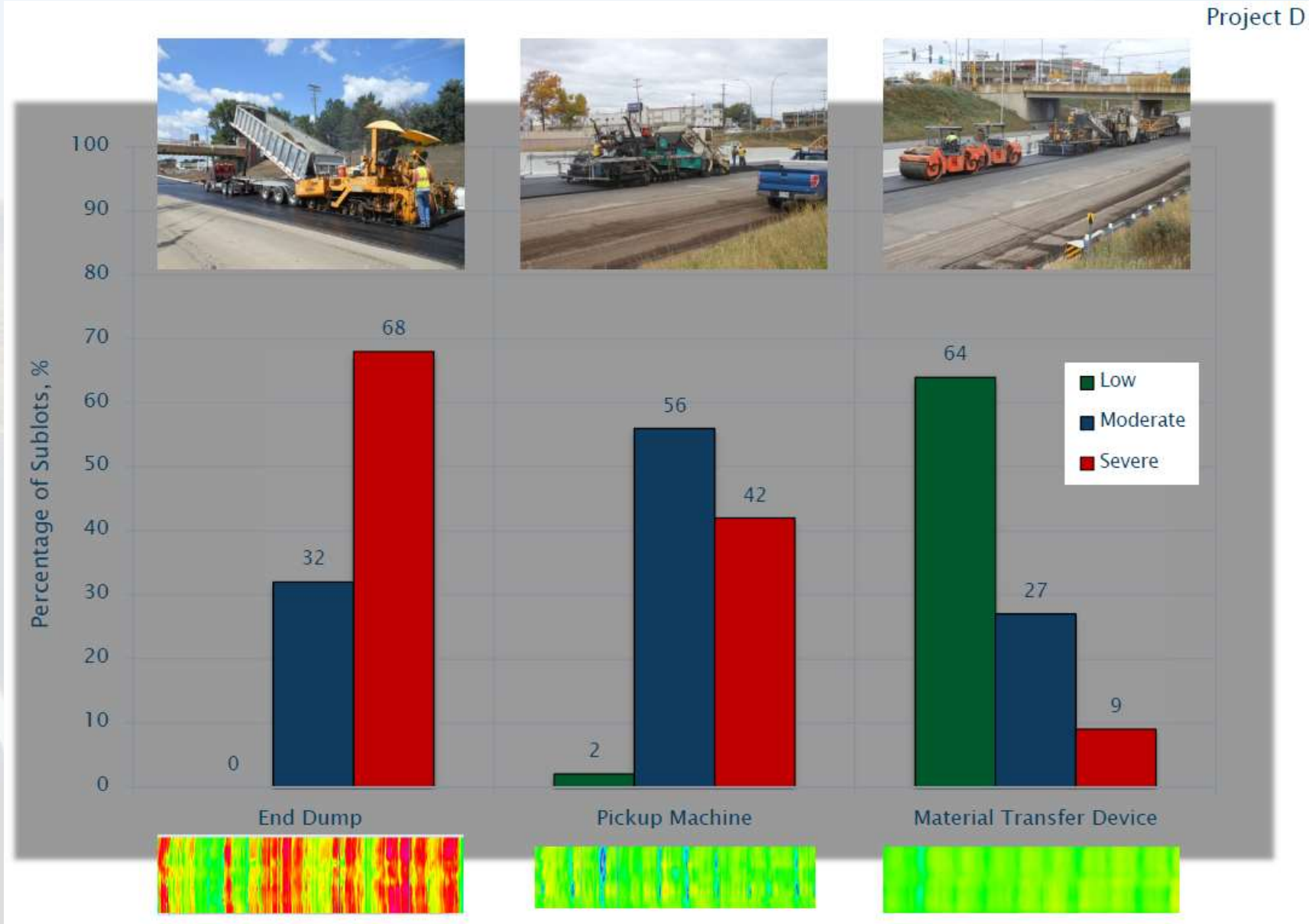
Courtesy of MnDOT

Keep windrows short

- Temperature!
- Good dump person is key!

Overlap windrows

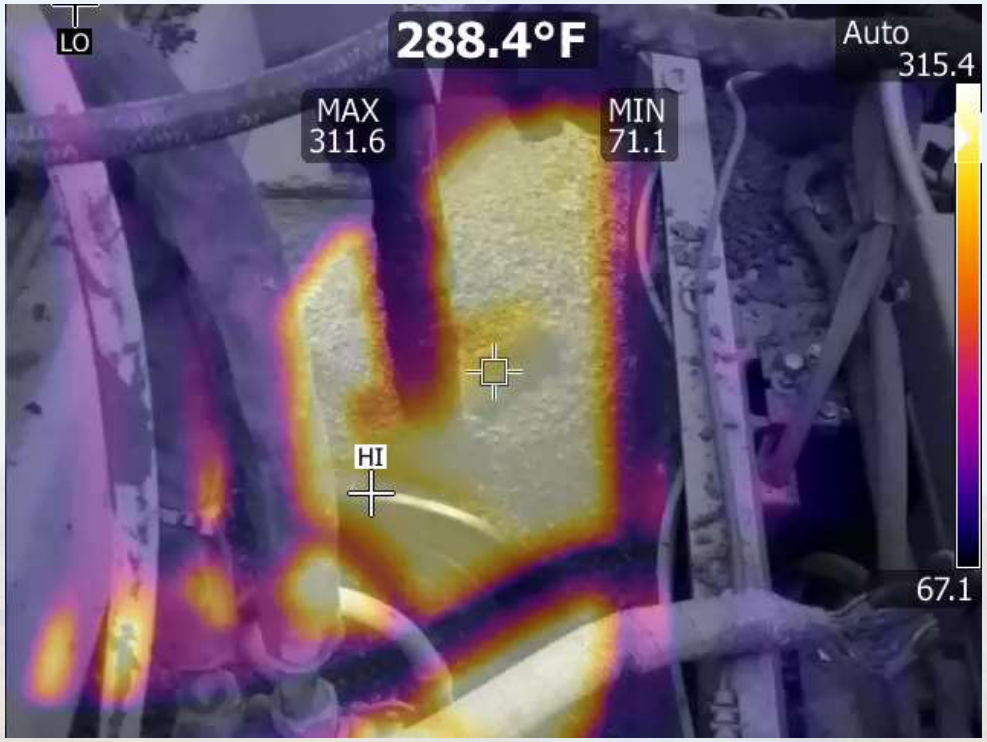
Material Transfer Device



Courtesy of MnDOT

Auger Speed

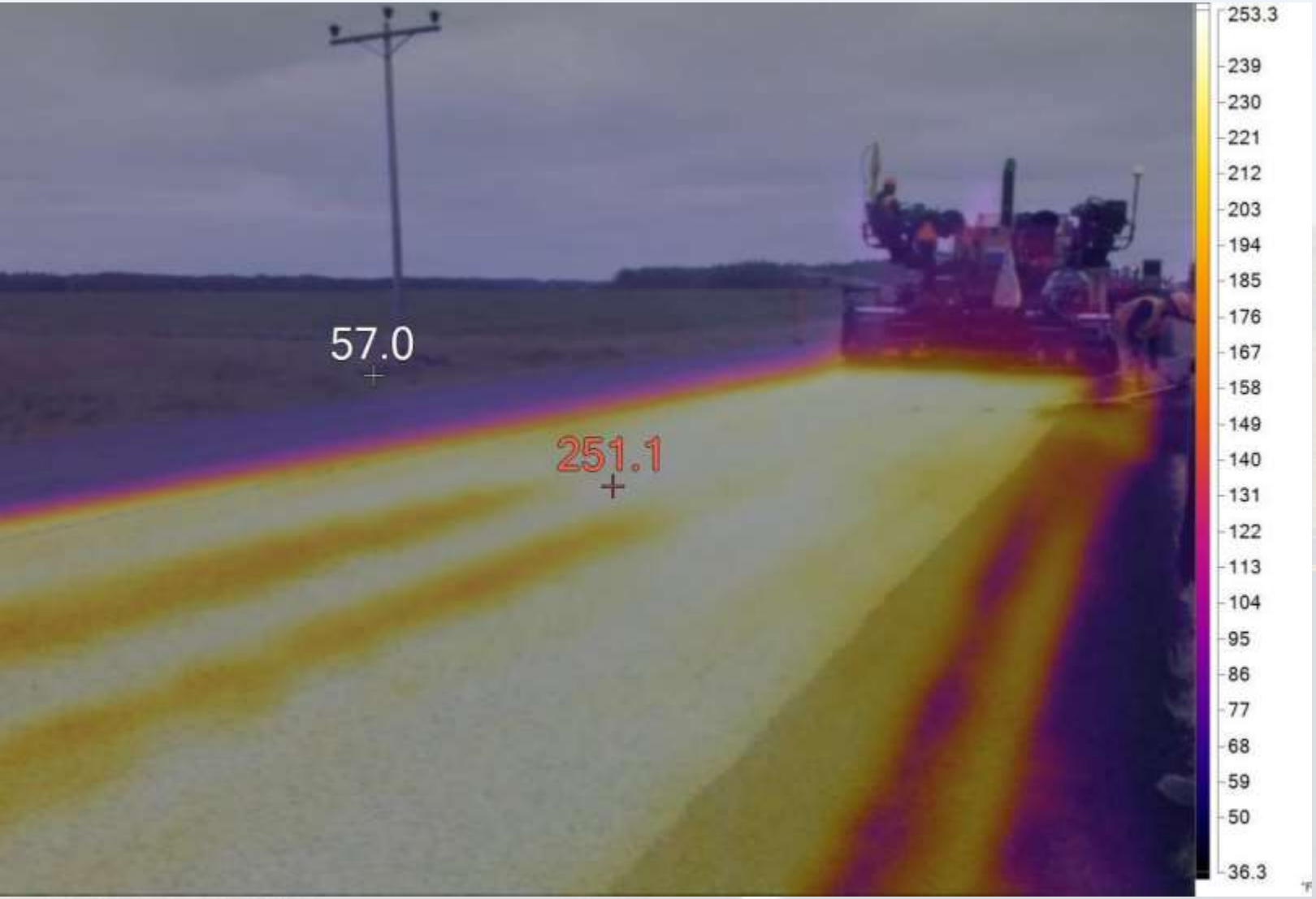

272.0
262
252
242
232
222
212
202
192
182
172
162
152
142
132
122
112
102
92
82
72
62
52
42
32
22.7
249.8
266.0
249.8
246.6
263.5


LO
288.4°F
Auto
315.4
MAX
311.6
MIN
71.1
HI
67.1

Auger Height

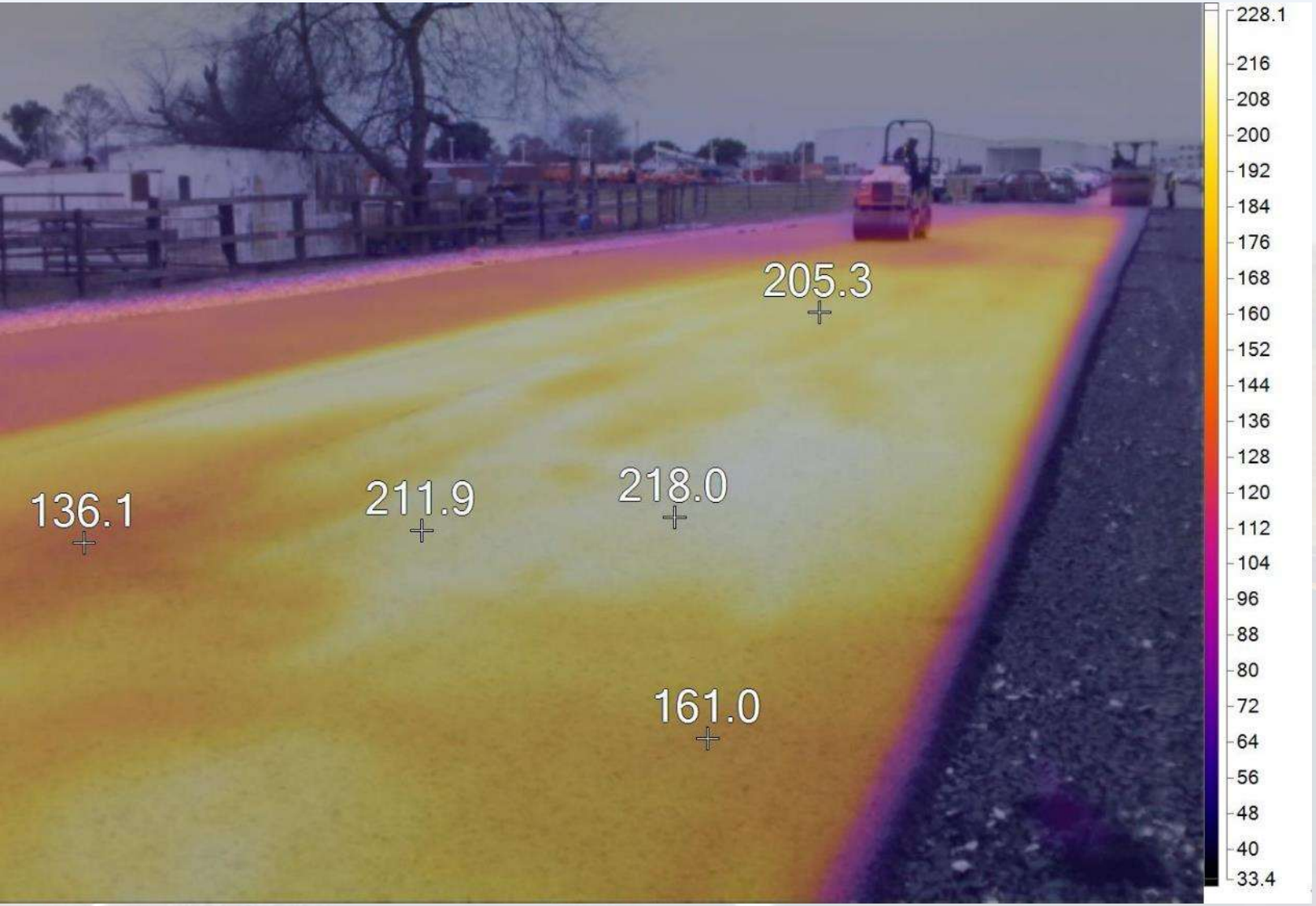
Slight change in auger height can change surface texture and thus temperature

Conveyor Speed



- Streaks after take off could be conveyor speed
- Low hopper and feed system starts quickly, then slows

Feeds Sensor position - on/off augers



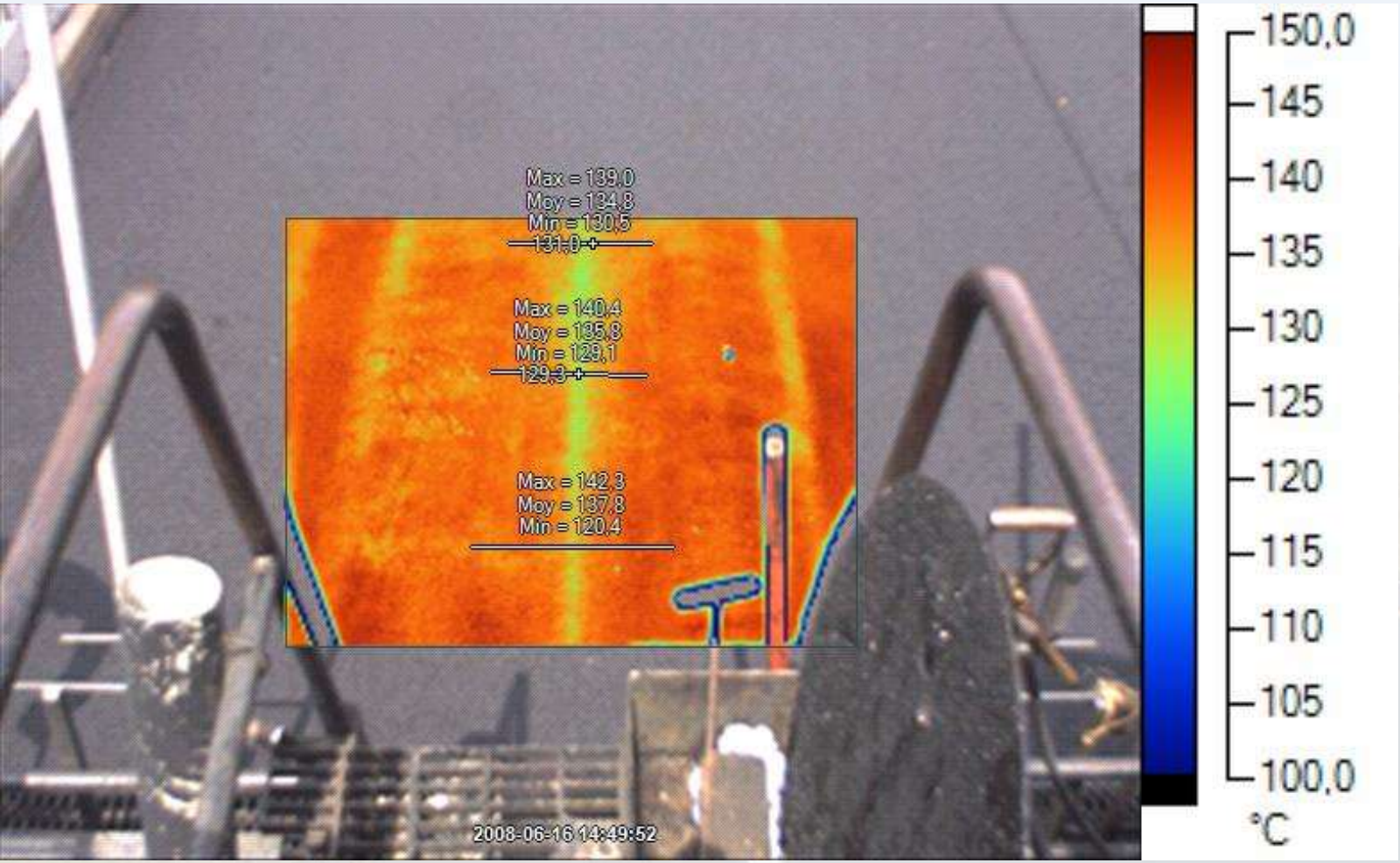
- Feed sensor position (aim) causing augers to go on/off

Aiming Sonic Feed Sensors

- Mechanical or sonic
- Control level of material
- Position Sensor 18" from end of augers

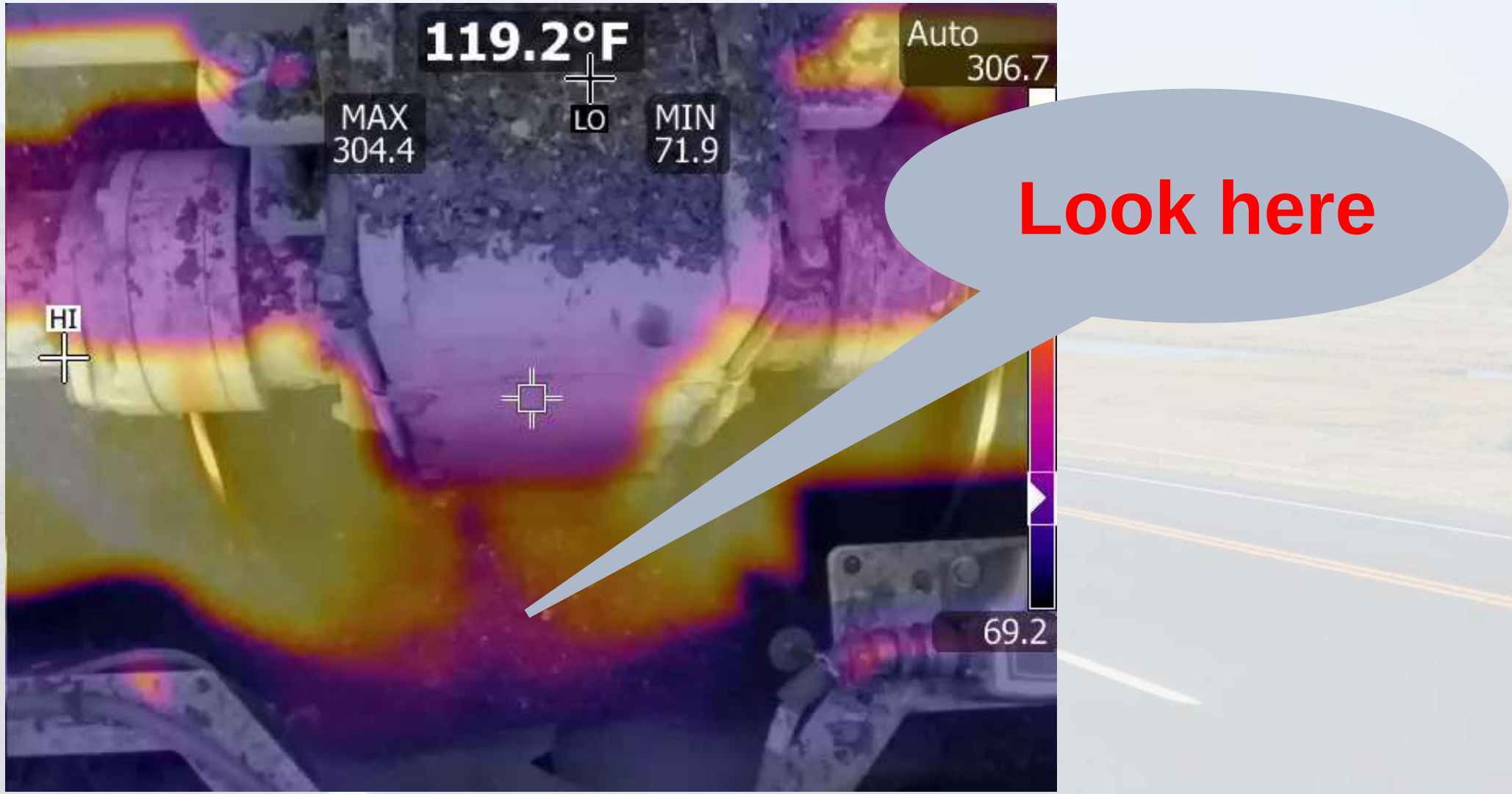
Centerline streak

Centerline streaks

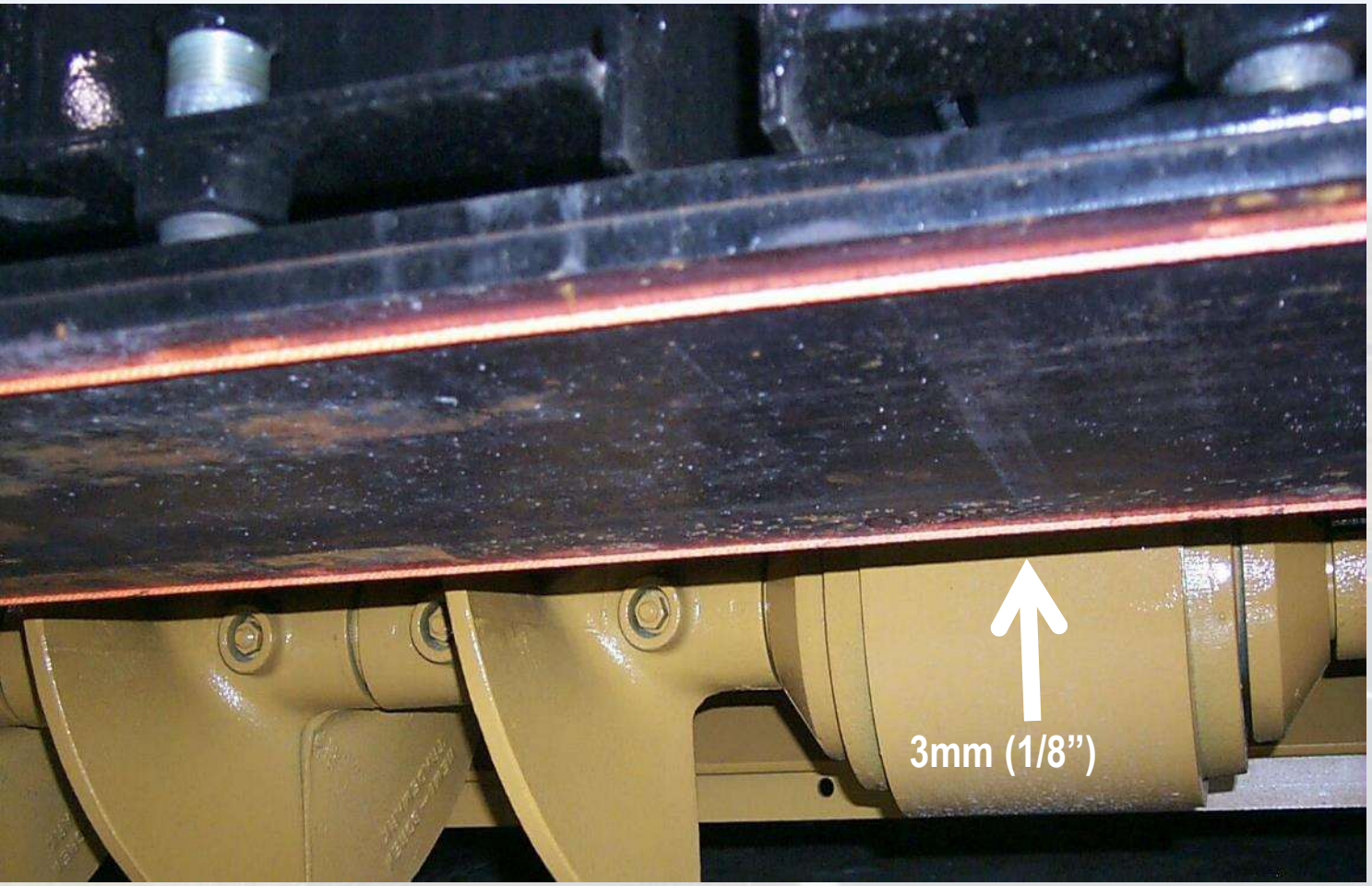


- Lead crown installed?
- Worn deflector plate(s)
- Reversing auger(s)
  - Do you have them?
  - Are they installed correctly?

Dead material on deflector plate

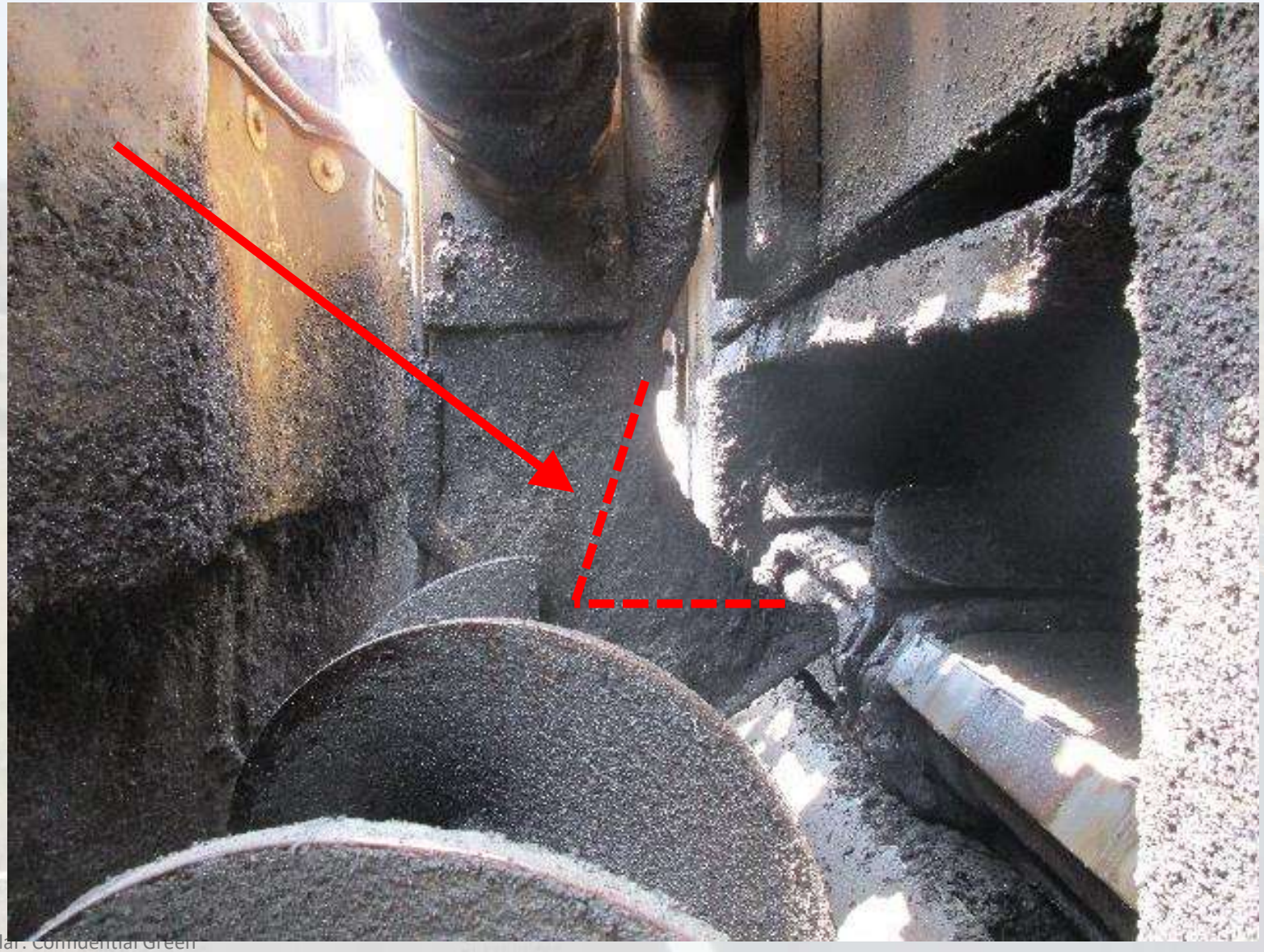


Centerline streak – Lead Crown



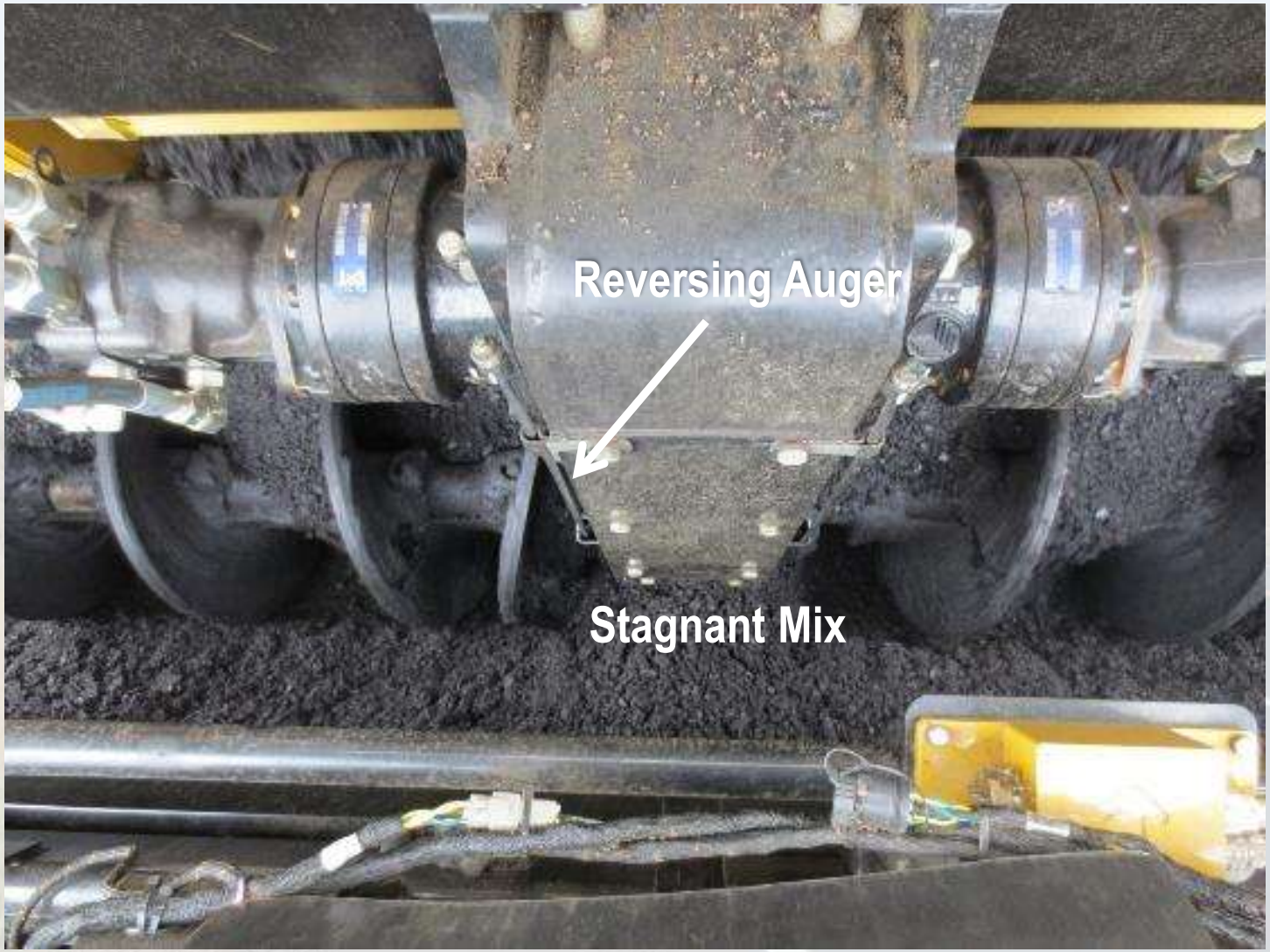
- Place stringline on front and rear of main screed.
- Adjust main screed crown until 3mm (1/8”) gap is present in center of main screed
- Helps large aggregate tuck under center of screed plate

Keep deflector plates clean

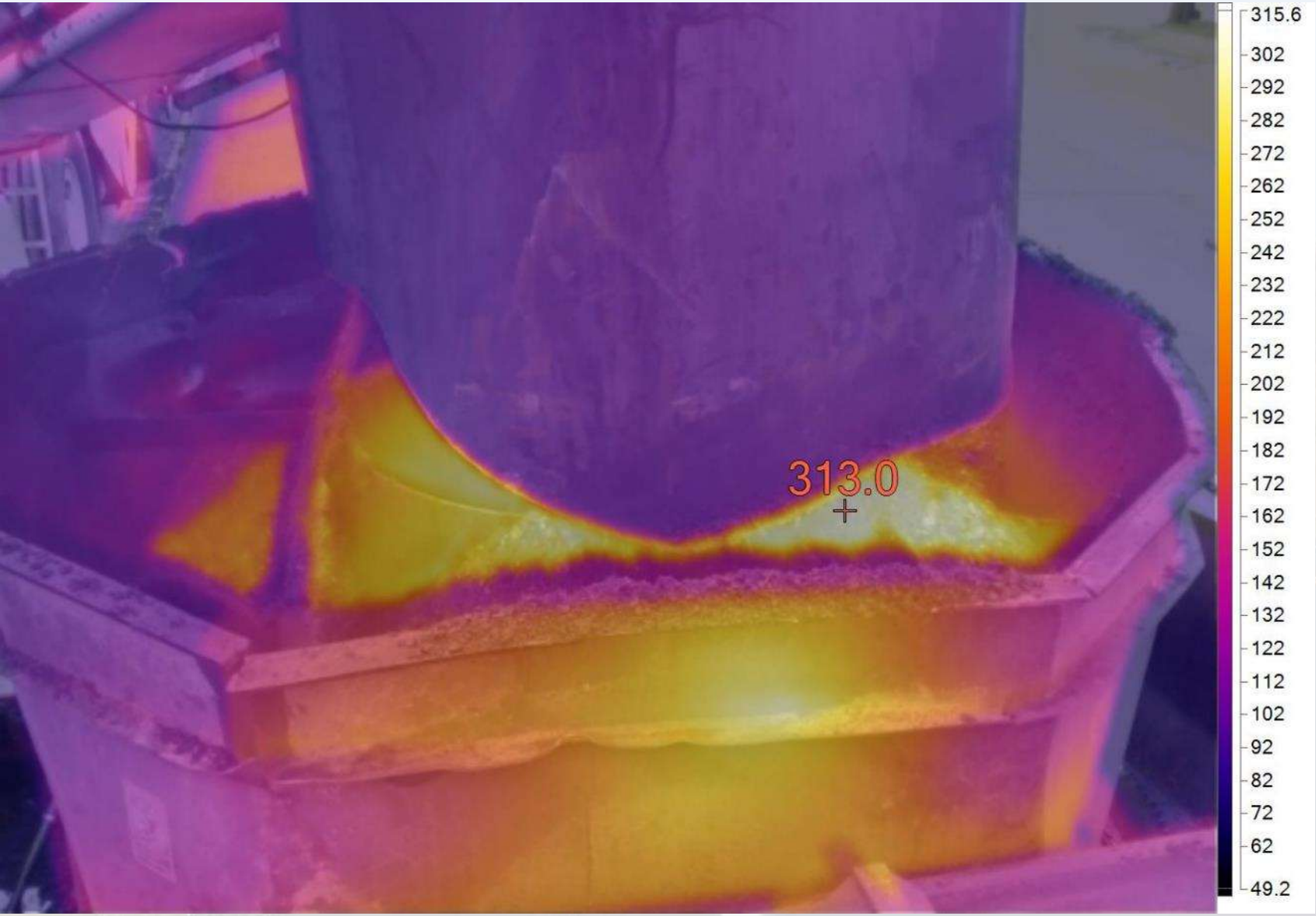


- Wear item to be replaced
- Needs daily cleaning
- Knock down with shovel handle
- Centerline streak

Reversing Augers

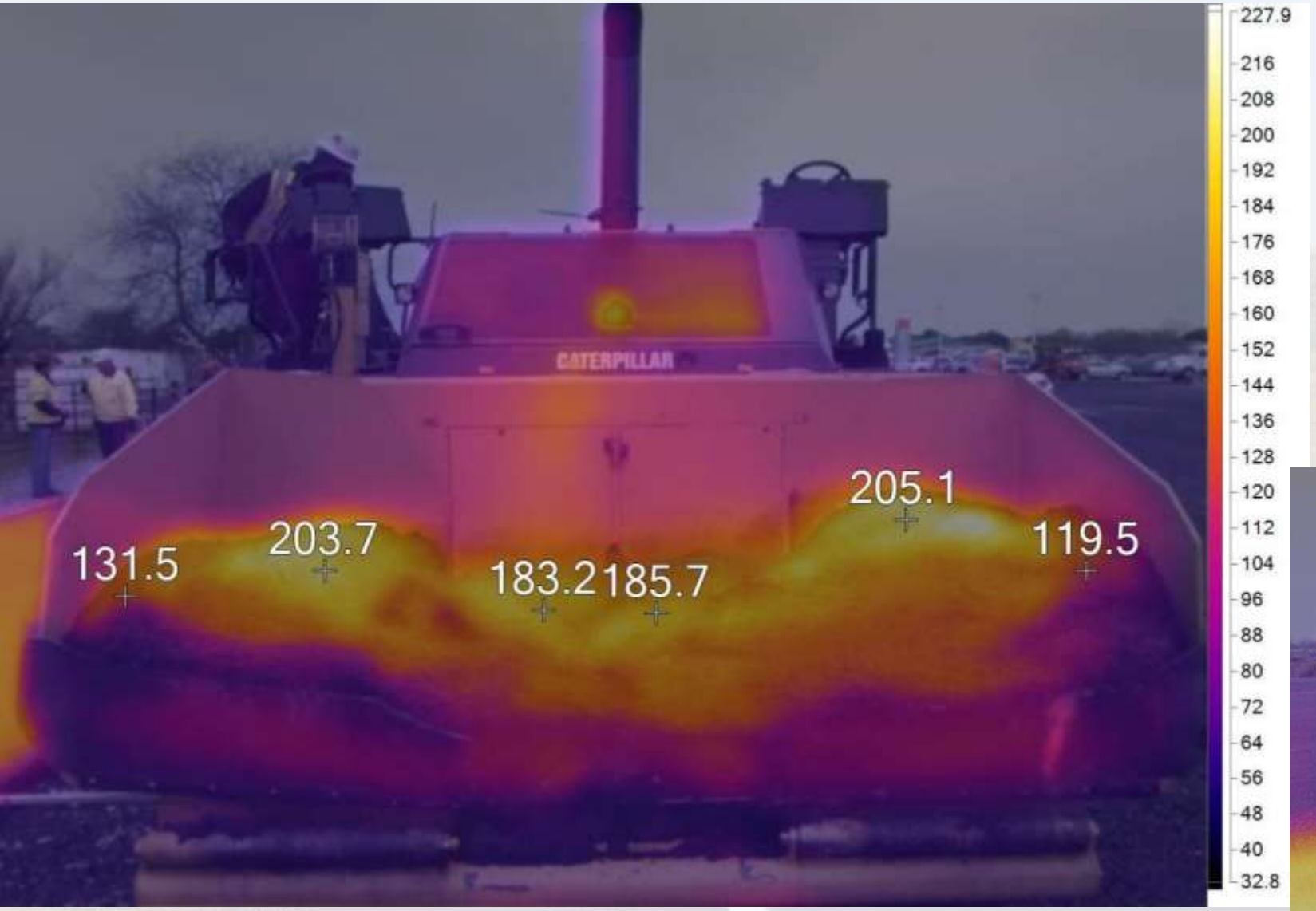


Hopper Inserts



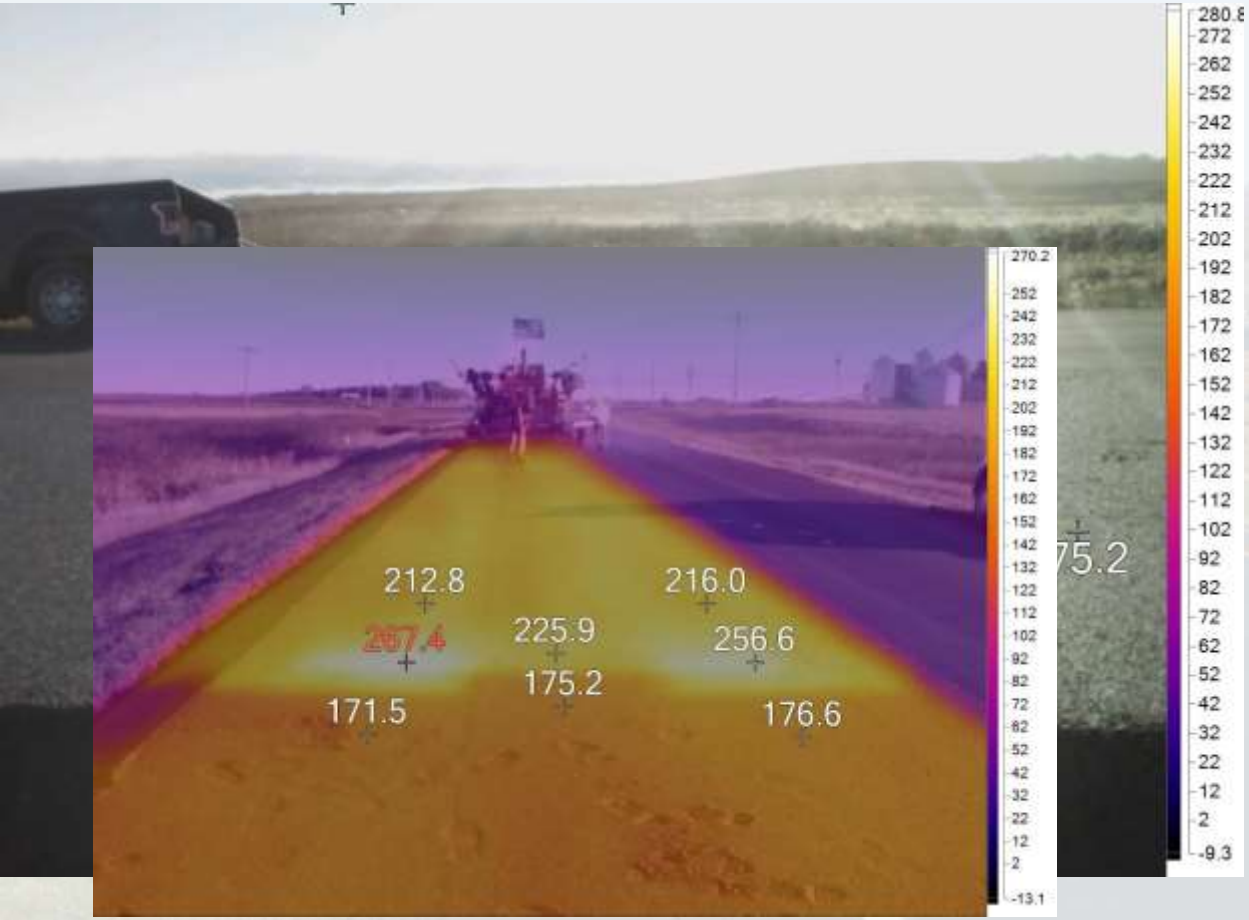
- Various designs/modification to hopper inserts
- Can change configuration if needed
- Drop height

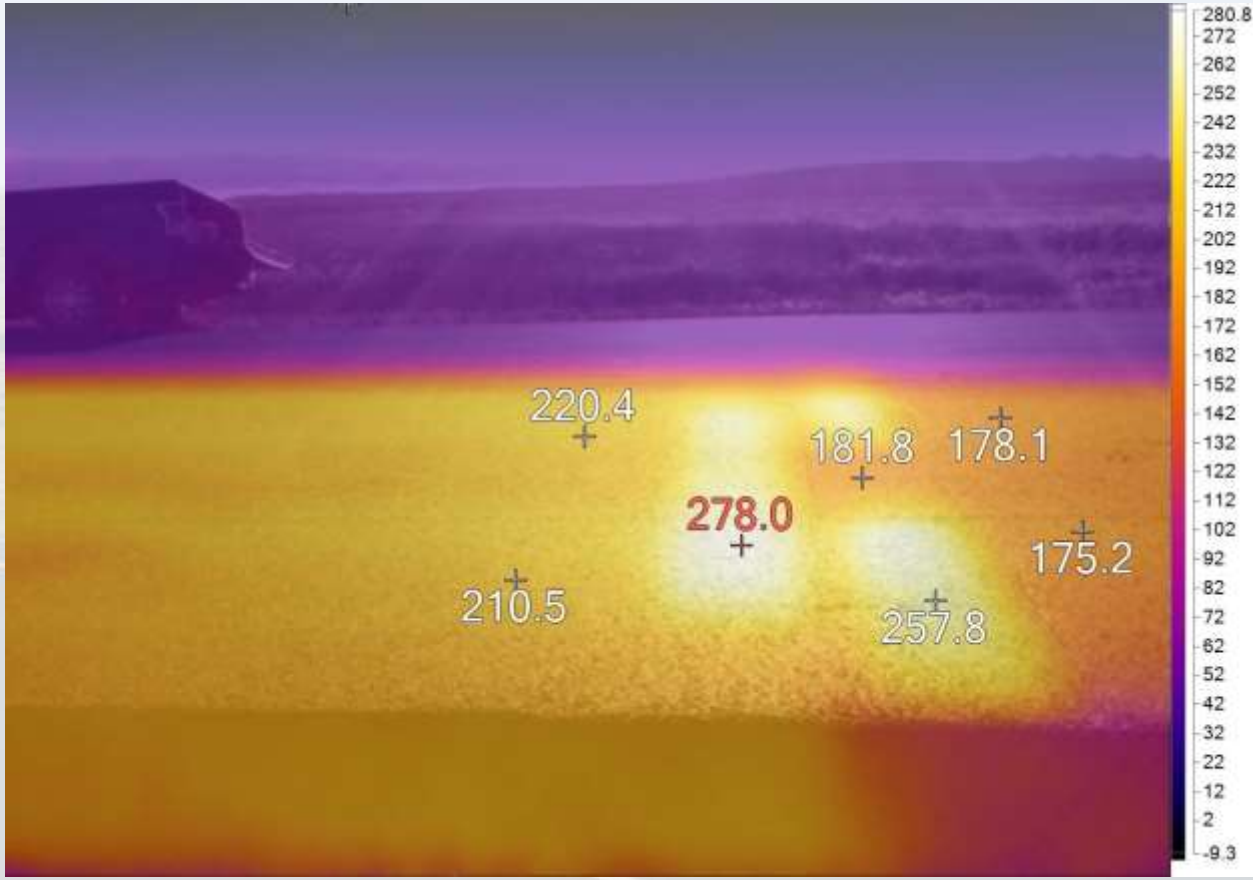
Head of Material



- Low hopper can lead to low head of material

Paver Stop – screed settlement



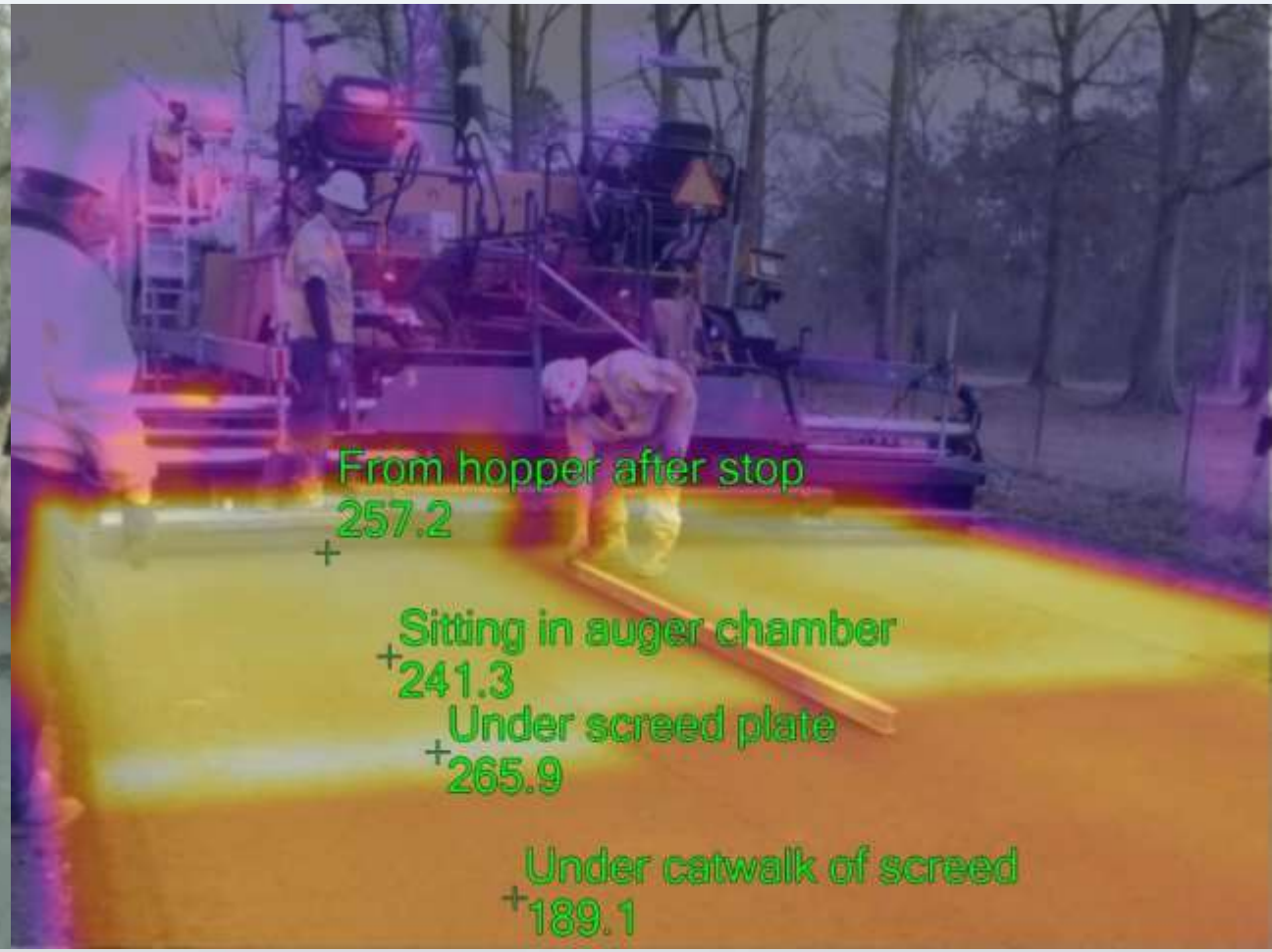


Same photo!

Paver Stop – correlate with IRI ? Minutes ?

Same photo!

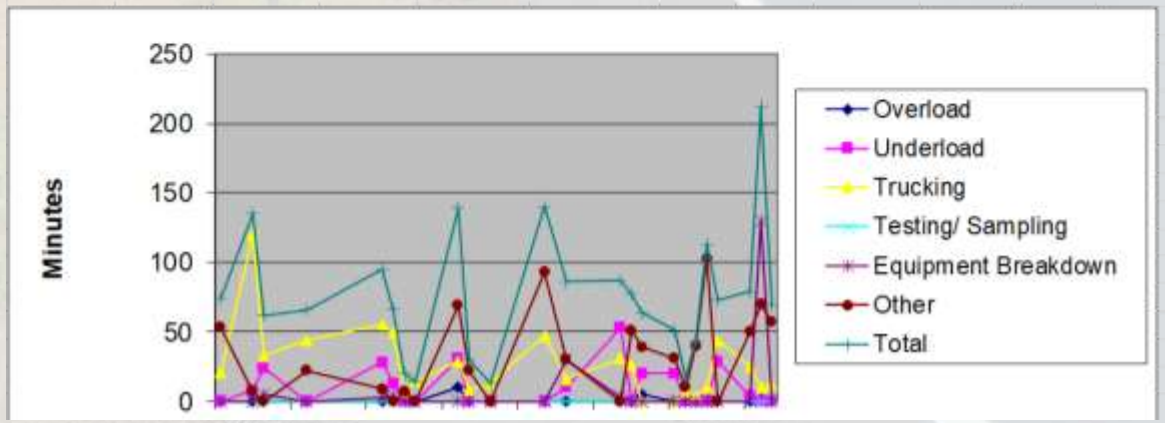
Effects of paver stops…



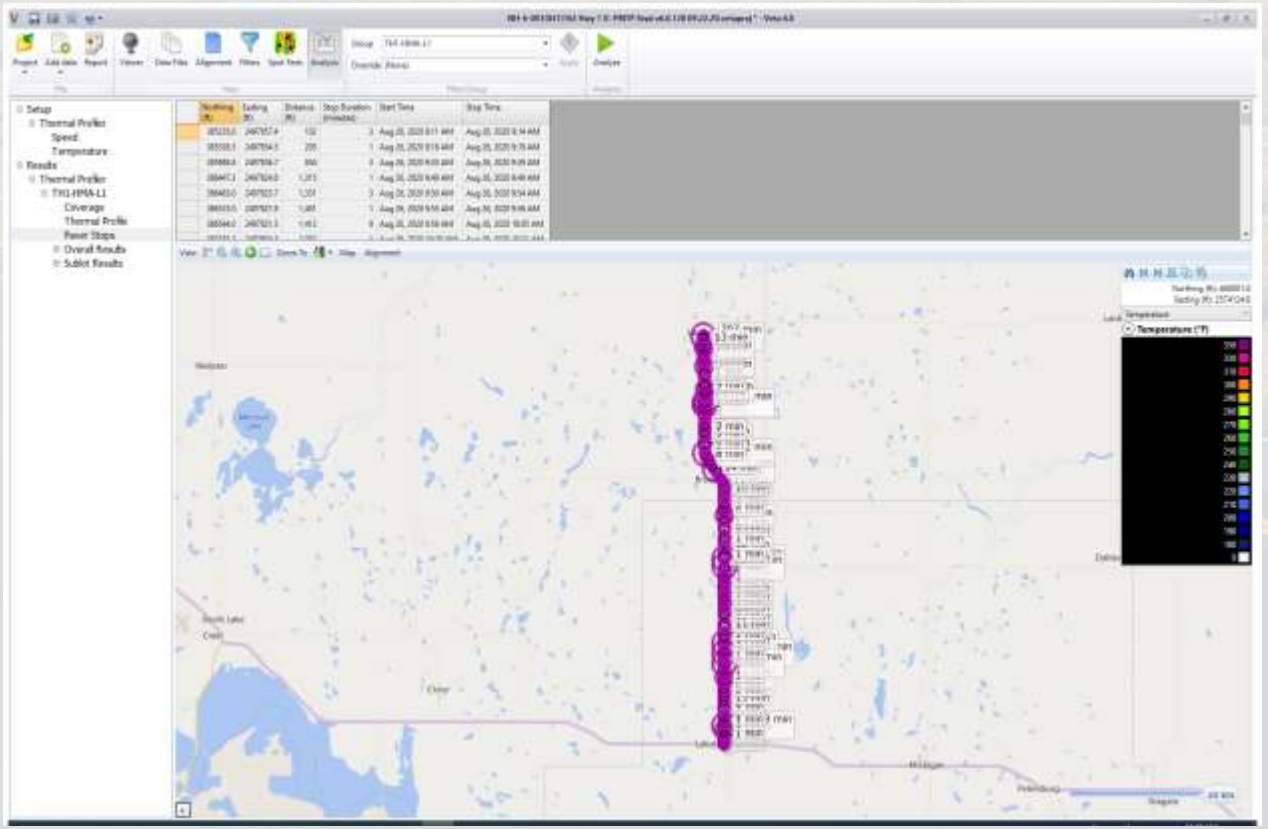
Paver Stop report – lost time

Job 783

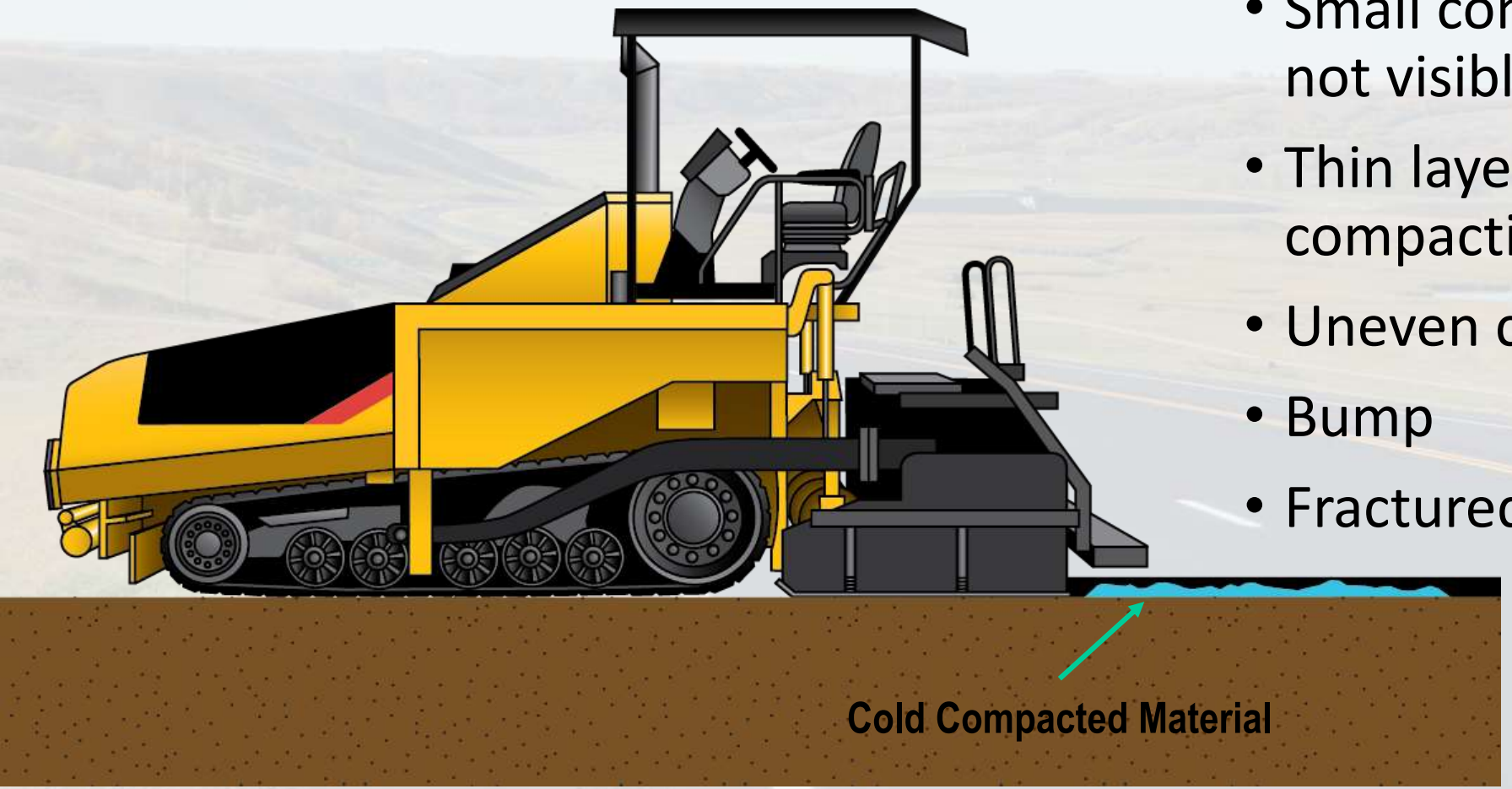
Date	Overload	Underload	Trucking	Testing/ Sampling	Equipment Breakdown	Other	Total	Number of Stops	Paving Time	Tons	Actual TPH
########	0	0	21	0	0	53	74	9	5.5	1080	253
########	0	8	120	0	0	7	135	29	8	2014	350
########	0	24	33	0	5	0	62	14	8	1998	287
########	0	0	44	0	0	22	66	11	8	1750	254
########	0	28	55	0	3	9	95	14	8	2050	319
########	0	13	49	0	4	0	66	13	8	2150	312
########	6	0	7	0	0	7	20	6	8	2079	271
########	0	0	14	0	0	0	14	4	7	1842	272
########	10	31	29	0	0	69	139	14	8	1300	229
########	0	0	8	0	0	22	30	3	3	266	106
########	0	0	13	0	0	0	13	5	8	1928	248
########	0	0	47	0	0	93	140	16	8	1673	295
########	0	10	16	0	30	30	86	9	8	1863	284
########	0	53	31	0	3	0	87	13	8	2061	315
########	0	0	26	0	0	51	77	10	6	1368	290
########	5	20	0	0	0	39	64	8	6	1484	301
########	0	20	0	0	0	31	51	5	6	1146	223
########	0	0	7	0	0	10	17	4	8	1706	221
########	0	0	4	0	0	40	44	5	8	1018	140
########	0	0	10	0	0	103	113	5	8	1533	251
########	0	29	44	0	0	0	73	11	8	2030	299
########	0	4	25	0	0	50	79	6	8	1153	173
########	2	0	10	0	130	70	212	6	8	1137	255
########	0	0	12	0	0	57	69	9	8	1941	283



- Find efficiencies / downtime
- 25% or more is very typical
- Example: Painting out lines!



Grade Conditions – Spills

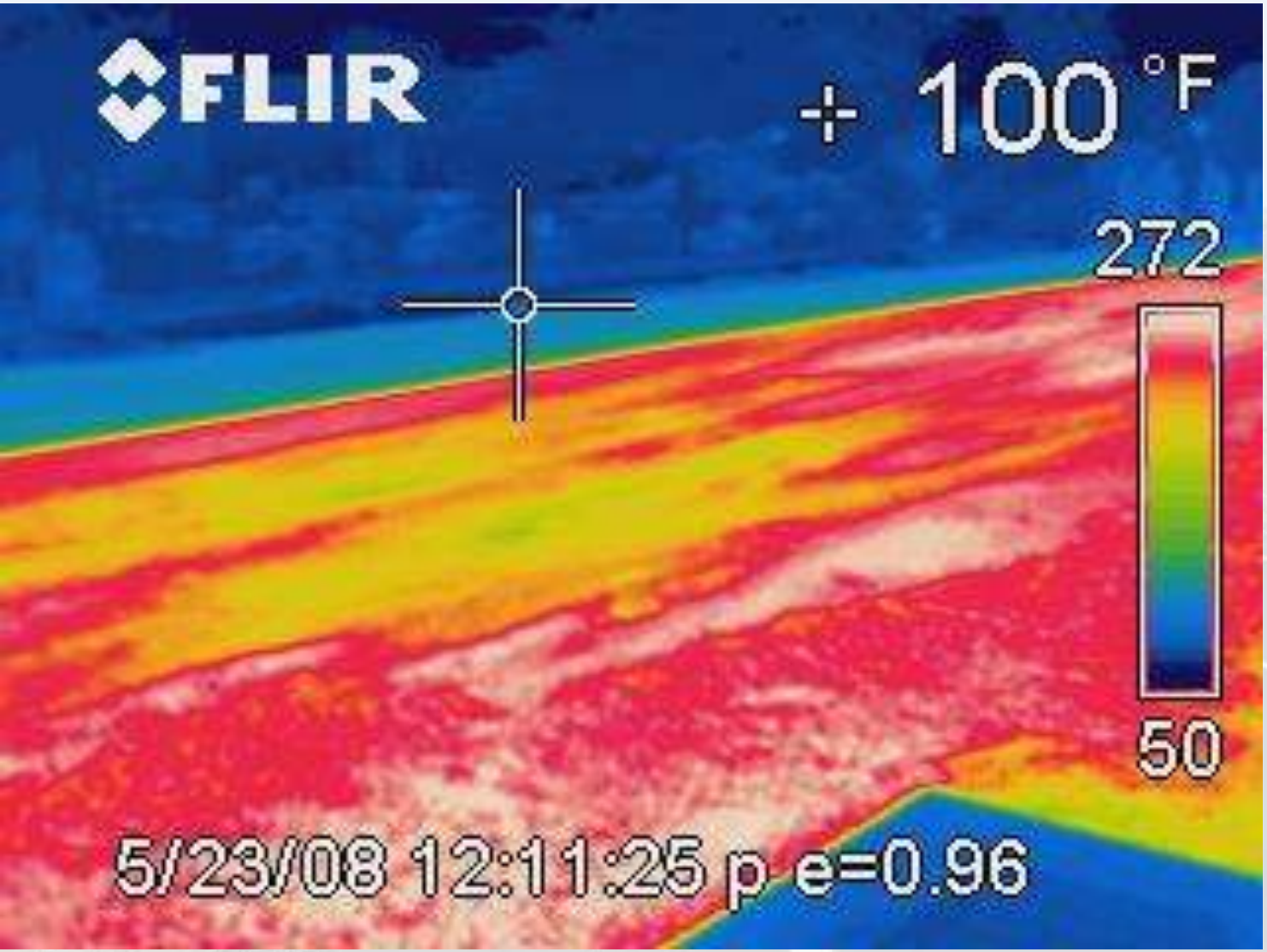


- Small compacted pile usually not visible in mat surface
- Thin layer of fresh mix for compaction
- Uneven compaction
- Bump
- Fractured aggregates

Grade Conditions − Spills

- Caused by folding hopper wings too soon
- Caused by damaged or missing flashing
- Becomes cooler mix covered by mat

Grade Conditions − Spills

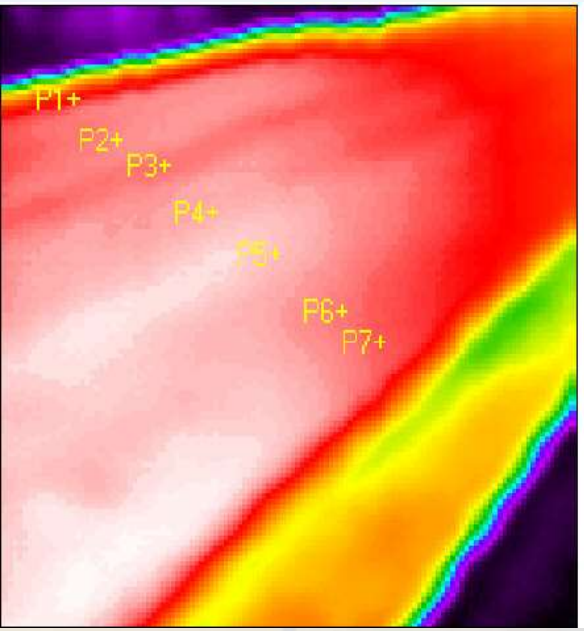


- Spilled material dragged out by screed
- Shows up as open texture
- Infrared image shows large temp. differential
- Density variation
- Rough ride

Banging tailgates in front of paver

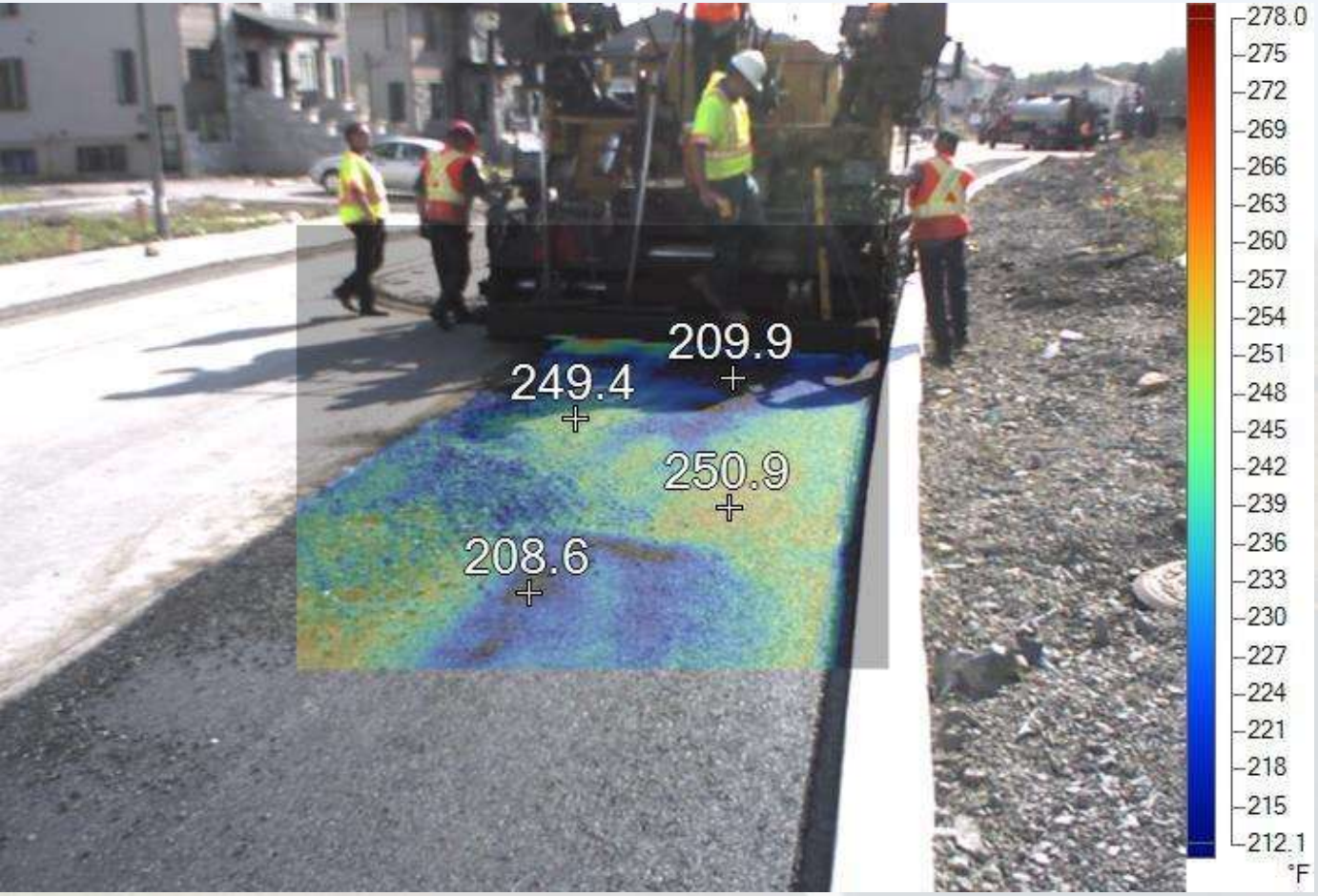
- Same effect as “spills” from the hopper

Outside Edges – Variable Grade



- Step between shoulder and driving lane
- Mat thinner over shoulder portion
- Visually little difference
- Large temperature difference
- Density variation

Grade Conditions – High Spot



- High spot in grade will drag and show cooler, irregularly-shaped patch pattern

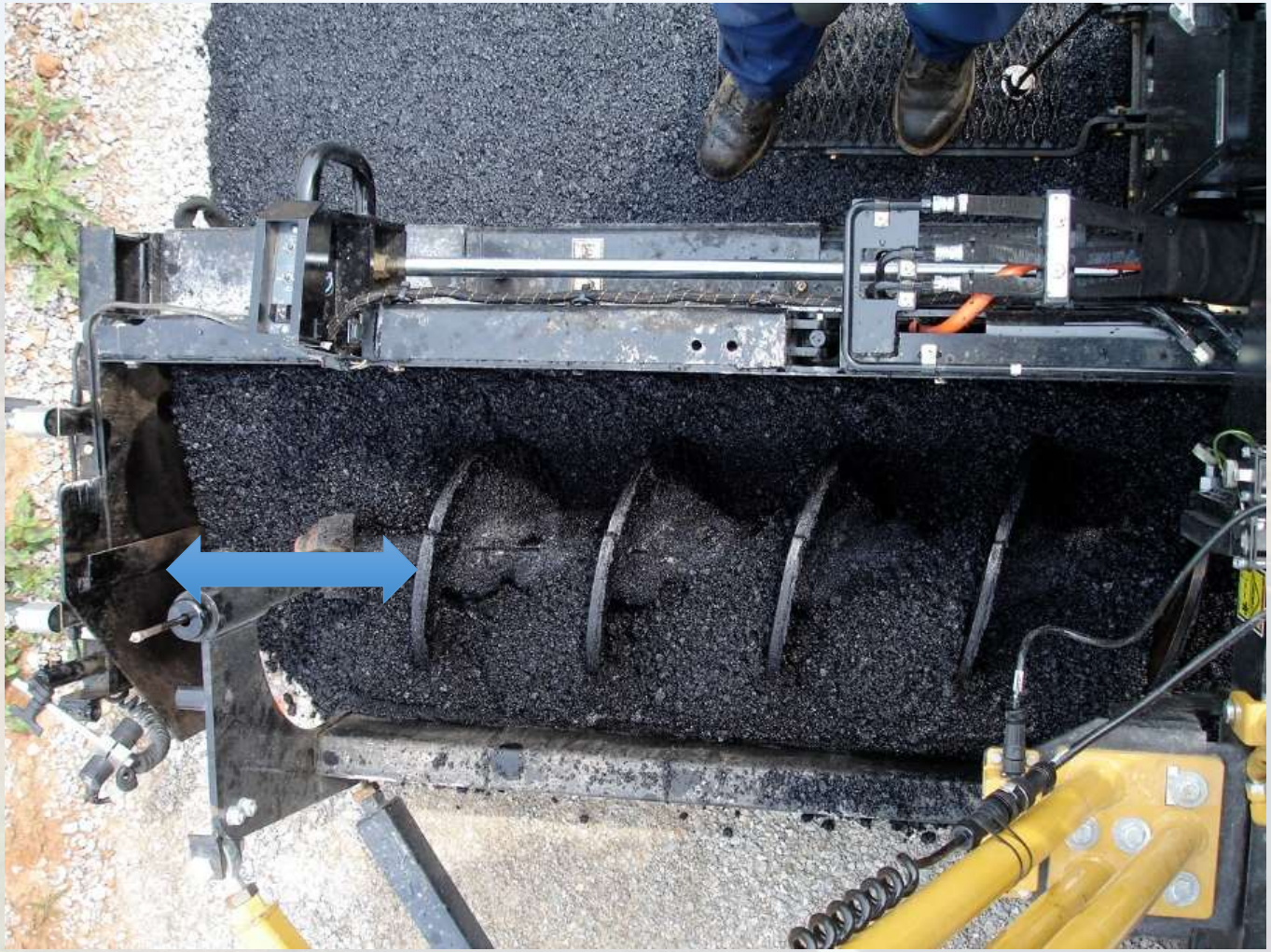
Auger Extensions & Tunnels

- Mix can run out and segregate
- Pattern could be observed in mat behind paver as cooler stripes

Auger Extensions & Tunnels

- Fixed width paving
- Variable width paving
- Front-mount screeds
- Rear-mount screeds

Auger Extensions

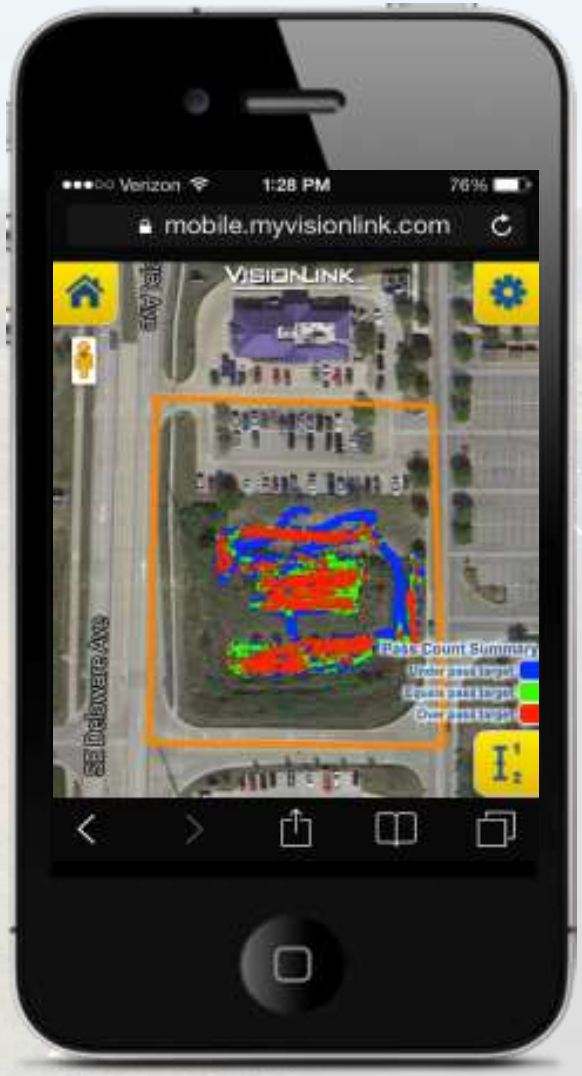


18” with front-mount

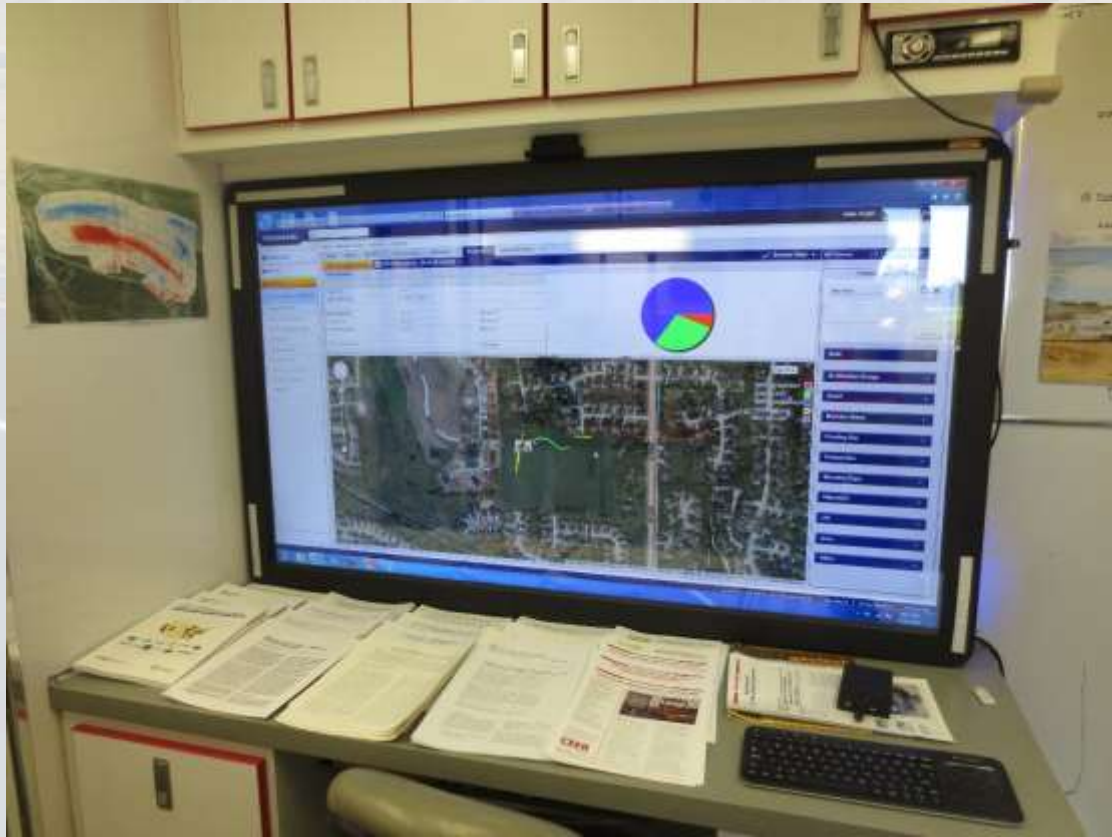
36” with rear-mount

Always Extend Tunnel in front of Augers

Wireless data near ‘real-time’



What data is going to help me?



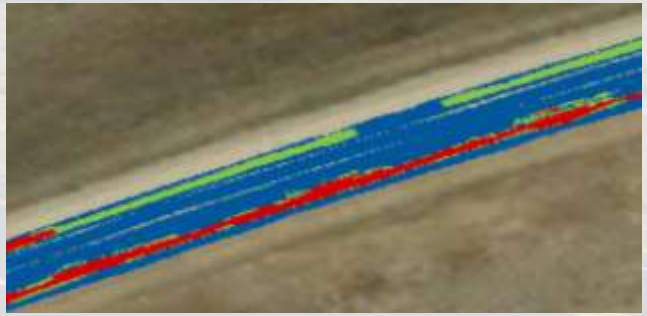
Integrating Technologies for Quality

IC Data - Consistency

- Base Section Performance
- Keeping Roller Operations smooth
- Roll Out Areas (Size of Rolling Pattern)
- Managing Roller Operators

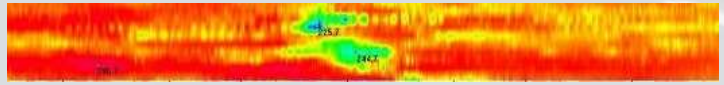
Thermal Data - Segregation

- Paver Screed
- Paver Start and Stops
- Material Hauling and Distribution
- Weather Conditions



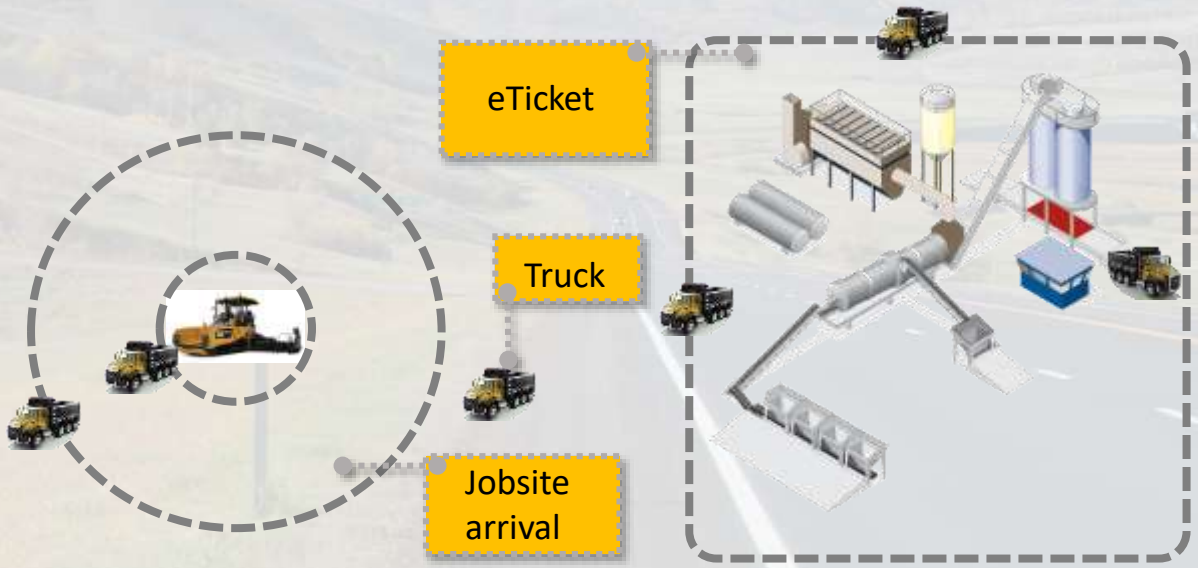
GPR Data - Uniformity

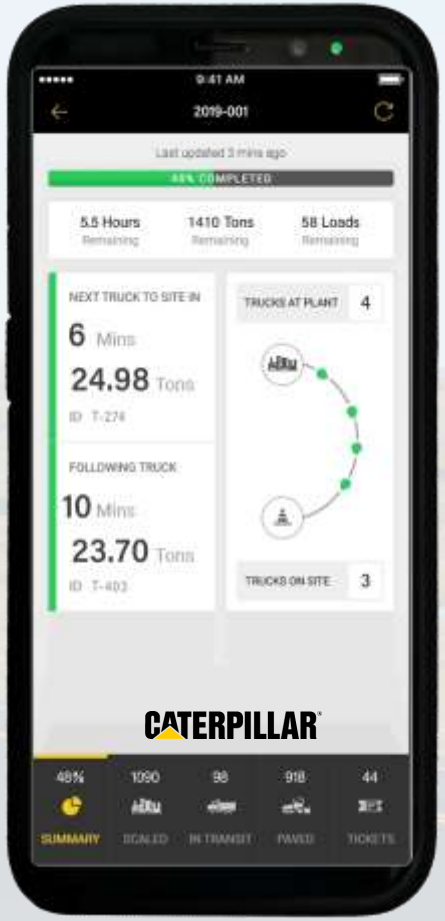
- Areas of low conformity (Shoulder, Joint, etc.)
- Areas that need more attention



Courtesy: Bryce Wuori, Wuori Consulting

eRoutes (e-ticketing)

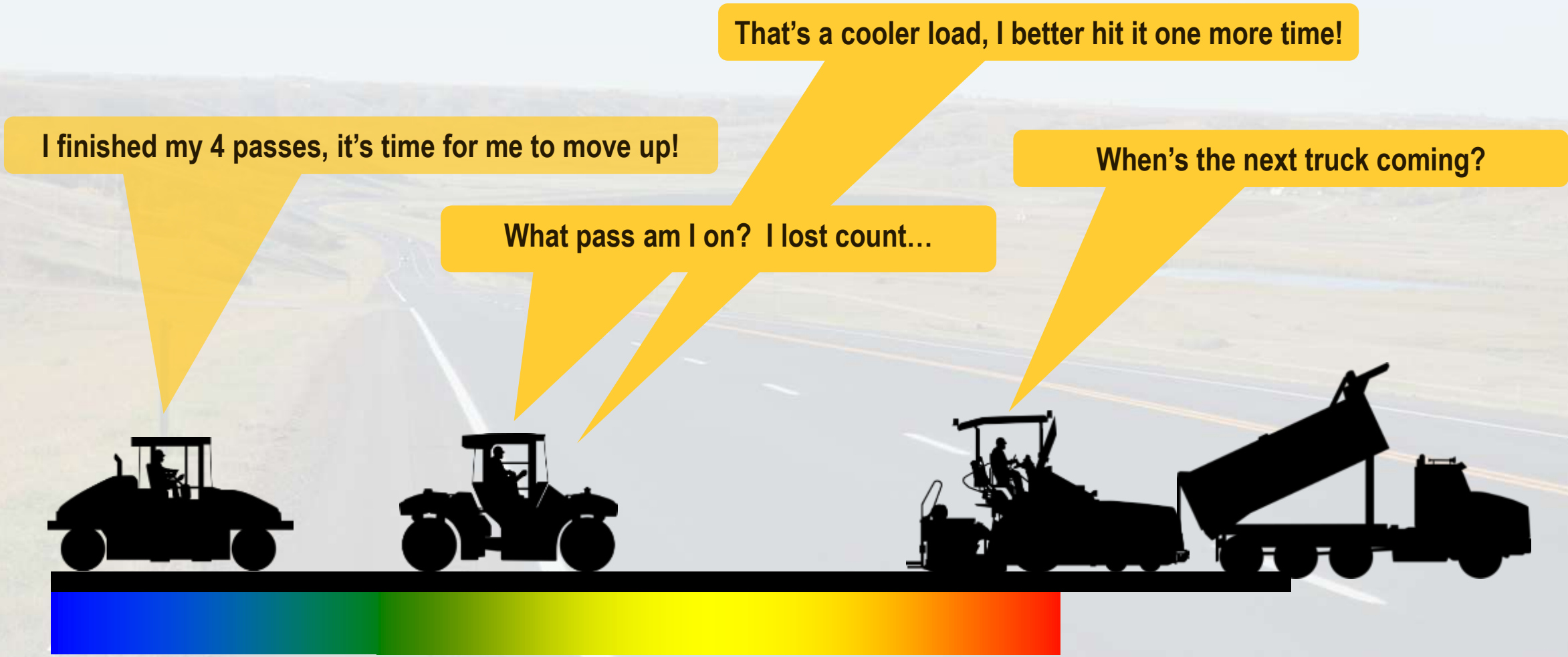




Web-based user interface primarily for management employees to monitor realtime information as well as post-process jobsite data.

Mobile application primarily for paving foremen and paving crew members giving them the information they need to do their jobs better.

Real-time information I can work with!!



Thank you for your attention!

Questions?

Cat Paving YouTube Channel

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