ALASKA ASPHALT SUMMIT

November 2009

THERMAL SERGREGATION

(unseen enemy)

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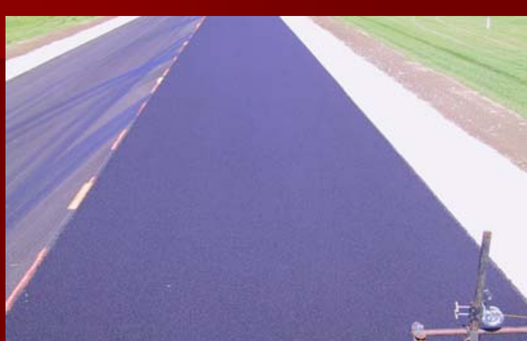
Flat, Black, Beautiful



6 Months Later

End of Load Segregation

WHY?

THERMAL SEGREGATION
Temperature Differentials

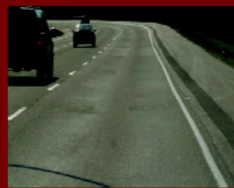
- WDOT & University of Washington-1996 Stephen Read/Dr. Joe Maloney
- Lead states of Washington, Texas, Minnesota
- Specs in Washington, Arkansas, Texas, Massachusetts, Missouri, South Dakota, South Carolina, Ontario, Illinois, etc. (26 states)
- Increased Interest (Auburn, Clemson, & TTI)
- ROADTEC Research-Technical Assistance

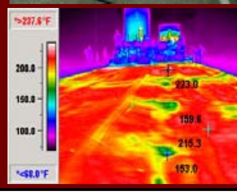
The Problem

- Localized “spots” of coarse surface texture
- Premature failure due to fatigue cracking, raveling, and moisture damage
- Increased roughness

The Problem

- Cooling of mix during transport is not remixed during the laydown process.
- Results in erratic mat temperatures that are not apparent to the laydown crew. (Unseen)

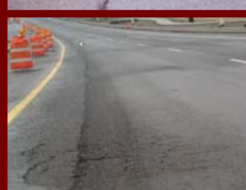




Damage Mechanism

- Placement of this cooler HMA creates pavement areas near cessation temperature (about 175°F)
- No significant compaction occurs below cessation temperature

Effects on Pavement



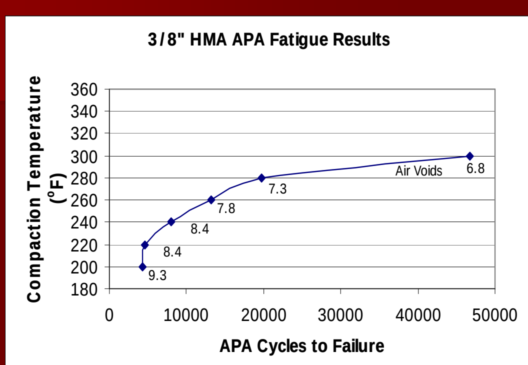
What Are We Trying to Avoid?

Cool area – usually seen in a cyclic pattern.

Streak – either down the center of the paved lane or either side of center.

Effects on Pavement

- Insufficient compaction
  - Increased raveling and moisture damage
  - Reduced fatigue life
  - Increased roughness
- One percent increase in air voids results in a minimum of ten percent reduction in pavement life (a rule of thumb)



Courtesy of PTI and Ron Collins

Time Line for Temperature and Density Differentials—Washington State

- 1995-1996: Initial field data reported in S. Read thesis and presented at TRB and Asphalt Paving Association of Washington Annual Meeting
- 1998: Four paving projects examined
- 1999: Approximately 40 paving projects examined
- 2000: Eighteen paving projects examined
- 2001-2006: Continued field monitoring and the development and evolution of specifications to address the problem

1998 Study Objectives

- Are WSDOT dense-graded mixes experiencing aggregation segregation, temperature differentials resulting in higher air voids, or a combination thereof?
- What specific roles do mix temperature differentials play in the "cyclic segregation" problem?

Study Description

- Four WSDOT paving projects—summer 1998
- Use infrared camera (provided by Astec Industries) and material tests by WSDOT Mat Lab
- Look for segregation
- Look for temperature differentials
- Measure effects

1998 Conclusions

- None of the 4 projects experienced significant aggregate segregation.
- All 4 projects experienced significant temperature differentials.
- Concentrated areas of significantly cooler HMA generally resulted in lower than desirable compaction of those areas.

1998 Conclusions (cont.)

- Concentrated areas of cooler HMA commonly occur during construction (based on this study and others).
- Good rolling practices can partially offset temperature differential related compaction problems.
- MTVs not specifically examined.
- Temperature differentials are easily identified by infrared imaging.

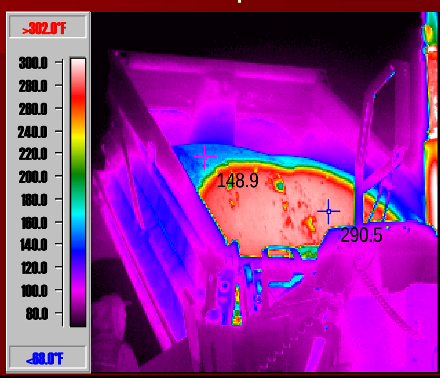
1999 Study Objectives

- Investigate the effectiveness of different MTVs and remixing devices/methods
- Investigate other possible mitigation techniques
- Reexamine criteria for when and where to use MTV's

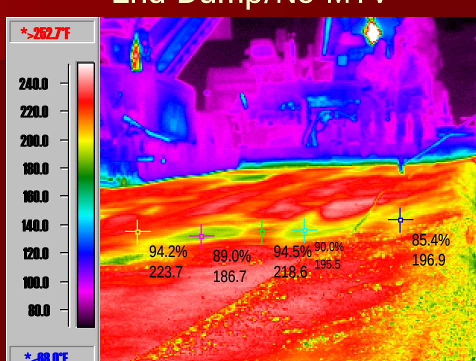
Data Collected

- Haul distance and time
- Weather conditions
- Equipment
  - Type of truck
  - MTV/MTD
  - Paver
  - Roller
- Nuclear density data
- Temperature data
  - Infrared camera
  - Probes
  - Hand held infrared thermometer
- Plant information
  - Temperature of mix
  - Loading operations
- Mat Placement

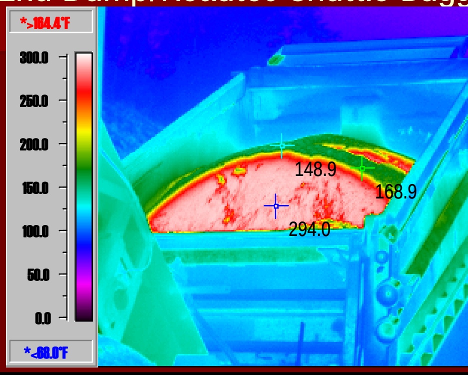
End Dump/No MTV



End Dump/No MTV

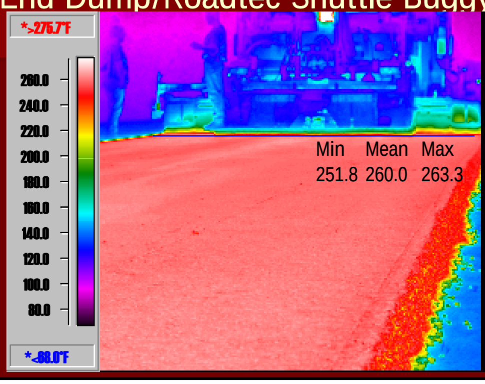


End Dump/Roadtec Shuttle Buggy



SR 2

End Dump/Roadtec Shuttle Buggy

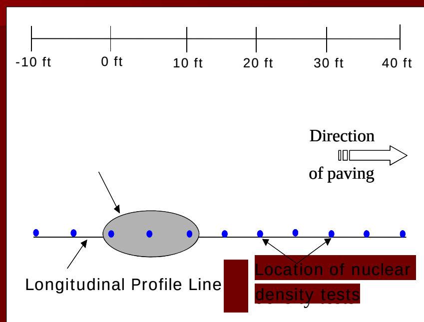


SR 2

Summary of Findings—1999

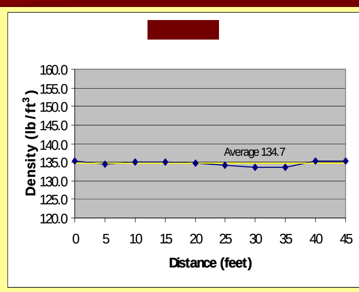
- Large temperature differentials were observed under a variety of paving conditions
- Generally, the higher the temperature differentials the higher the as-compacted air voids associated with the cooler portions of the mat
- Temperature differentials generally decreased when the air temperature ≥ 85 °F (limited data)
- Large temperature differentials occurred over a wide range of pavement surface temperatures

Temperature Differential Spots



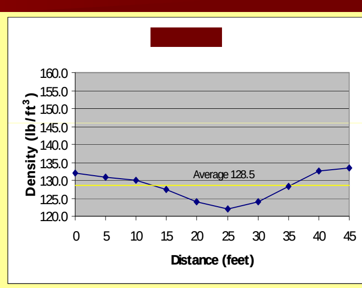
Passing Density Profile

ΔT=2°F	Average Readings (pcf)
Average	134.6
Maximum	135.4
Minimum	133.5
	Ranges
Max-Min	1.9
Ave-Min	1.1



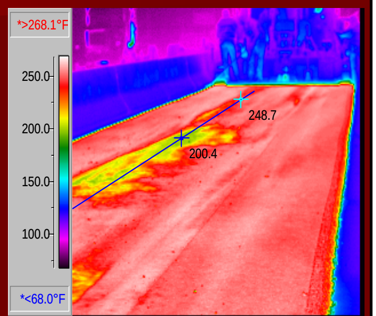
Failing Density Profile

ΔT=66°F	Average Readings (pcf)
Average	128.5
Maximum	133.5
Minimum	121.9
	Ranges
Max-Min	11.6
Ave-Min	6.6



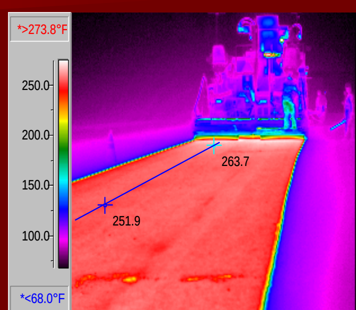
End Dump/No MTV

- Density Profile #1
- Readings
  - Average 152.7
  - High 156.4
  - Low 149.8
- Ranges
  - High – Low = 6.6
  - Ave – Low = 2.9
- ΔT = 48ºF



End Dump/Roadtec Shuttle Buggy

- Density Profile #3
- Readings
  - Average 140.7
  - High 142.9
  - Low 138.4
- Ranges
  - High – Low = 4.5
  - Ave – Low = 2.3
- ΔT = 11ºF



Summary of Findings—2000

- In general, the occurrence of temperature differentials decreased when compared to the 1999 data (more transfer devices used)
- The higher the temperature differentials, the higher the in-place air voids associated with the cooler portions of the mat
- Temperature differentials decreased when remixing occurred

Summary of 1999-2000 Projects

Equipment	Number of Projects
MTVs	22
Windrow Elevators	20
No MTV/End Dumps	9
Other Combinations	2

Summary of 1999-2000 Projects

Equipment	Number of Projects		
	Normal	Cool	Total
No MTV	0	9	9
Blaw-Knox MC-30	3	9	12
Paddles working	3	4	
Paddles not working	0	5	
Roadtec Shuttle Buggy	10	0	10
Cedarapids MS-3	1	2	3
Cedarapids MS-2	6	5	11
Other Windrow Elevator	3	3	6
CMI MTP-400	1	0	1
Windrow Elevator/MC-30	1	0	1

"Cool" defined as $\Delta T \geq 25°F$

Bottom Line 1999-2000 Projects

- Temperature and density differentials can be a significant issue on paving projects.
- Approximately ½ of projects (28 out of 53) studied during 1999 and 2000 regularly had temperature differentials ≥ 25°F.
- Following three years of data collection and analyses, differential densities resulting from cooler than desirable mix can be significant. How significant?

1999 Study Objectives

- Investigate the effectiveness of different MTVs and remixing devices/methods
- Investigate other possible mitigation techniques
- Reexamine criteria for when and where to use MTV's

Bottom Line 1999-2000 Projects

- How significant is the problem?
- Densities 3 pcf less than the density lot mean result in an air void increases of about 2%.
- The following table provides examples.

Bottom Line 1999-2000 Projects

Percent of Rice Density Mean	Mix Air Voids @ Density Mean	Mix Air Voids @ Mean – 3 pcf	Mix Air Voids @ Mean – 6 pcf
95%	5.0%	7.0%	9.0%
94%	6.0%	8.0%	10.0%
93%	7.0%	9.0%	11.0%
92%	8.0%	10.0%	12.0%

(1) Assumed Rice Density of 155 lb/ft^3; (2) Long Term WSDOT Average 92.7%

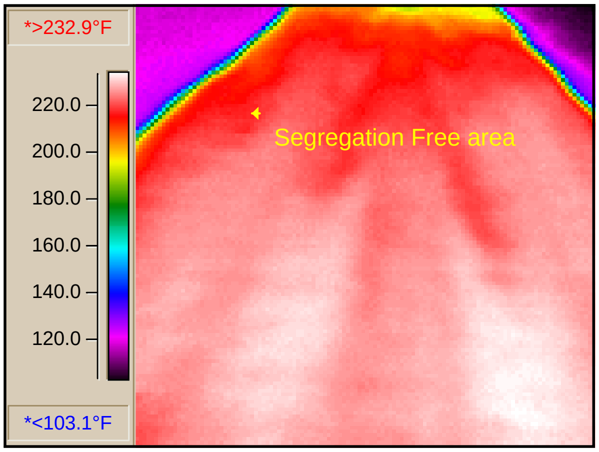
2001-2006

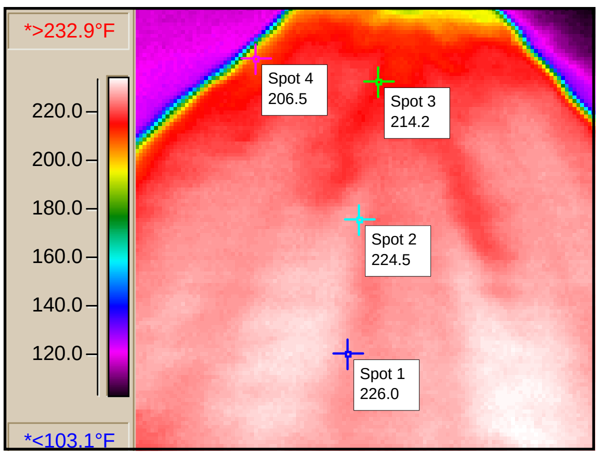
- A number of State DOTs have developed and implemented specifications to address this issue.
- WSDOT's current specification
  - Cyclic density areas are defined as less than 89.0 percent of maximum density.
  - If four or more low cyclic density areas are identified in a lot, a price adjustment will be assessed for that lot (a lot is 400 tons).
  - The price adjustment will be calculated as 15% of the unit bid price of HMA represented by that lot.
  - This assessment starts with examining the mat for temperature differences of 25°F or greater. If these do not exist, then no further special density testing is performed.

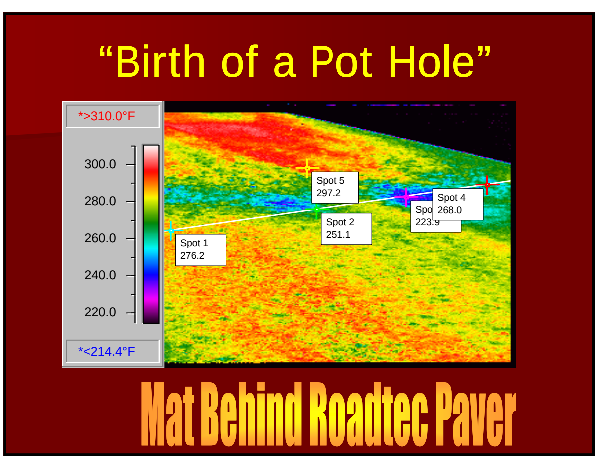
Washington Conclusions 2009

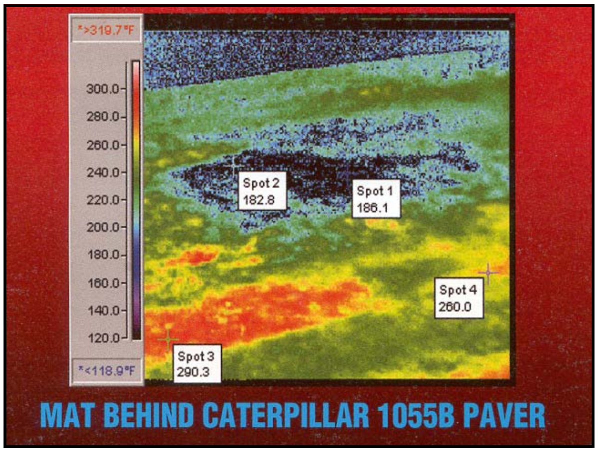
- Survey results of DOT & Contractors-Use of MTV greatest improvement in quality.
- Temperature testing and MTV use increased life of HMA by 50%
- All 2010 projects require use of MTV

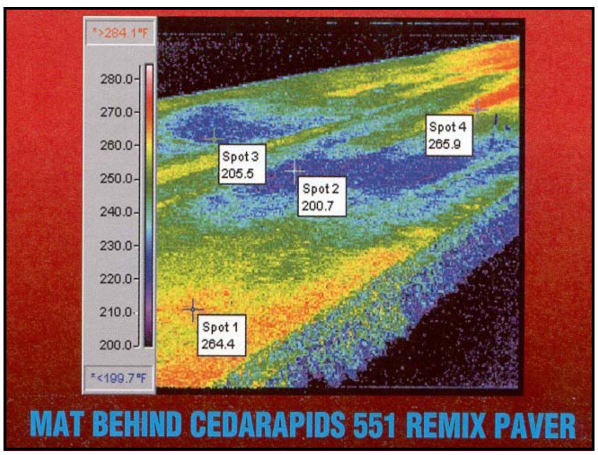
THERMOGRAPHY

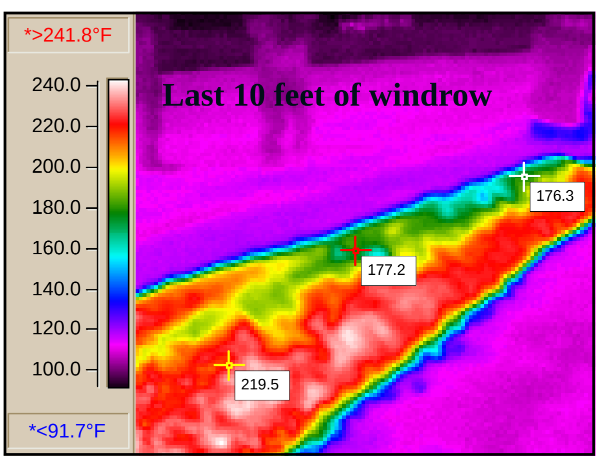

*>232.9°F
220.0
200.0
180.0
160.0
140.0
120.0
*<103.1°F
Segregation Free area

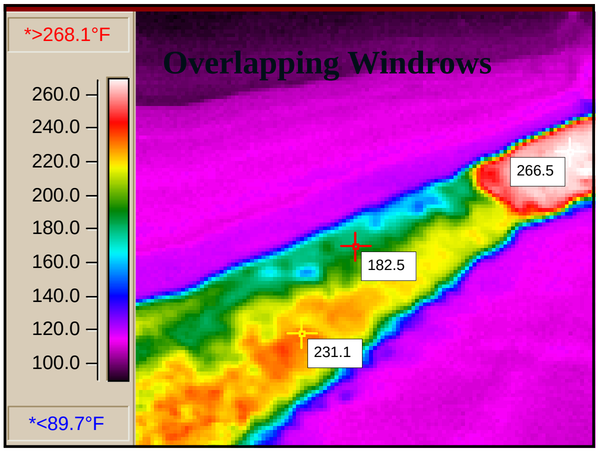

*>232.9°F
220.0
200.0
180.0
160.0
140.0
120.0
*<103.1°F
Spot 4
206.5
Spot 3
214.2
Spot 2
224.5
Spot 1
226.0

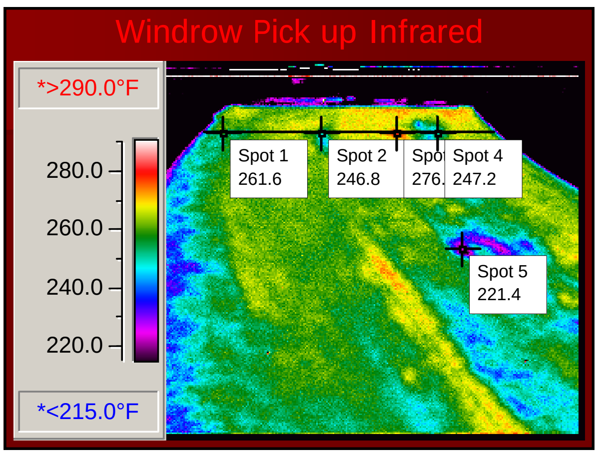

"Birth of a Pot Hole"
*>310.0°F
300.0
280.0
260.0
240.0
220.0
*<214.4°F
Spot 5
297.2
Spot 2
251.1
Spot 4
268.0
223.9
Spot 1
276.2
Mat Behind Roadtec Paver

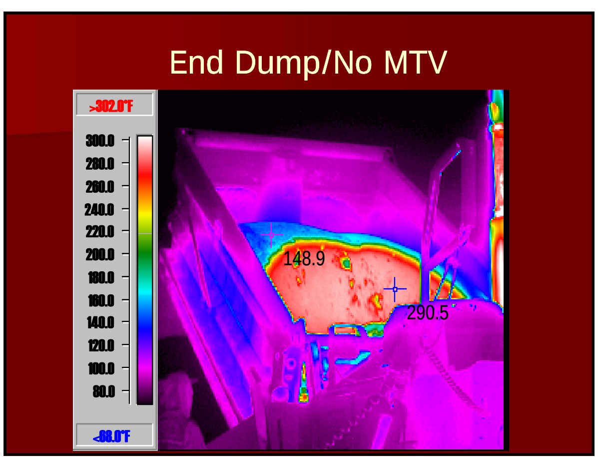

*>319.7°F
300.0
280.0
260.0
240.0
220.0
200.0
180.0
160.0
140.0
120.0
*<118.9°F
Spot 2
182.8
Spot 1
186.1
Spot 4
260.0
Spot 3
290.3
MAT BEHIND CATERPILLAR 1055B PAVER


*>284.1°F
280.0
270.0
260.0
250.0
240.0
230.0
220.0
210.0
200.0
*<199.7°F
Spot 4
265.9
Spot 3
205.5
Spot 2
200.7
Spot 1
264.4
MAT BEHIND CEDARAPIDS 551 REMIX PAVER

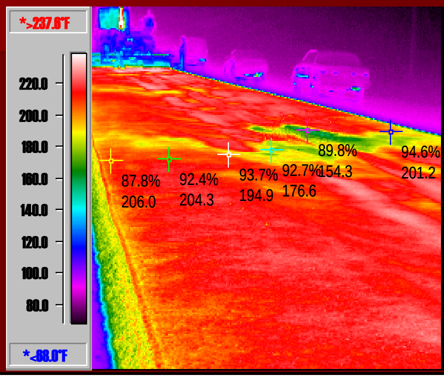

*>241.8°F
240.0
220.0
200.0
180.0
160.0
140.0
120.0
100.0
*<91.7°F
Last 10 feet of windrow
176.3
177.2
219.5


*>268.1°F
260.0
240.0
220.0
200.0
180.0
160.0
140.0
120.0
100.0
*<89.7°F
Overlapping Windrows
266.5
182.5
231.1

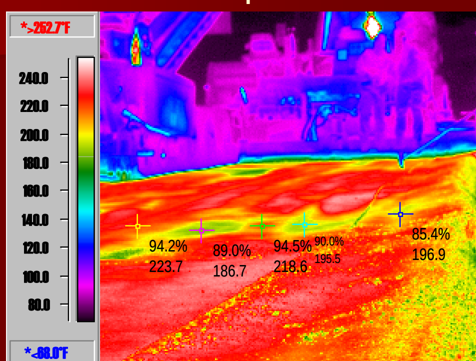

Windrow Pick up Infrared
*>290.0°F
280.0
260.0
240.0
220.0
*<215.0°F
Spot 1
261.6
Spot 2
246.8
Spot 4
247.2
Spot 5
221.4


End Dump/No MTV
148.9
290.5

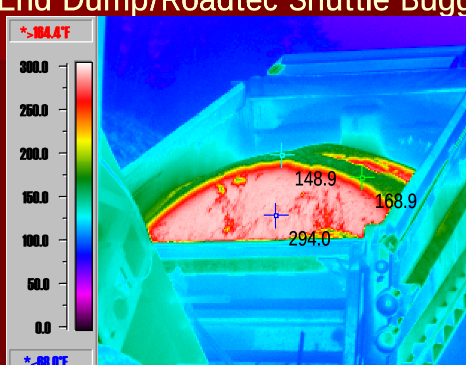
End Dump/No MTV



End Dump/No MTV

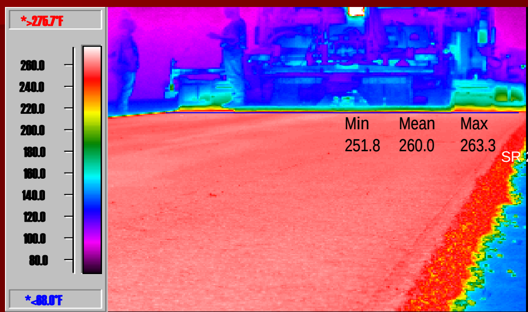


End Dump/Roadtec Shuttle Buggy

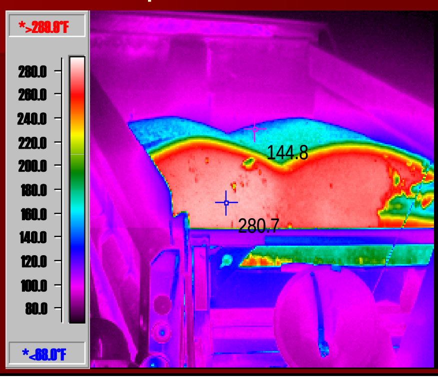


SR 2

End Dump/Roadtec Shuttle Buggy

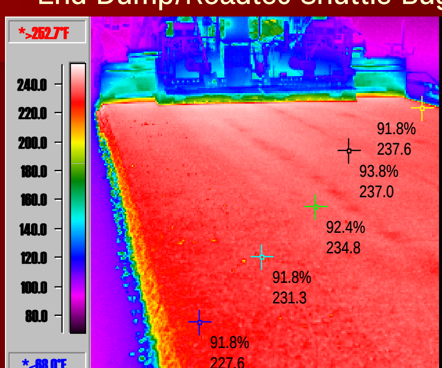


End Dump/Roadtec Shuttle Buggy

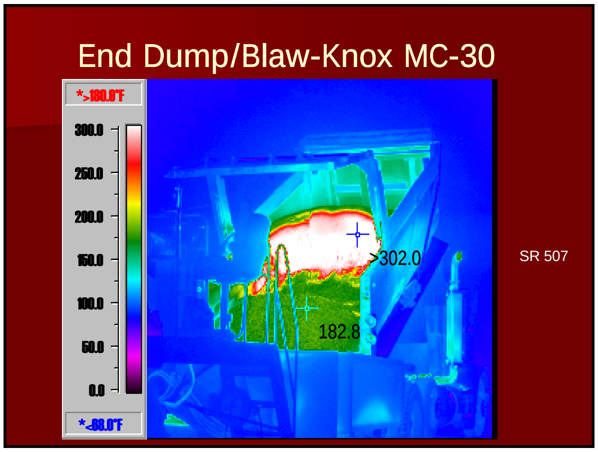


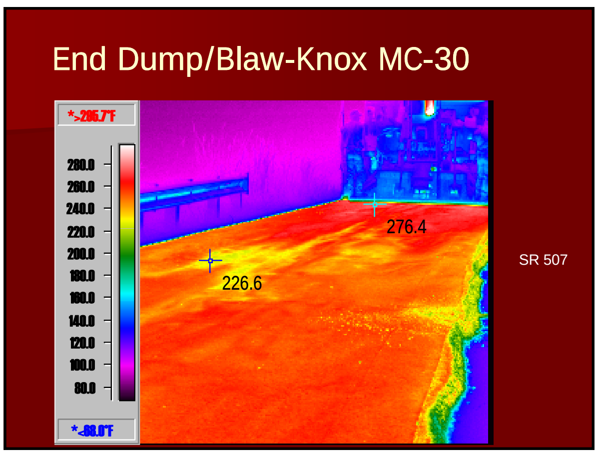
SR 12

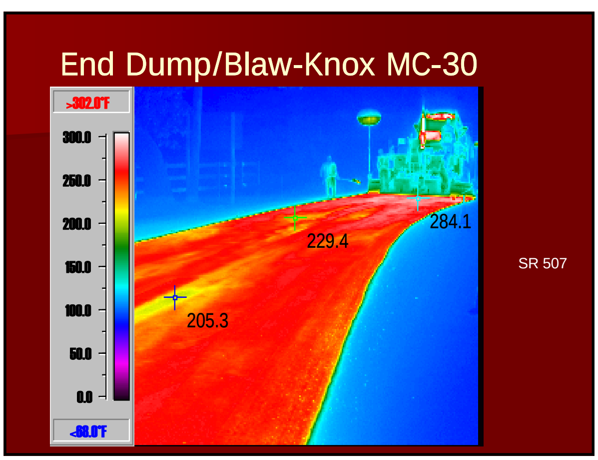
End Dump/Roadtec Shuttle Buggy



SR 12

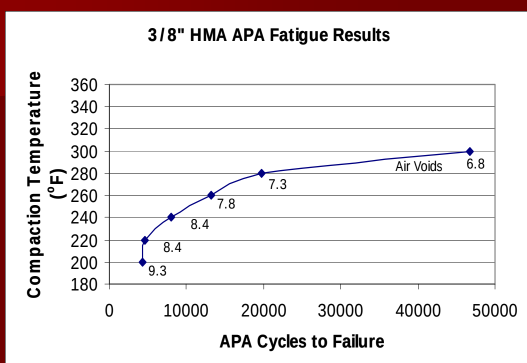

End Dump/Blaw-Knox MC-30
300.0
250.0
200.0
150.0
100.0
50.0
0.0
302.0
182.8
SR 507


End Dump/Blaw-Knox MC-30
280.0
260.0
240.0
220.0
200.0
180.0
160.0
140.0
120.0
100.0
80.0
276.4
226.6
SR 507


End Dump/Blaw-Knox MC-30
300.0
250.0
200.0
150.0
100.0
50.0
0.0
229.4
284.1
205.3
SR 507

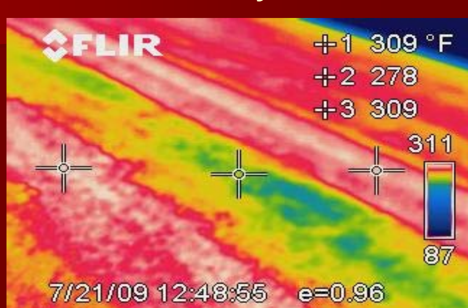
Thermal Segregation

- 20° Differential-1% to 2% Air Voids
- Over 7% Air Voids Reduces Life
- Each 1% Over-Reduces Life 10%

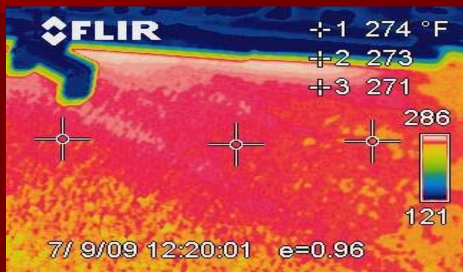


Courtesy of PTI and Ron Collins

Alaska Overlay w/o MTV



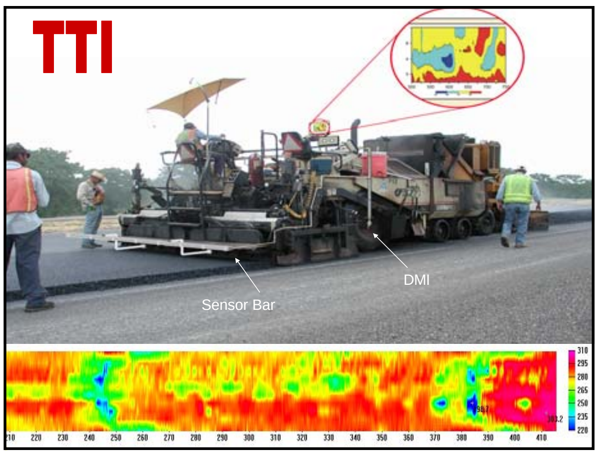
Fairbanks Airport/Shuttle Buggy

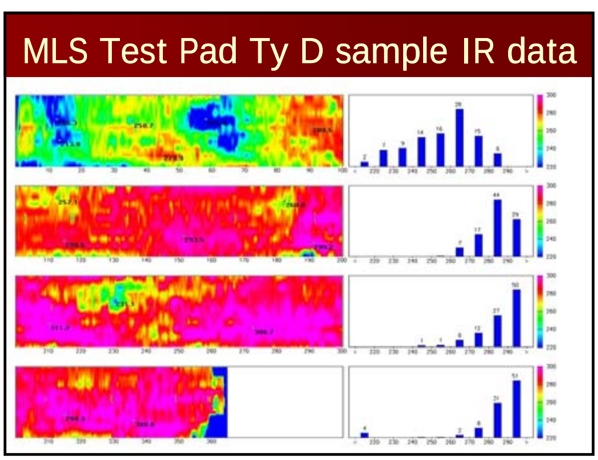


UPDATE

- **TTI**-Research on thermal segregation----Tom Scullion/Steve Sebeste
- **Auburn**----Dr. M. Stroup-Gardiner
- **TRB** Report----"Initial Ride Quality of HMA Pavements"
- **Clemson**----Dr. Serji A. Amirkhanian


Real Time Thermo-imaging in Texas


TTI
DMI
Sensor Bar


MLS Test Pad Ty D sample IR data

CONCLUSION:

- Initial Ride Quality can be improved by minimizing stops and including a material transfer device
- When used properly, MTV's improved the ride quality and eliminated thermal & physical segregation
- Results show no significant thermal segregation when a material transfer device was used

SAVINGS

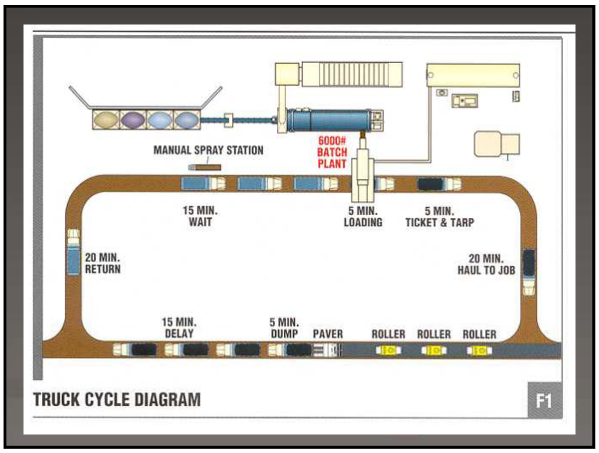
- Eliminate Truck Delay
- Reduce Trucking Costs (25%)
- Increase Productivity (25%)
- Smoother Roads

OWNERSHIP:

Purchase Price		$ 375,000
20%	Residual Value	$ 75,000
NET:		$ 300,000
5	Year Depreciation	$ 60,000
1%	Annual Insurance	$ 3,000
1%	Tax	$ 3,000
ANNUAL TOTAL:		$ 66,000

Hourly Cost Based	500 hrs	750 hrs	1000 hrs	1200 hrs
On Annual Usage	$ 132.00	$ 88.00	$ 66.00	$ 55.00

			OPERATIONAL:							
Labor:			500		750		1000		1200	
Operator	$ 20.00	/hr	$ 20.00	/hr	$ 20.00	/hr	$ 20.00	/hr	$ 20.00	/hr
Fuel:										
gal/hr @	$ 2.25	/gal	$ 27.00	/hr	$ 27.00	/hr	$ 27.00	/hr	$ 27.00	/hr
Daily Maintenance:										
Grease, Oil, Filters, etc.			$ 2.00	/hr	$ 2.00	/hr	$ 2.00	/hr	$ 2.00	/hr
Repairs & Parts:										
$20,000	/year		$ 40.00	/hr	$ 32.00	/hr	$ 24.00	/hr	$ 20.00	/hr
SUBTOTAL:			$ 89.00	/hr	$ 81.00	/hr	$ 73.00	/hr	$ 69.00	/hr
OWNERSHIP:			$ 132.00	/hr	$ 88.00	/hr	$ 66.00	/hr	$ 55.00	/hr
OVERHEAD: 15%			$ 19.80	/hr	$ 13.20	/hr	$ 9.90	/hr	$ 8.25	/hr
TOTAL COST/HOUR			$ 240.80	/hr	$ 182.20	/hr	$ 148.90	/hr	$ 132.25	/hr
Cost/Ton @300t/h			$0.81		$0.61		$0.50		$0.44	
ANNUAL COST			$ 120,400		$ 136,650		$ 148,900		$ 158,700	



ROADTEC SERVICES

- Thermography Research
- Certified Thermographer
- Research on your projects, your materials, your timetable
- Equipment
- “Birth of a Pothole” (Technical Papers)
- Recommended Specifications


THANK YOU!
ROADTEC
Contact: Jim Hedderich
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