R27-204

Overlay Design for Controlling Reflective Cracking

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Illinois Bituminous Paving Conference

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Research Team

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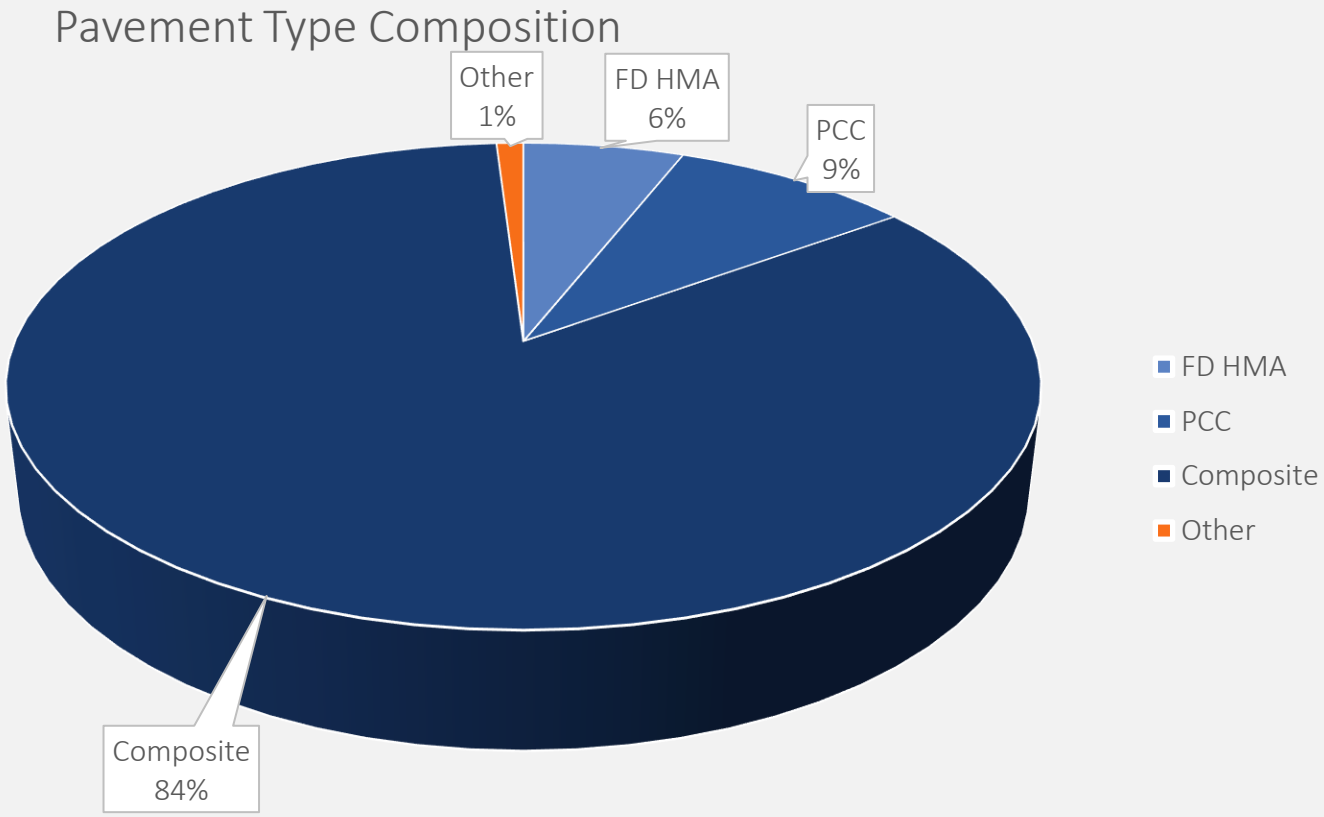
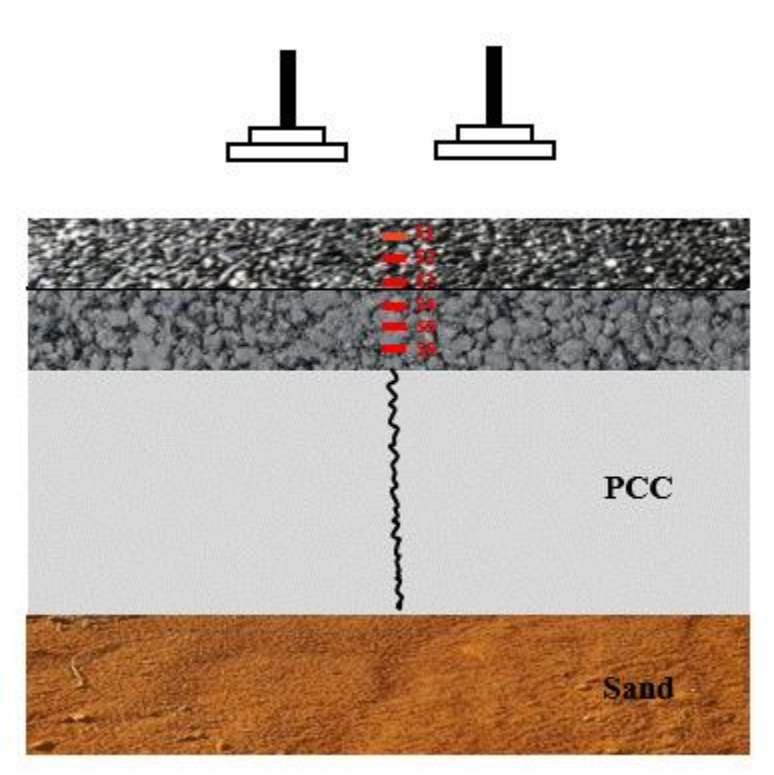
Illinois Roadway Network



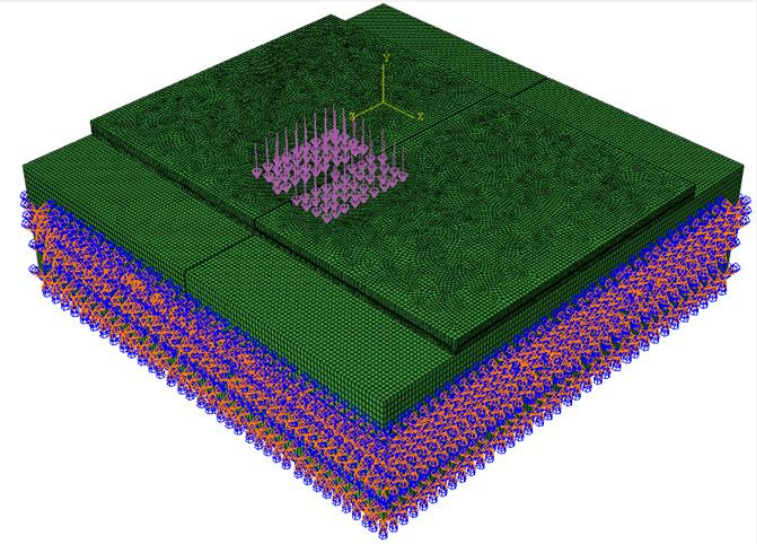
- 15,900 Centerline State Maintained Highway Miles
- 90% HMA Surfaced
- Composite pavements contain anywhere from 2.5” – 14” of HMA

Project Review

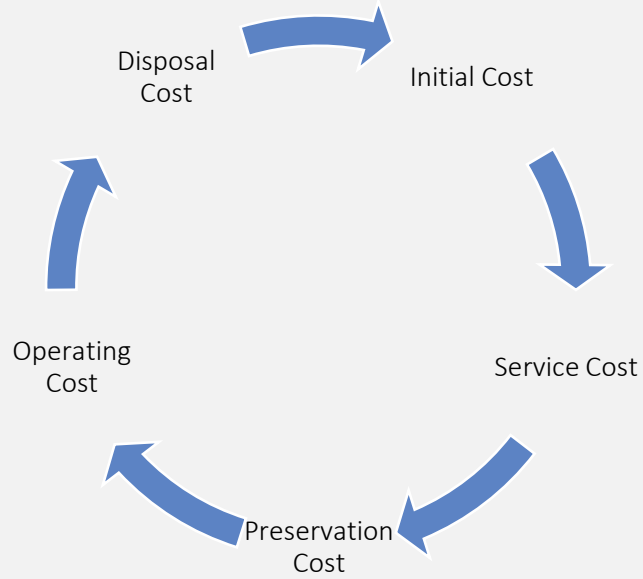
Lab Testing



Mechanistic Analysis



Life Cycle Cost Analysis

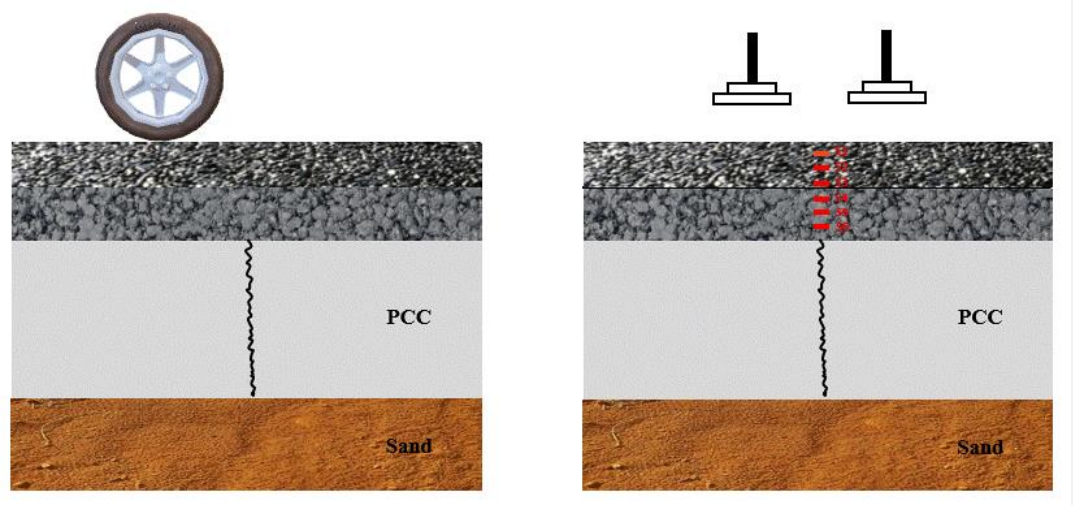


Lab Testing Overview

Small-Scale

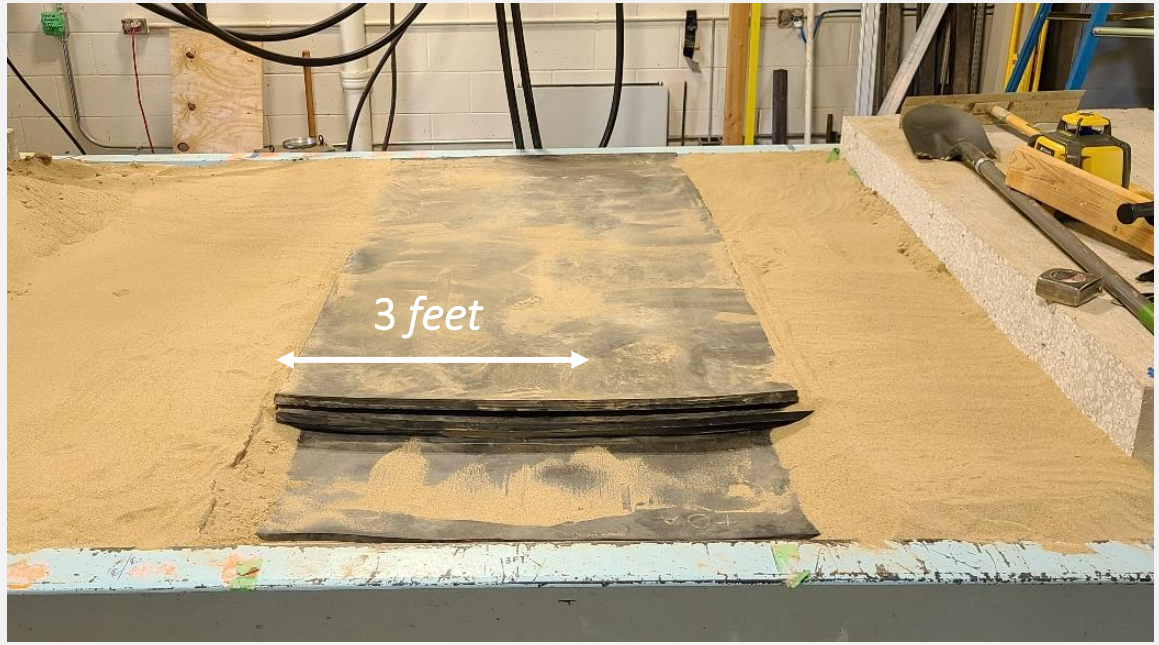
- I-FIT
- HWTT
- E*

Large-Scale



Subgrade Preparation

Compaction



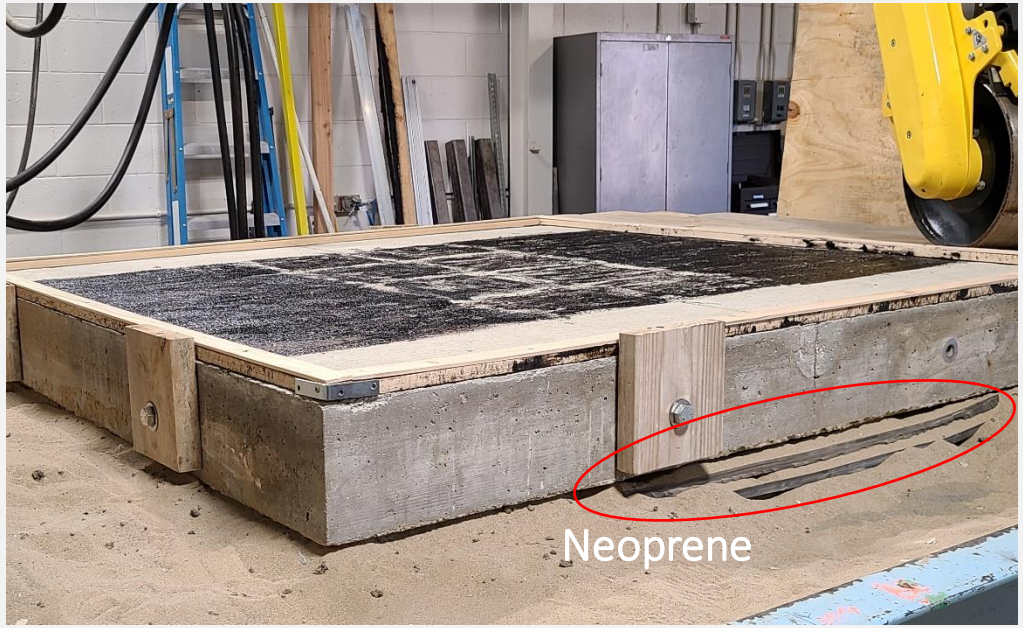
3.75in Neoprene Sheet

- *Amplify Deflection*
- *Accelerate Testing*

Concrete Slab Preparation and Placement

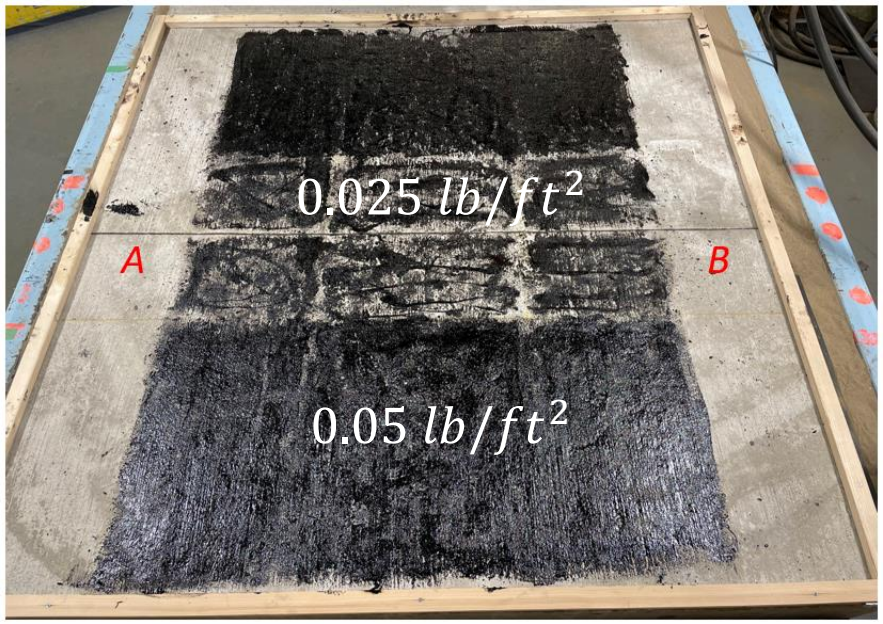
Saw Cut 6-in-deep

Place PCC



Place HMA

Slab Construction – Mix Preparation



Apply Tack Coat
(SS-1h)

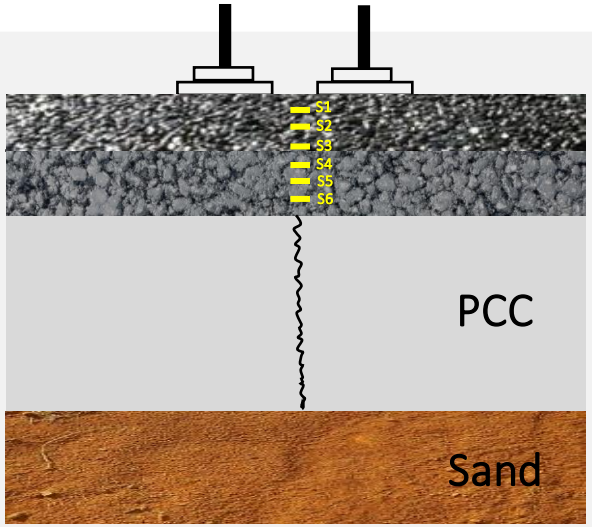
Pre-heat AC to
loose-state in oven

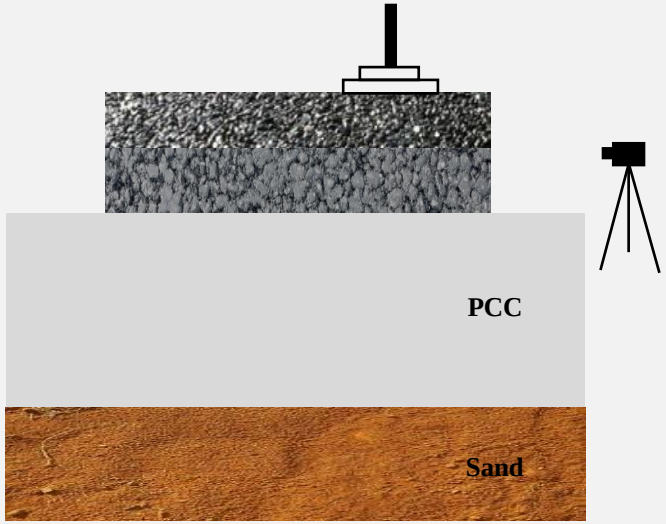
Heat to compaction
temperature in mixer

Slab Construction – Compaction

Discharge Materials → Spread & Level Materials → Lift Compaction → Saw Cut Overlay Edge

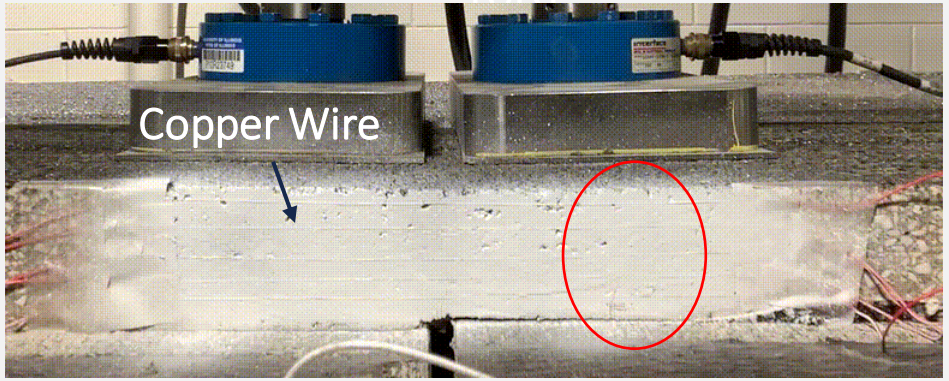
Instrumentation





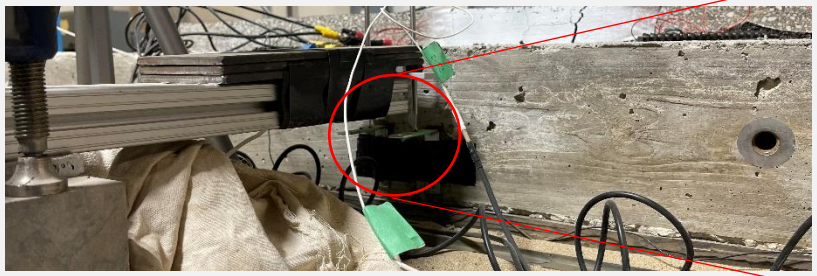
Goal 1: Measure Crack Propagation Speed

Camera & Copper Wires



Goal 2: Measure PCC Deflection

LVDT

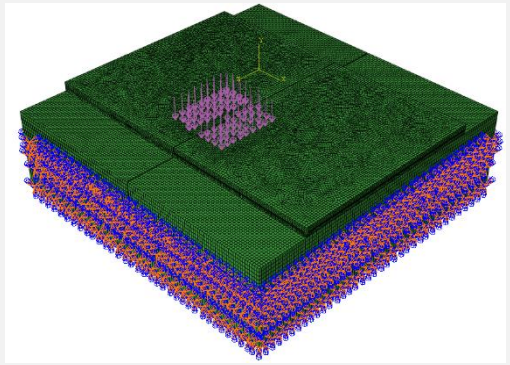


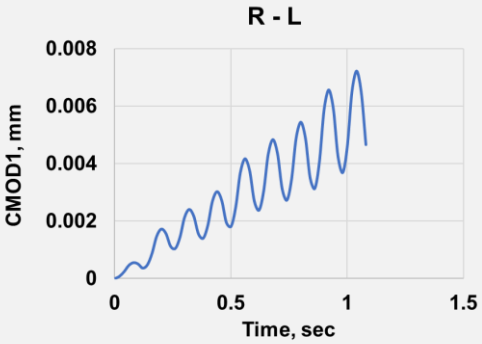
HMA Mixtures Included

ID	N-Design	AC (%)	Binder Grade	ABR (%)
IL-4.75	50	8.2	SBS PG 70-22	10.0
IL-9.5	70	6.1	PG 58-28	29.3
IL-9.5FG	90	5.9	SBS PG 70-22	0.0
IL-19	70	5.3	PG 58-28	20.0
SMA-9.5	80	6.6	SBS PG 76-22	9.8
SMA-12.5	80	6.3	SBS PG 76-28	14.7

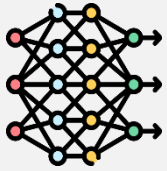
Summary of Mechanistic Analysis

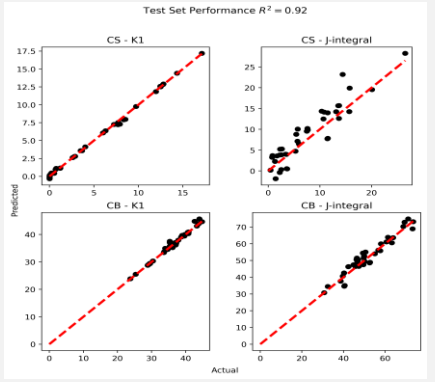
- Test slab was modeled
  - Computed fracture parameters using assigned crack
  - Mode I was dominant
- Model validation
  - Ranking based on fracture parameter
  - K_I was a good measure
- Surrogate model
  - Simulation matrix of 128 cases
  - Neural network – Generalized and accurate





Average K_1 (MPa.mm$^{-0.5}$)	Rank	Actual Rank (From experiments)
30.28	NIS Alt-3	NIS Alt-3
31.32	NIS Alt-2	NIS Alt-2
31.90	NIS Control	NIS Control
33.23	NIS Alt-1	NIS Alt-1
26.14	IS Alt-2	IS Alt-2
29.61	IS Alt-1	IS Alt-1
31.32	IS Control	IS Alt-3
32.31	IS Alt-3	IS Control



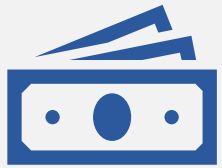


LCAA Overview

AC usage and cost data analysis

Statistics of overlay scenarios (thickness, mixes)

Cost breakdown of projects per district



Unit price analysis

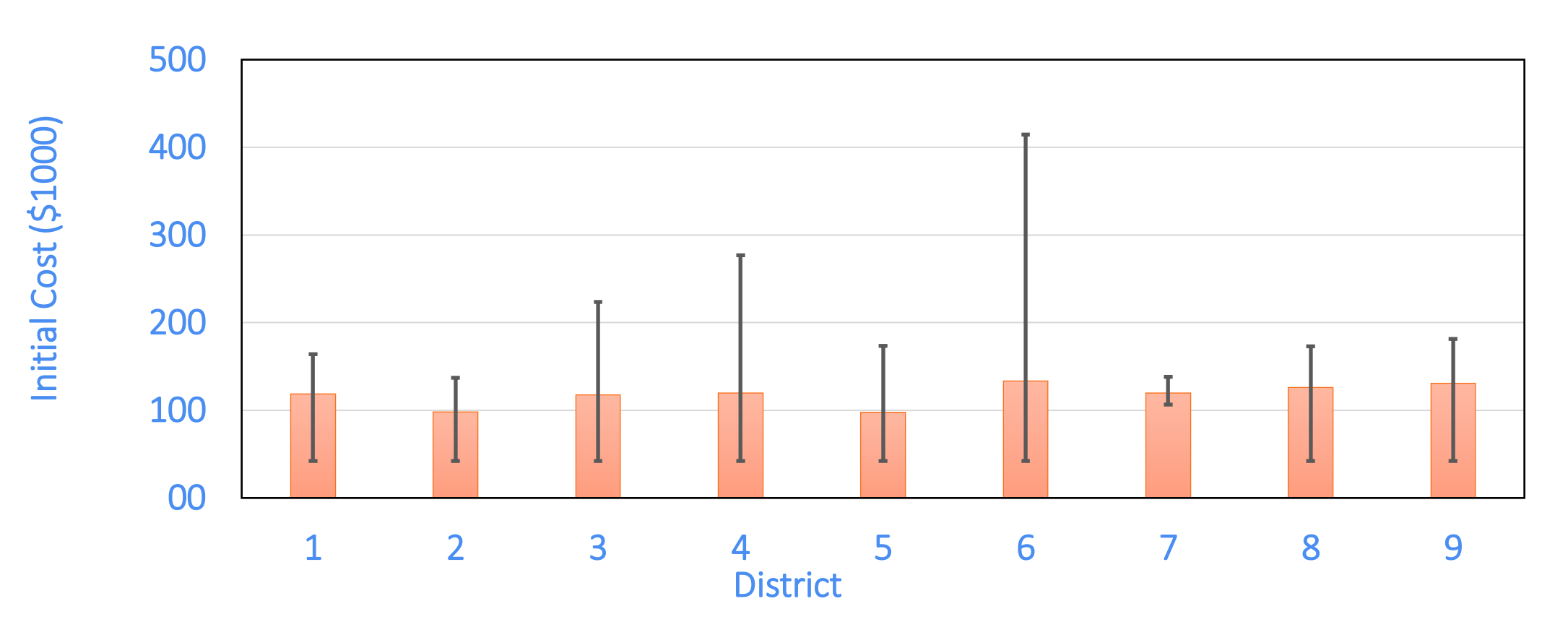
LCCA analysis of overlay scenarios

Based on large-scale test performance ranking

Sensitivity analysis

Average Initial Cost for Projects 2018-2019

Calculated for one lane-mile based on total AC quantity and unit price



Unit Prices for Different Scenarios

DISTRICT		Non-interstate				Interstate			
		C	1	2	3	C	1	2	3
1	Surface Binder	$91.2 $89.8	$91.2	$100.8 $89.8	$89.8	$63.5	$100.8 $108.8	$108.8 $63.5	$100.8
2	Surface Binder	$72.8 $110.0	$72.8 $71.4	$110.0	$71.4 $110.0				
3	Surface Binder	$85.1	$85.1 $85.4		$85.4	$79.4 $80.7	$123.0	$123.0 $80.7	$79.4
4	Surface Binder	$117.8		$116.8 $117.8	$117.8	$113.3	$116.8 $111.0	$111.0 $113.3	$116.8
5	Surface Binder	$118.5	$73.0	$118.5	$73.0 $118.5		$129.2	$129.2	
7	Surface Binder		$80.5		$80.5	$99.6 $87.1	$119.5	$119.5 $87.1	$99.6
8	Surface Binder	$90.6	$90.6 $93.2		$93.2	$93.6 $89.5		$89.5	$93.6
9	Surface Binder	$88.2	$88.2 $91.5		$91.5	$110.4 $71.7		$71.7	$110.4
Avg.	Surface Binder	$85.6 $109.0	$85.6 $82.5	$108.8 $109.0	$82.5 $109.0	$95.8 $84.3	$108.8 $118.3	$118.3 $84.3	$108.8 $95.8

Life Cycle Cost and Large Scale Testing

Classification		Surface Course	Binder Course	Number of Cycles to Failure	Assumed Service Life (Years)	Annual Cost Per Mile ($/Yr)
Non-Interstate	Control	1.5” IL-9.5	0.75” IL-4.75	14,600	10	14,902
	Alt 1	1.5” IL-9.5	1.25” IL-9.5FG	14,600	10	15,754
	Alt 2	1.5” SMA-9.5	0.75” IL-4.75	69,850	14	11,474
	Alt 3	1.25” IL-9.5FG	0.75” IL-4.75	111,500	14	9,772
Interstate	Control	1.5” IL-9.5	2.25” IL-19	9,700	10	19,751
	Alt 1	1.5” SMA-9.5	2.0” SMA-12.5	16,200	12	18,550
	Alt 2	2.0” SMA-2.5	2.25” IL-19	23,700	14	16,579
	Alt 3	1.5” SMA-9.5	1.5” IL-9.5	10,200	10	18,711

Interesting Findings

Significant joint opening, caused by loading and low bonding at binder-PCC interface, induced rapid failures of AC overlays

- Debonding at binder-PCC interface substantially affected crack initiation
- Least debonding would delay crack initiation, and, hence, failure

Debonding at surface-binder interface impacted crack propagation

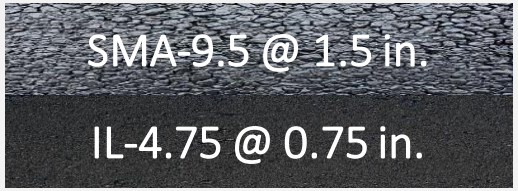
- Specially if one AC layer is polymer-modified while the other is not

Conclusions

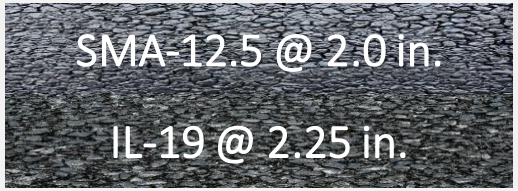
- An optimum overlay to control reflective cracking comprises of a high modulus and flexible surface, and a flexible binder course
- The thicker the AC overlay is, the enhanced resistance to reflective cracking
- Mode I SIF could be used to rank overlay's reflective cracking potential
- A developed robust surrogate model could be used to design overlay
- An overlays with premium mixes or extra thickness could be cost-effective if service life could be improved (e.g., two years).

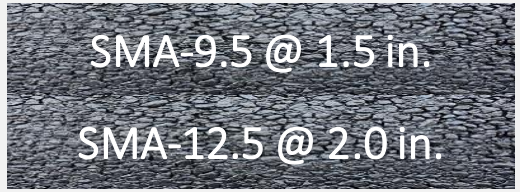
Recommendations

Non-Interstate



Interstate





Other Things to Consider

- Pretreat joints and cracks
- Ensure the mixes meet the FI specifications
- Polymer-modified lifts
- Sufficient bonding between HMA and PCC

Technical Review Panel Members – Thank you!

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Questions

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