52st Annual Illinois Bituminous Paving Conference

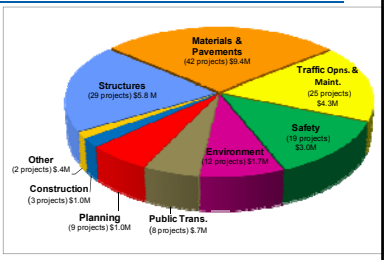
ICT Current Research on Bituminous

Durable Thin Overlays, Tack Coats, Moisture Damage, Mixes with High RAP, and Warm Mixes

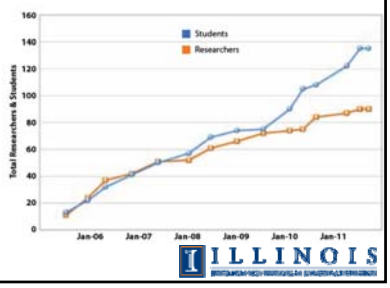
Imad L. Al-Qadi

ICT Research Status

- **Research Project**
  - Total Projects Approved to Date = 149
  - 84 Projects are completed
  - ICT reports published on the website
  - Project quarterly progress on the website



- **Research Participants**
  - 90 Researchers (PI's / Co PI's)
  - 137 Graduate students
  - 12 Universities
  - 6 Private consulting firms
  - 2 Federal/ Local government agencies
  - 1 Not-for-profit agency



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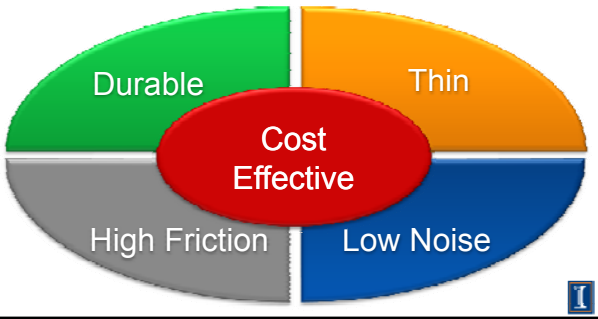
On-Going Projects

- Durable Thin Overlays
- Tack Coats
- Moisture Damage
- Mixes with High RAP
- Warm Mixes
- Fine Mixes

Durable Thin Overlays

R 27-42: Development of a Thin, Quiet, Long-Lasting, High Friction Surface Layer for Economical Use in Illinois

- **Objective**
  - Develop a cost-effective mix for a new generation of wearing surface and overlay cross-sections



Durable Thin Overlays

Summary of AC Mixtures

Quartzite Mix	Slag/Fiber Mix	Sprinkle Mix	4.75 SMA
• Friction/ rut resistance	• Tensile st./ rut resistance	• Friction/ cost-effective	• Thin/ durable




Mix Type		NMAS (mm)	Gradation	Binder (SBS)	N_{des}	Air Voids (%)	VMA	AC (%)
Control Mixes	F-mix	9.5	Coarse Dense	PG 70-22	90	4.0	14.5	5.1
	SMA	12.5	SMA	PG 76-22	80	3.5	17.6	6.0
New Mixes	Quartzite Mix	9.5	Fine Dense	PG 70-22	90	4.0	15.2	5.8
	Slag/Fiber Mix	9.5	Fine Dense	PG 70-22	90	4.0	15.4	5.7
	Sprinkle Mix	9.5	Fine Dense	PG 70-22	90	4.0	15.3	6.1
	4.75 SMA	4.75	SMA	PG 70-22	80	4.0	18.5	7.3

Durable Thin Overlays

Performance Tests

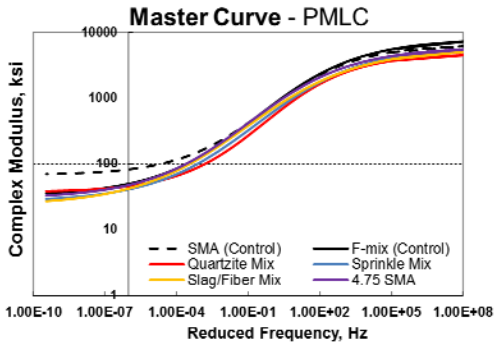
Performance	Test Method	Laboratory/ Field
Durability	Cantabro Loss Test	LMLC & PMLC
Moisture Susceptibility	IL Modified Lottman Test	LMLC & PMLC
Fracture	Semi Circular Bending Test	LMLC & PMLC
Complex Modulus	Complex Modulus Test	LMLC & PMLC
Rutting	Wheel Tracking Test Dip Stick Transverse Profiling	LMLC & PMLC PMFC
Friction	Locked Wheel Skid Test	PMFC
Noise	On-Board Sound Intensity Test	PMFC
Surface Texture	Laser Texture Measuring	PMFC

Note:
LMLC: Lab-Mixed & Lab-Compacted, **PMLC:** Plant-Mixed & Lab-Compacted, **PMFC:** Plant-Mixed & Field-Compacted (in place/cores)

Durable Thin Overlays

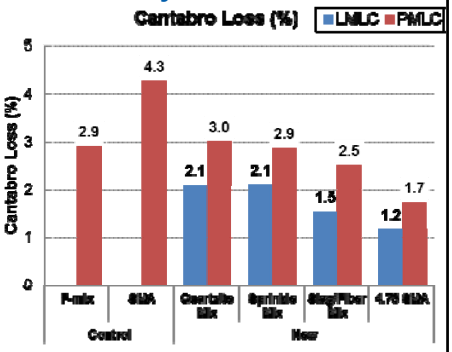
Test Results

Complex Modulus



- Control SMA is expected to have higher rut resistance due to highly modified binder (PG 76-22).
- Both control mixes are expected to be more brittle than new mixtures at low temperature.

Durability

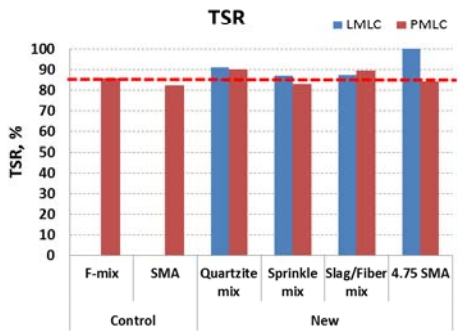


- New mixes are expected to be more durable than control mixes.

Durable Thin Overlays

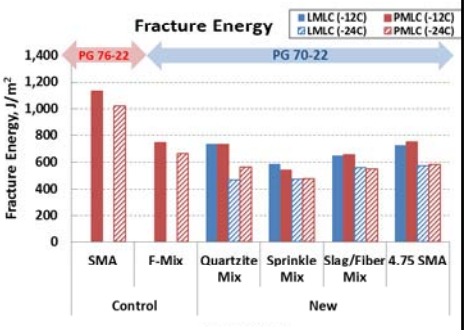
Test Results

Moisture Susceptibility



- New mixes provide higher tensile strength than the control mixes.
- 4.75 SMA shows the highest TSR with the lowest tensile strength.

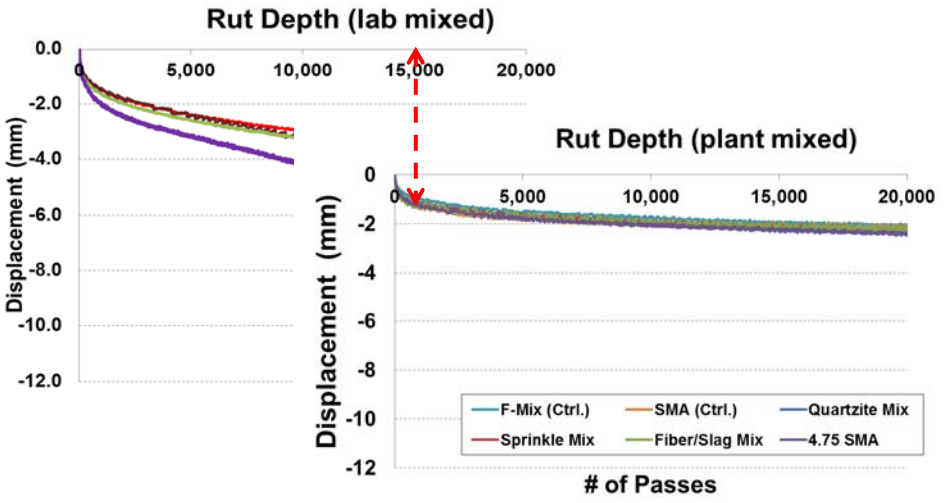
Fracture



- The control SMA has the highest fracture resistance due to highly modified binder.
- For the slag/fiber mix, the fibers increase fracture energy by **57%** when located at fracture face.

Durable Thin Overlays

Rutting Potential



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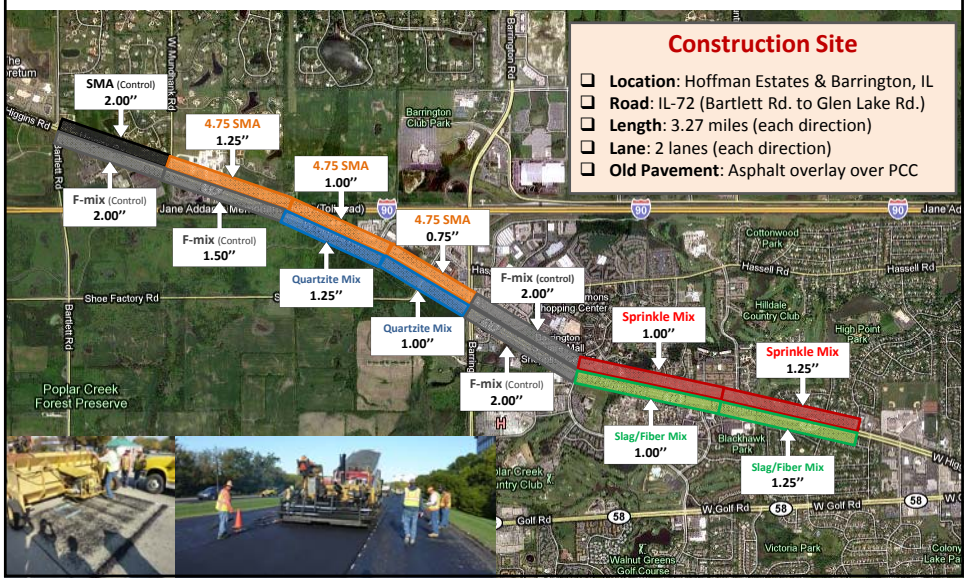
Durable Thin Overlays

Field Construction

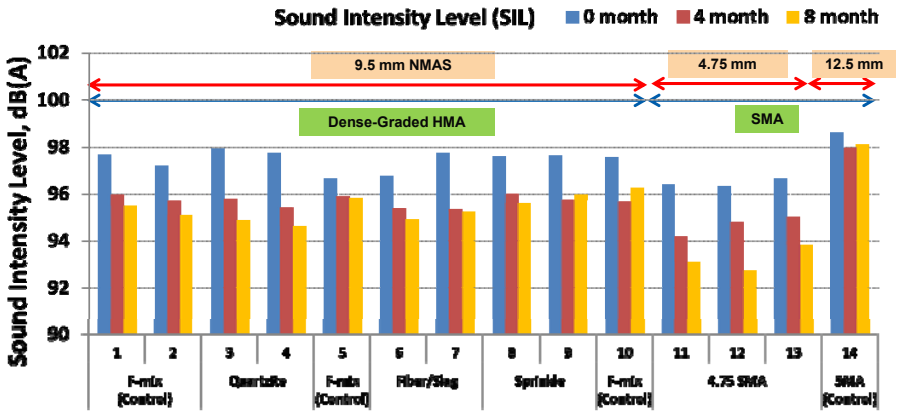


Construction Site

- **Location**: Hoffman Estates & Barrington, IL
- **Road**: IL-72 (Bartlett Rd. to Glen Lake Rd.)
- **Length**: 3.27 miles (each direction)
- **Lane**: 2 lanes (each direction)
- **Old Pavement**: Asphalt overlay over PCC

Durable Thin Overlays

Noise



- Noise level was observed to be affected by NMAS rather than gradation.
- Larger NMAS results in more noise at tire-pavement surface.
- 4.75 SMA showed significant noise reduction by time.

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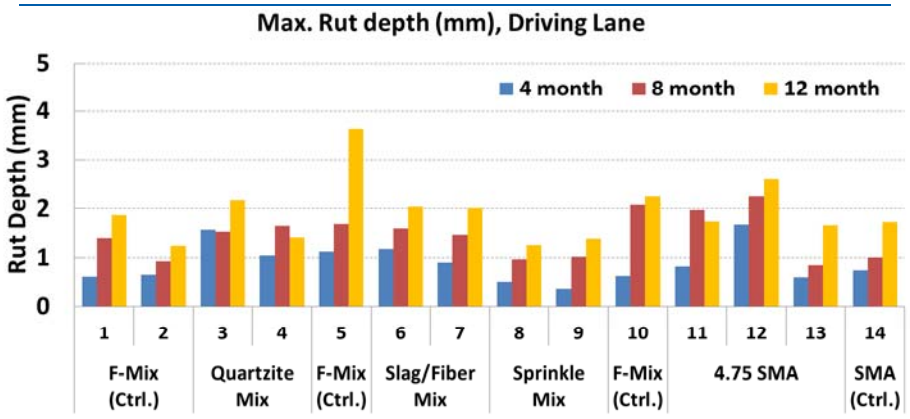
Durable Thin Overlays

Rutting Potential



- Field maximum rut depth increased with time.
- Sprinkle mix and control SMA provide best rut resistance: contain coarse aggregate on the surface.
- 4.75 SMA showed relatively lower rutting resistance due to higher asphalt content.

Preliminary Outcome (to date)

- New mixtures that could be cost-effective and innovative showed comparable performance with control mixes (*to date*).
- Test results of plant-prepared specimens were affected by reheating process and aging.
  - Increase in modulus and rutting resistance
  - Decrease in tensile strength and durability
- Engineering value analysis is underway and cost-effective mixture(s) will be selected.
- Long-term field performance monitoring is needed.

Mixes with High RAP

To examine the impact of high RAP in asphalt mixes on the mix performance

- **Candidate Mixtures**
  - Two Control Mixtures
    - **District 1**
    - District 5
  - Six mixtures with RAP
    - 30% RAP
    - 40% RAP
    - 50% RAP
- **Laboratory Tests**
  - Dynamic Modulus
  - Fatigue
  - Moisture Susceptibility
  - Fracture
  - Rutting

Mixes with High RAP

Mixture Volumetrics: *District 1*

RAP (%)	Total AC (%)	Binder Replaced (%)	Air Void (%)	VMA (%)	VFA (%)
0	4.9	0	4.0	13.7	70.8
30	4.9	27.6	4.0	13.6	70.6
40	5.1	34.6	4.0	13.7	70.8
50	5.0	43.7	4.0	13.7	70.8

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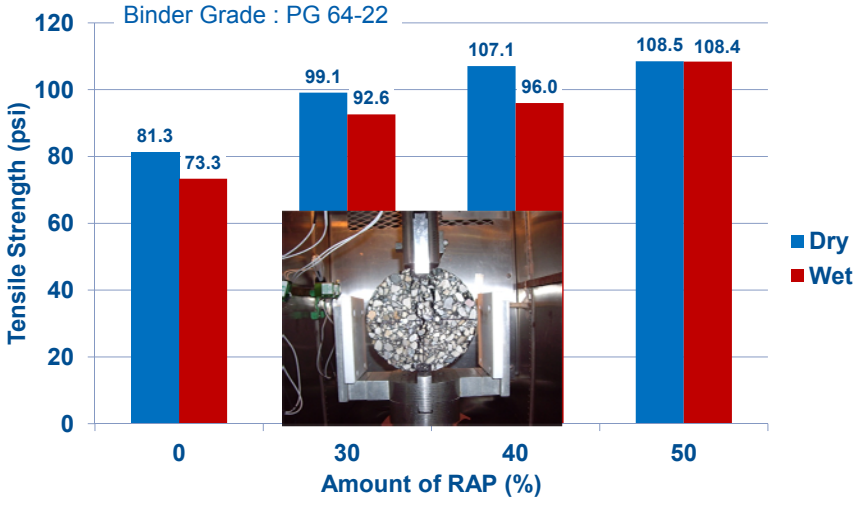
Moisture Susceptibility Test

Tensile Strength



1 psi = 6.89 kPa

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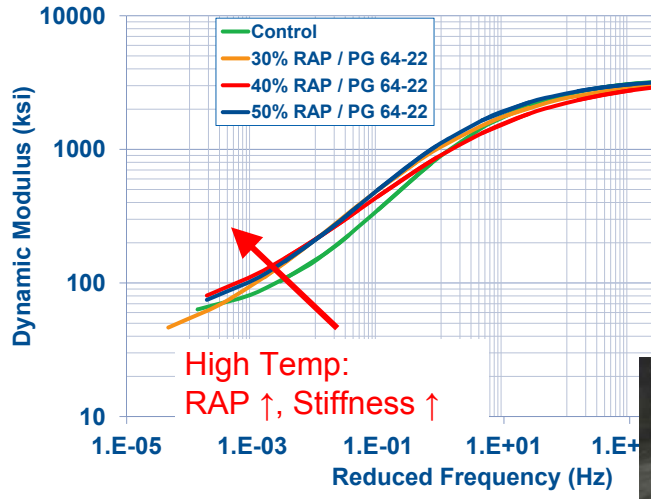
E* Master Curve

Effect of RAP Content



1 ksi = 6.89 MPa

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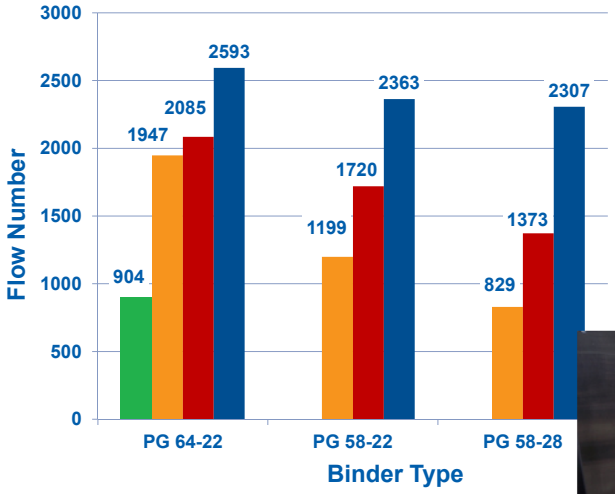
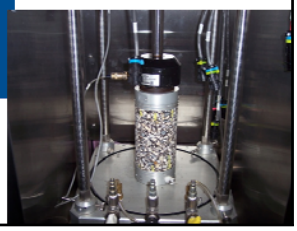
RAP & Binder Effect

Flow Number Test





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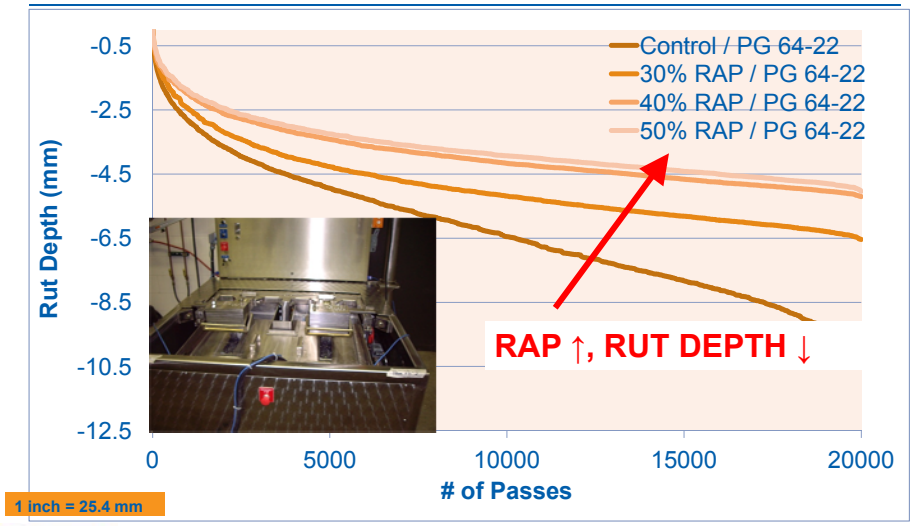
Wheel Tracking Test

Effect of RAP



1 inch = 25.4 mm

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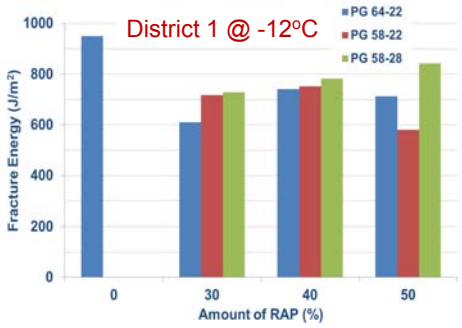
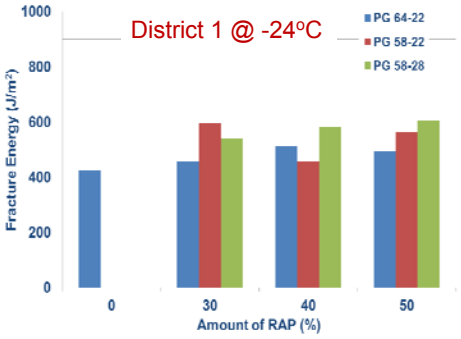
Mixes with High RAP

Semi-Circular Bend (SCB) Test





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Preliminiary Outcome

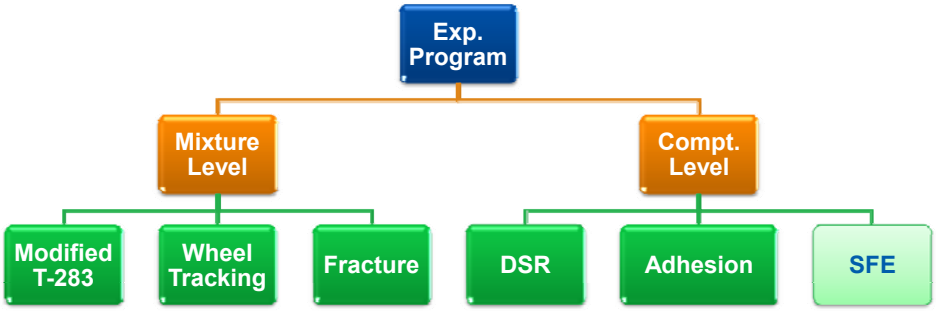
- Achieving acceptable and consistent mixture volumetrics (e.g. VMA) is possible when using high RAP.
- Proper RAP processing and fractionation ensured high quality production of AC mixtures with RAP.
- The AC mixtures with RAP performed equal to or better than the mixtures produced with virgin aggregate.
- Single and Double binder grade bumping is proved to be effective most of the times.

Moisture Damage

- Determine short- and long-term effects of selected additives/modifiers on controlling moisture damage of typical Illinois mixes:
  - Lab testing
  - Validation of lab results through full-scale APT
- Additives/modifiers considered:
  - Liquid Antistrip
  - Hydrated Lime
  - SBS
  - Poly-Phosphoric Acid (PPA)
  - Foamed Binder

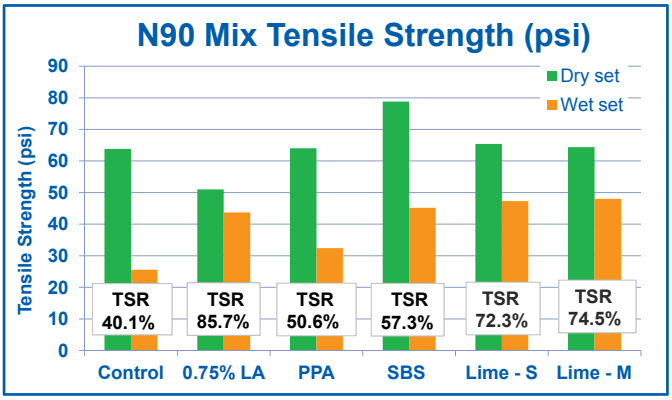
Moisture Damage

Experimental Program



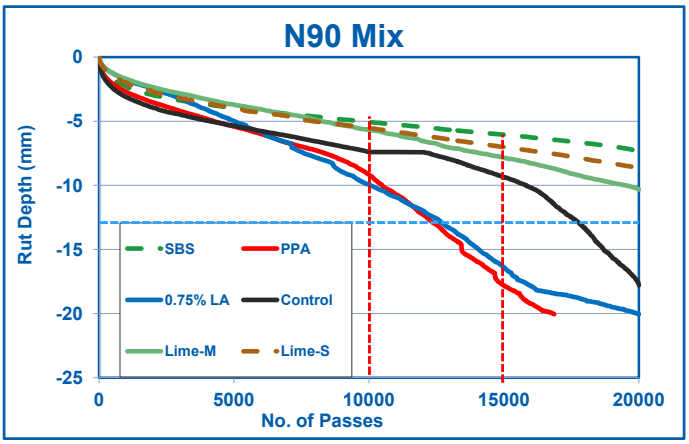
Moisture Damage

AASHTO T-283 Test – 5 FT Cycles



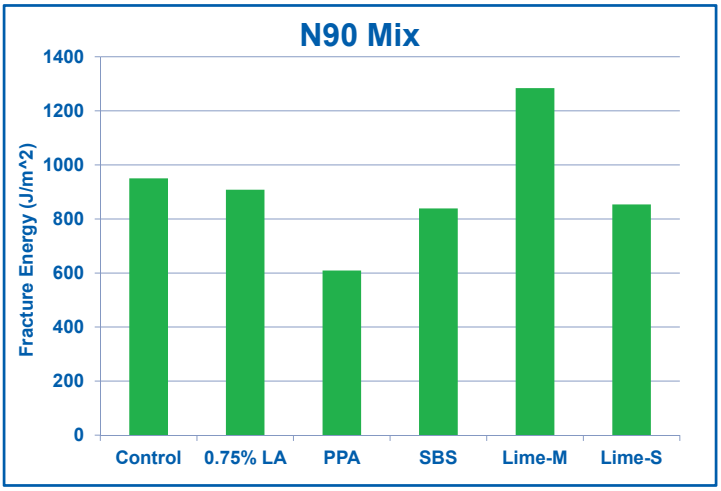
Moisture Damage

Wheel Track Test



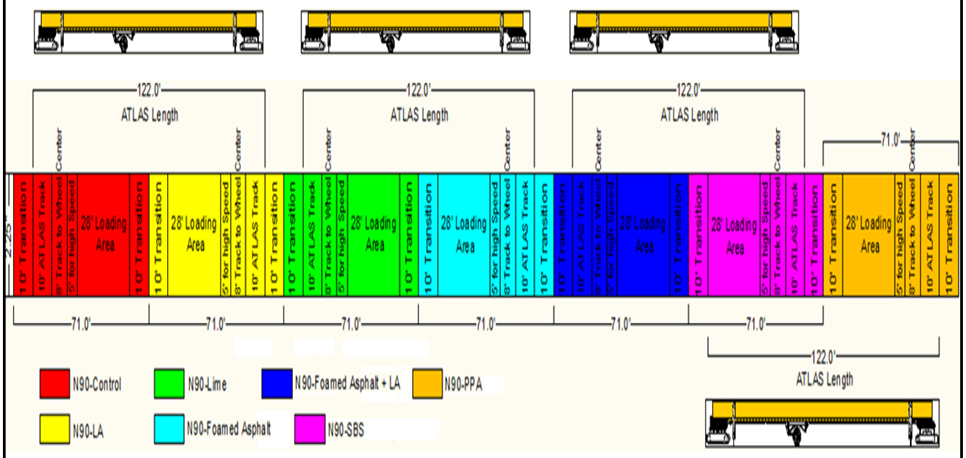
Moisture Damage

Fracture Test (SCB)



Moisture Damage

APT Testing



Moisture Damage

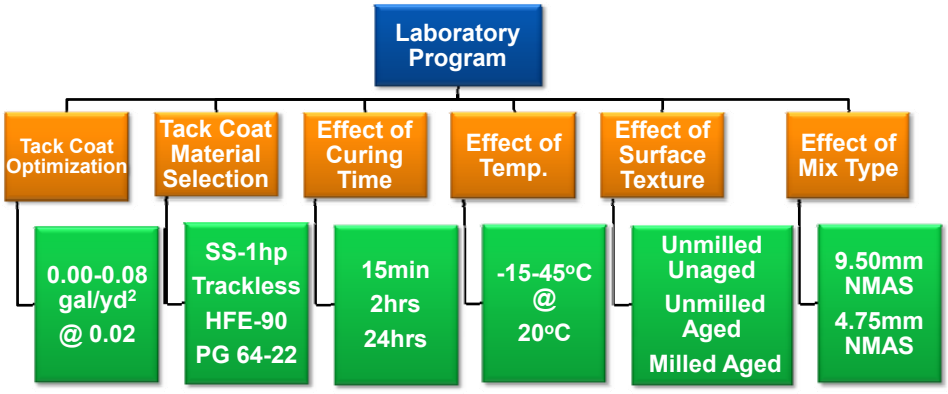
Preliminary Outcome

- Lime maintained the highest tensile strength for conditioned set
- SBS and Lime provided the highest rutting resistance
- TSR value shows that Liquid antistrip provides the least moisture susceptible mix
- Liquid antistrip and Lime enhanced mix fracture energy
- PPA in general had the least performance in all tests

Best Practices for Implementation of Tack Coat

- **Objective**
  - Identify the best methods for applying tack coat at verified application rate to optimize tack coat material selection and application method
- **Research was conducted in two phases:**
  - Laboratory Phase
  - Field Evaluation Phase

Laboratory Phase



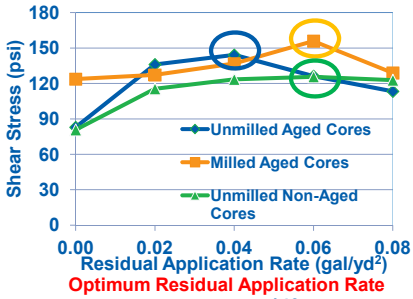
Testing Equipment

- **Shear Test (Shear Stress)**

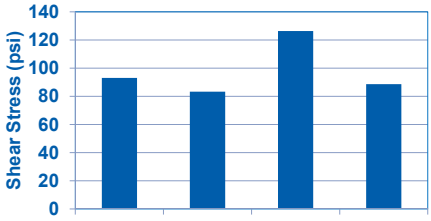
- **Torque Test (Bond Strength)***

*Field Study Only

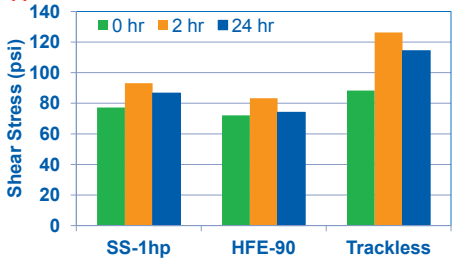
Results & Analysis



Optimum Residual Application Rate



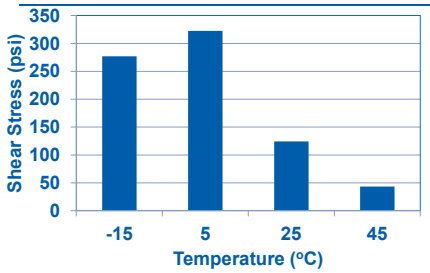
Tack Coat Material Selection



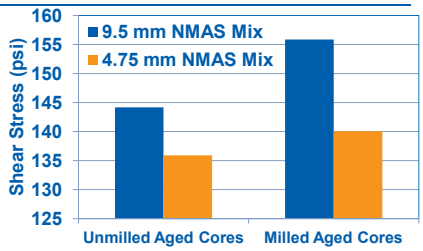
Effect of Curing Time

Tack Coats

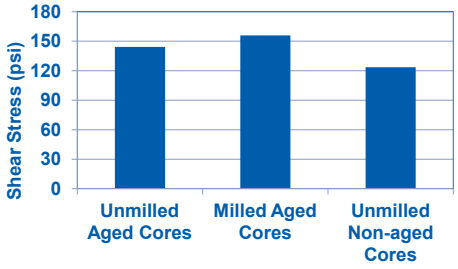
Results & Analysis Cont.



Temperature Effect



Mix Type Effect



Surface Texture Effect

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Tack Coats

Field Study

- Field Study
  - I-80 Project (26 Sections)

  - IL-98 Project (19 Sections)

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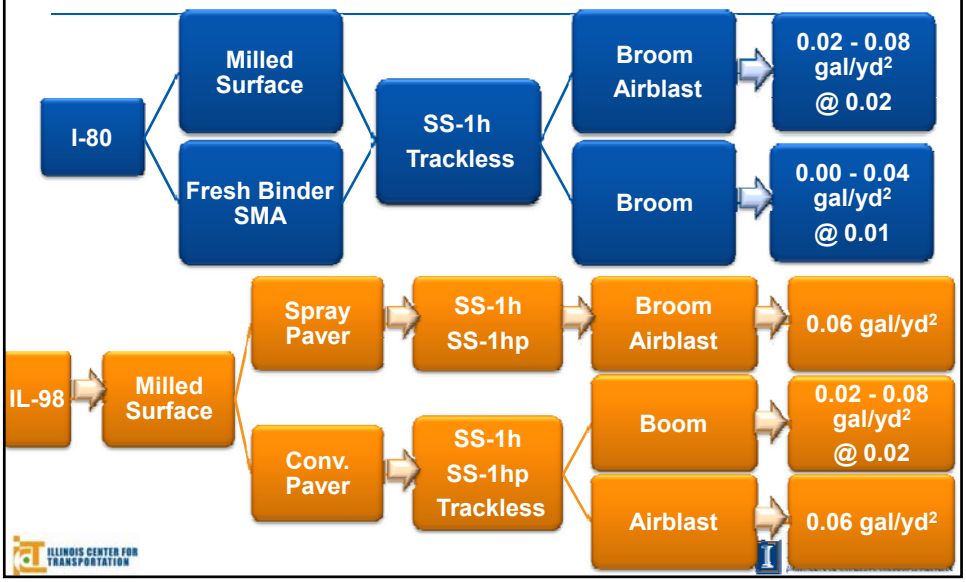
Tack Coats

Field Matrices



Tack Coats

Trackless Application

- Distributor truck was used at both construction projects
- Application temperature was 175°F

I-80 Trackless Application

IL-98 Trackless Application

Tack Coats

Spray Paver at IL-98




Tack Coats

Results I-80

- Optimum residual application rate decreases with air blast, maintaining the same bond strength.

Testing Method	Tack Coat	Surface Type	Cleaning Method	Optimum. Res. App. Rate (gal/yd^2)
Shear	SS-1h	Milled AC	Broom	0.06
			Air Blast	0.04
	Trackless	Milled PCC	Broom	
			Air Blast	
	SS-1h	SMA Binder	Broom	0.00
	Trackless			0.02

Tack Coats

Preliminary Outcome

- Optimum Residual Application Rate for milled surface 0.06 gal/yd^2 and for aged unmilled surface 0.04 gal/yd^2
- Trackless tack coat performed better than SS-1h at both field and lab testing.
- Life cycle assessment will be performed (air blast cleaning and spray paver will be considered)
- IL-98 specimens are being tested and results will be available soon.

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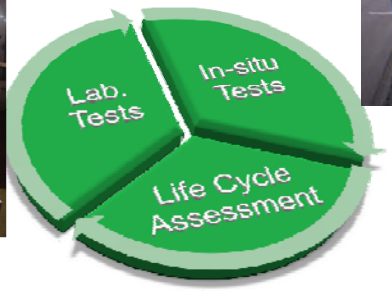
Warm Mixes

Short-term Performance Characterization of Warm-Mix SMA

- **Objective:**
  - Investigate Performance Characteristics of Early-Age Warm-Mix SMA
- **Methodology**



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Warm Mixes

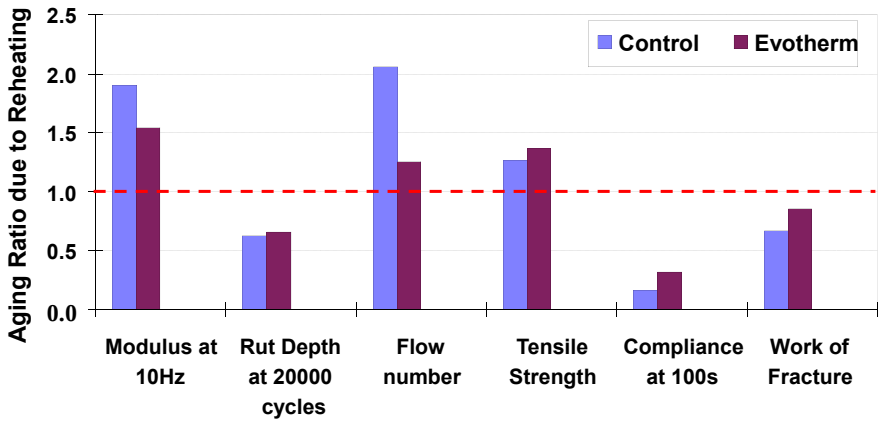
SMA Mix Design and Curing Time

Mixture	N	NMAS (mm)	Binder	RAP	RAS	Comp. Temp. (°F)	WM Additive
Control	80	12.5	PG 64-22 (12% GTR)	8%	X	305	X
Evotherm			PG 64-22 (12% GTR)		X	260	0.5% of binder
Sasobit			PG 70-22 (SBS modified)	5%	5%	260-280	1.5% of binder
Foamed			PG 64-22 (12% GTR)	13%	X	260	1.0% of binder

Test (Replicates)	Curing Time								
	3h	6h	12h	24h	3d	7d	3w	6w	12w
E* (3)	■	■	■	■	■	■			
Flow Number (3)				■	■	■			
Hamburg (2)	■	■	■	■	■	■			
IDT Creep/Strength (2)	■	■	■	■	■	■			
SCB (4)				■	■	■	■	■	■

Warm Mixes

Aging Effect due to Reheating



$$\text{Aging Ratio} = \frac{\text{performance of reheated mix}}{\text{performance of fresh mix}}$$

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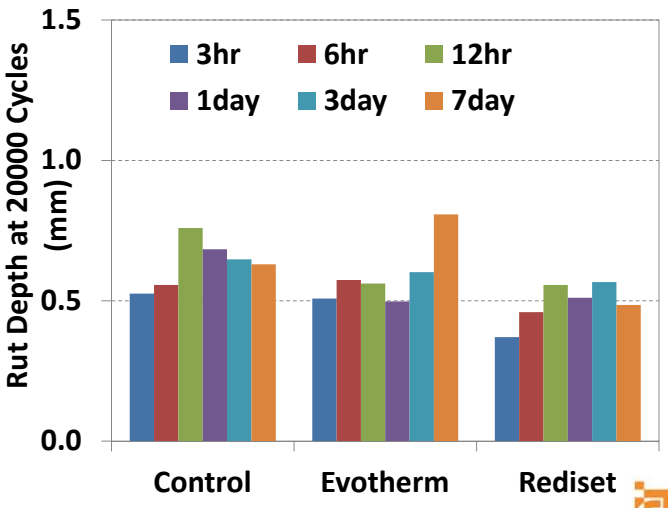
Preliminary Results: Wheel Track (LPLC)



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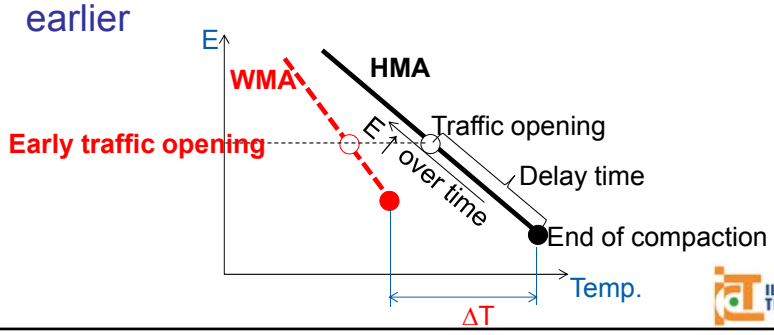
Traffic Opening Time

- Compaction Temperature
  - High enough to ensure workability
  - Low enough to guarantee early-age performance
- Warm mix may have lower modulus than control SMA at same temp., but it still opens to traffic earlier



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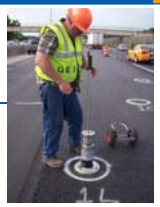
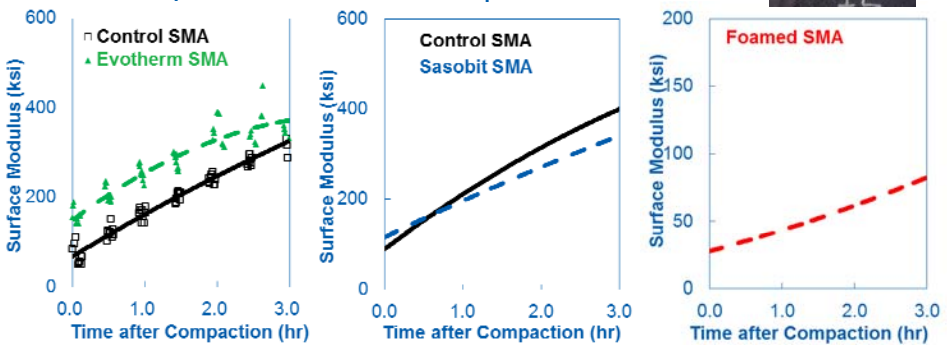
Warm Mixes

On-Site LWD Modulus



- Surface Deflection Modulus
  - Up to 3 hours after compaction



- I-355 (driving lane)
- Control and Evotherm SMA

- I-355 (driving lane)
- Control and Sasobit SMA

- I-90 (ramp)
- Foamed SMA

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Warm Mixes

Traffic Opening Time: Evotherm SMA

- **Criterion:** Control SMA and Warm SMA have the same modulus/strength (NOT temperature) at the traffic opening time

Traffic Opening Temperature for Control (°F)	Surface Modulus (ksi)	Temperature for Evotherm (°F)	Traffic Opening Time (hr)	
			Control	Evotherm
140	40.8	132.9	0	0
120	205.7	110.5	1.4	0.5
100	370.7	88.1	3.7	3.2

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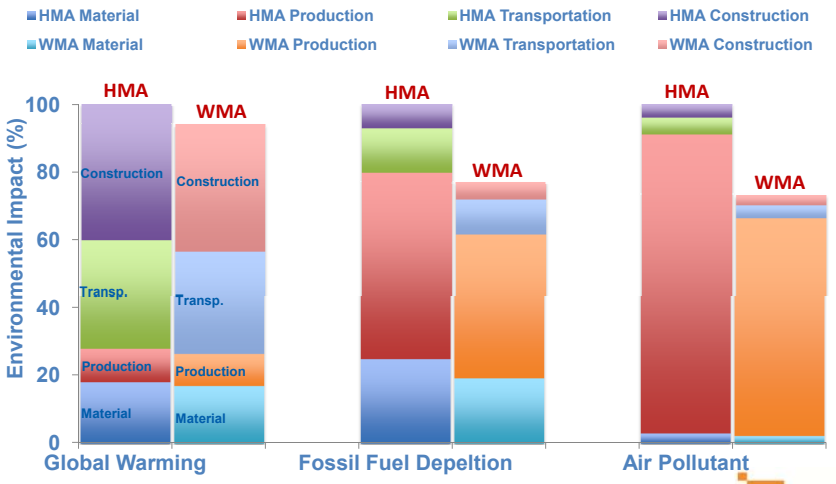
Environmental Effect: HMA vs WMA



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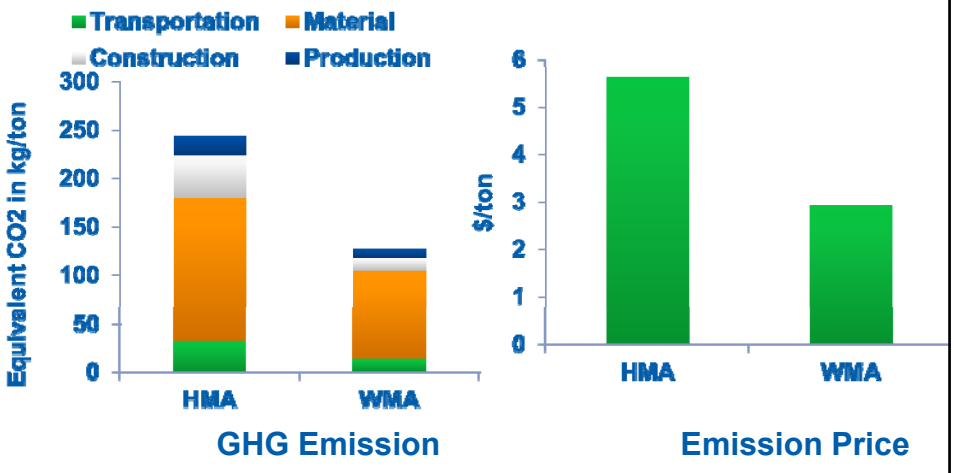
Green House Gas



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Life Cycle Cost of WMA

Cost \ Mixture	Control SMA	Warm SMA	Warm SMA (with 10% more RAP)
Agency Cost	$47,628	$49,094	$45,963
User Cost	$18,170	$13,463	$13,463
Environmental Cost	$977	$921	$921
Total Cost	$66,775	$63,479	$60,347

** Costs were calculated based on 1 lane-mile of binder layer (1.75 in thick) construction at the I-355 using control SMA and Evotherm SMA.*

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Warm Mixes

Expected Outcome to Date

- **Asphalt mixtures with various warm mix additives show comparable performance with control SMA**
- **Reheating affects mix performance characteristics**
  - Reheating effect is more significant for control SMA mixtures
- **Due to lower compaction temperature, WMA may be opened to traffic earlier than HMA, providing the same modulus**
- **WMA is more environmentally friendly than HMA, while at the same time being cost competitive**
- **Performance tests using lab-mixed and lab-compacted samples are currently underway**

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Questions/ Comments?

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