

Performance of Recycled Shingles in HMA

Update of Pooled Fund Study TPS-5(213)

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RAP ETG Meeting

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Introduction

- Started in 2009
- Three year study
- Principle Investigator
 - Chris Williams (Iowa State University)
- Co-Researchers
 - Debra Haugen (Debra Haugen, LLC)
 - Mihai Marastaneu (University of Minnesota)
 - Jim McGraw (Minnesota DOT)

Partners

- Missouri (Lead State)
- Iowa
- Minnesota
- Indiana
- California
- Illinois
- Colorado
- Wisconsin
- FHWA



Research Tasks

- Conduct a literature review of nationwide application of manufactured and tear-off asphalt shingles including specifications, case studies/demonstration projects, and environmental white papers and completed research on asbestos and polycyclic aromatic hydrocarbons in RAS.
- Review and implementation of QC/QA of equipment and best practices for processing and sourcing of shingles through demonstration projects.
- Development of mix design and construction specification criteria for HMA utilizing post consumer RAS.
- Construction of demonstration projects utilizing post consumer RAS included QC/QA testing of materials during construction.
- Characterization of binder qualities of RAS and recovered mix binders from demonstration projects.
- Mix performance testing of design mixtures as well as procured samples from field demonstration projects.
- Field performance surveys of constructed demonstration projects.
- Statistical analysis of data including relationships between recovered binder characteristics and mixture performance.
- Development of the final report including recommendations for technology transfer.



Agency Interests in RAS

Agency	Research Interest	Mix Design Experimental Plan			
Iowa	» Percentage of RAS	0% RAS	4% RAS	5% RAS	6% RAS
Minnesota	» Post-Man. vs. Post-Consumer	0% RAS 30% RAP	5% Mfr RAS	5% Post-Cons. RAS	
Missouri	» Coarse vs. Fine Grind RAS	0% RAS 15% RAP	5% Fine RAS 10% RAP	5% Crse RAS 10% RAP	
Indiana	» RAS with Foaming WMA	15% RAP HMA	3% RAS HMA	3% RAS WMA	
Colorado	» Replacement of RAP with RAS	0% RAS 20% RAP	3% RAS 15% RAP	(Maintained 70% Virgin Binder Content in each mix)	
Illinois	» 5% RAS in SMA (no fibers added)	PG70-28 Lab Mix	PG70-28 Plant Mix	PG58-28 12% GTR	
Wisconsin	» RAS w/ RAP & 3G Compaction Aid	5% RAS No 3G	5% RAS 3G		

Laboratory Testing Plan



Laboratory Test		Iowa State University	University of Minnesota	Minnesota DOT
Processed Shingles	Binder Extraction			X
	High Temperature PG			X
	Gradation (Before Extraction)	X		
	Gradation (After Extraction)	X		
Mixture	Binder Extraction			X
	Binder PG Characterization	X		
	Gradation	X		
	Dynamic Modulus	X		
	Flow Number	X		
	Beam Fatigue	X		
	Semi-Circular Bending (SBC)		X	6

RAS Properties



(Gradations are prior to extractions)

	Iowa	Minnesota	Minnesota	Missouri	Missouri	Indiana	Colorado	Illinois	Wisconsin
RAS Source	Post-Cons.	Manuf.	Post-Cons.	Post-Cons.	Post-Cons.	Post-Cons.	Manuf.	Post-Cons.	Post-Cons.
3/4"	100	100	100	100	100	100	100	100	100
1/2"	97	100	100	100	98	100	99	100	100
3/8"	95	95	99	99	94	97	95	100	100
#4	84	70	85	82	75	74	70	91	83
#8	67	56	73	67	62	62	55	74	70
#16	44	32	49	43	42	38	31	48	47
#30	22	12	24	21	22	18	13	24	24
#50	10	4	10	12	12	9	6	11	11
#100	3	1	3	5	5	4	2	3	3
#200	0.6	0.4	0.5	0.9	1.2	0.7	0.3	0.5	0.6
% AC	21.1%	14.6%	20.5%	25.0%	21.7%	21.1%	18.1%	32.8%	35.4%
High PG	124.1	109.1	122.5	137.3	146.1	NA	111.2	131.3	128.8

Iowa Demonstration Project



- Tri-State Paving
- July 2010
- State Highway 10
- 16 miles
- 2" overlay
- 30k Tons



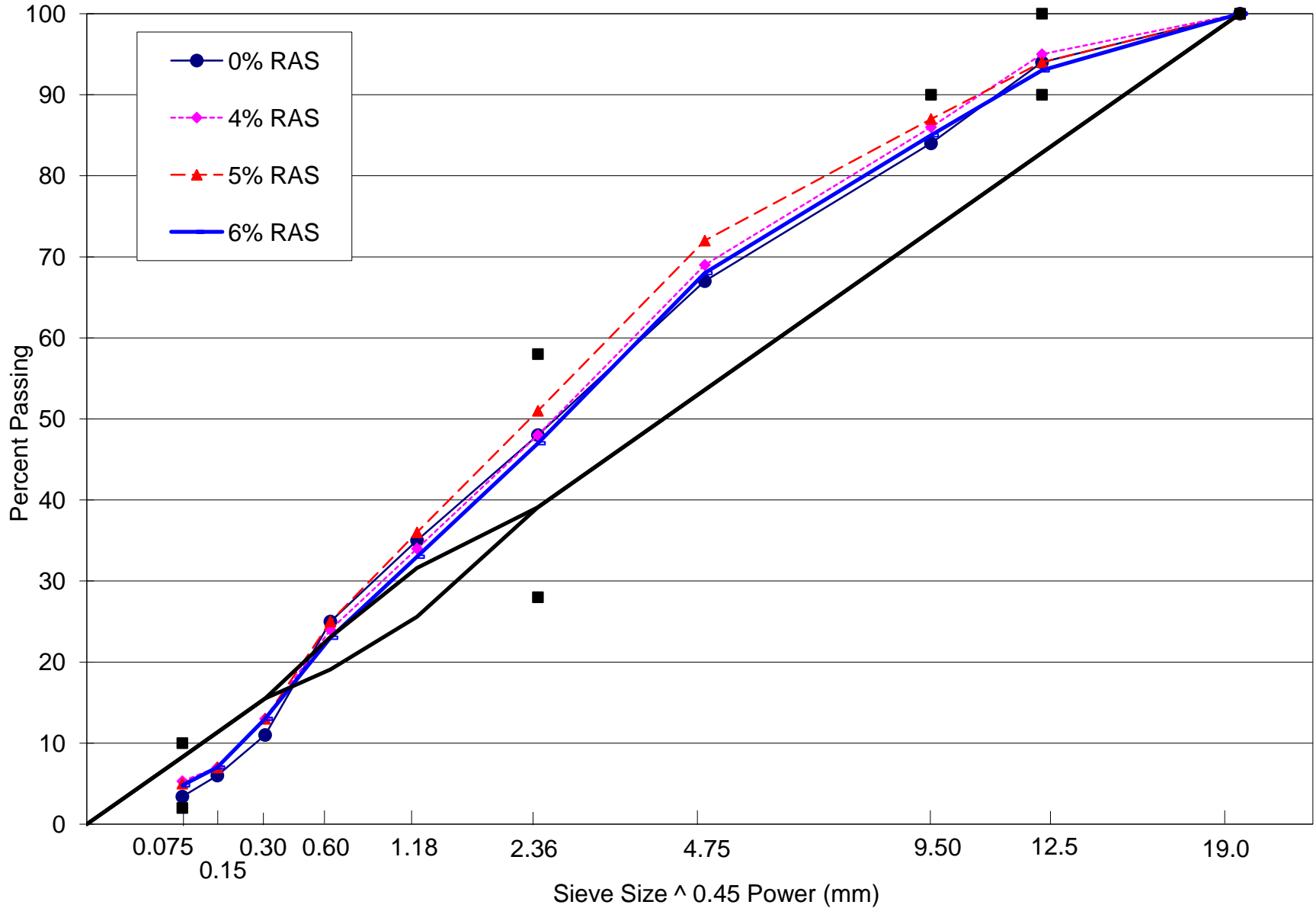


Iowa Mix Properties

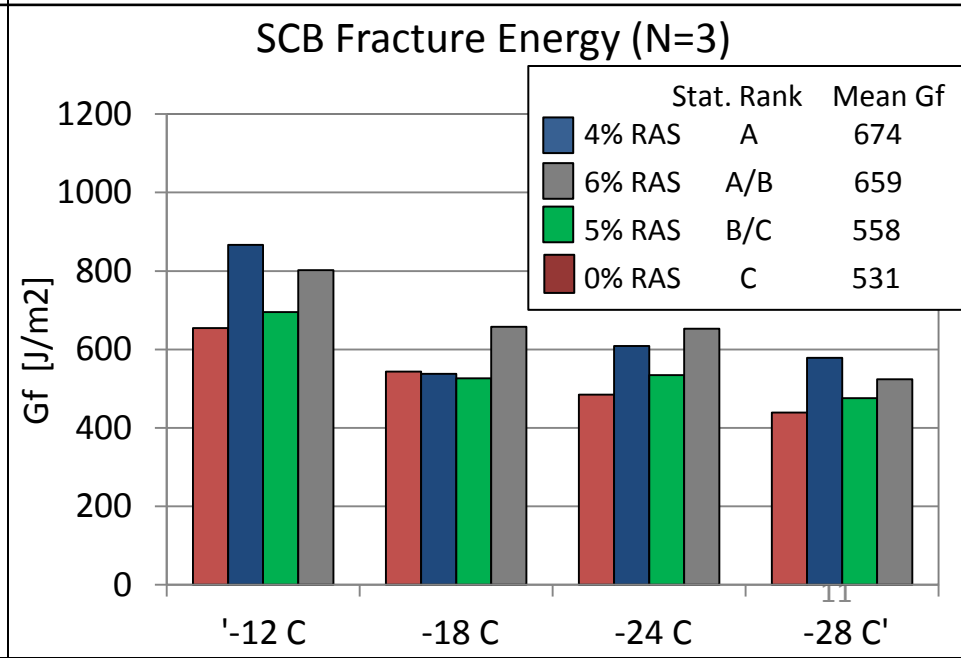
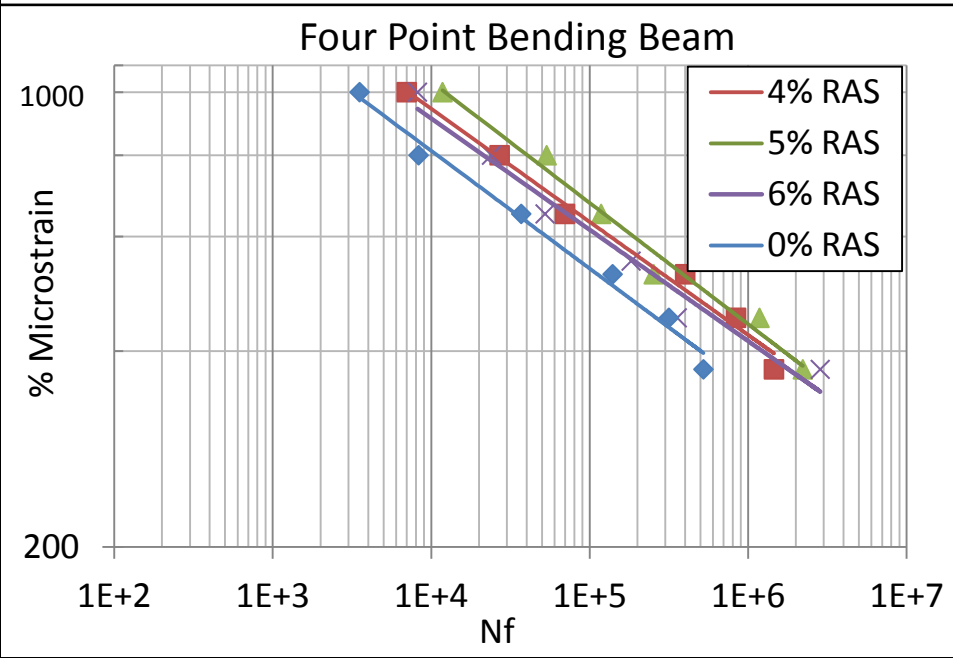
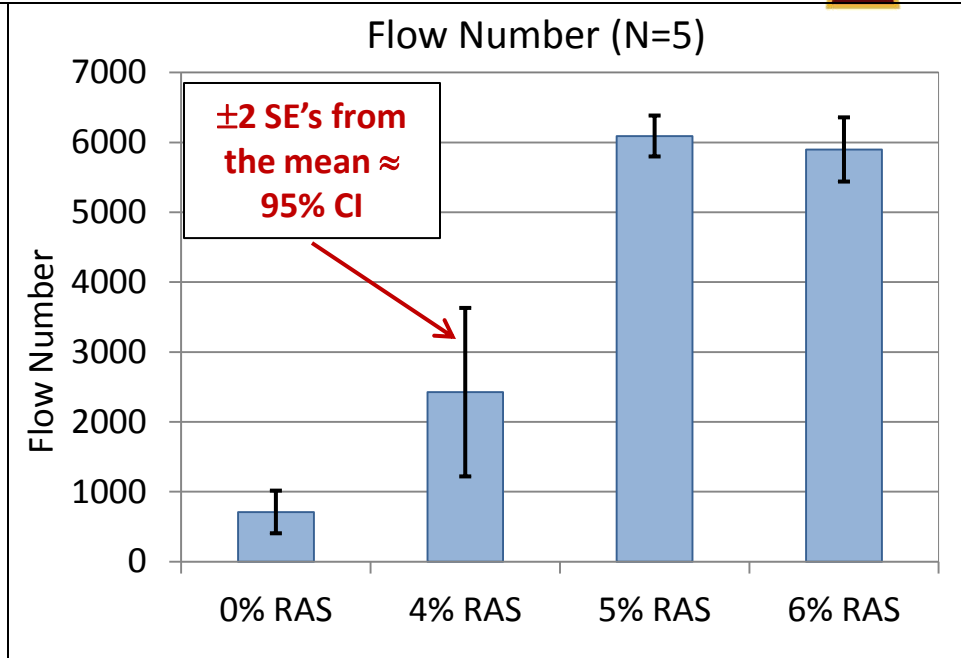
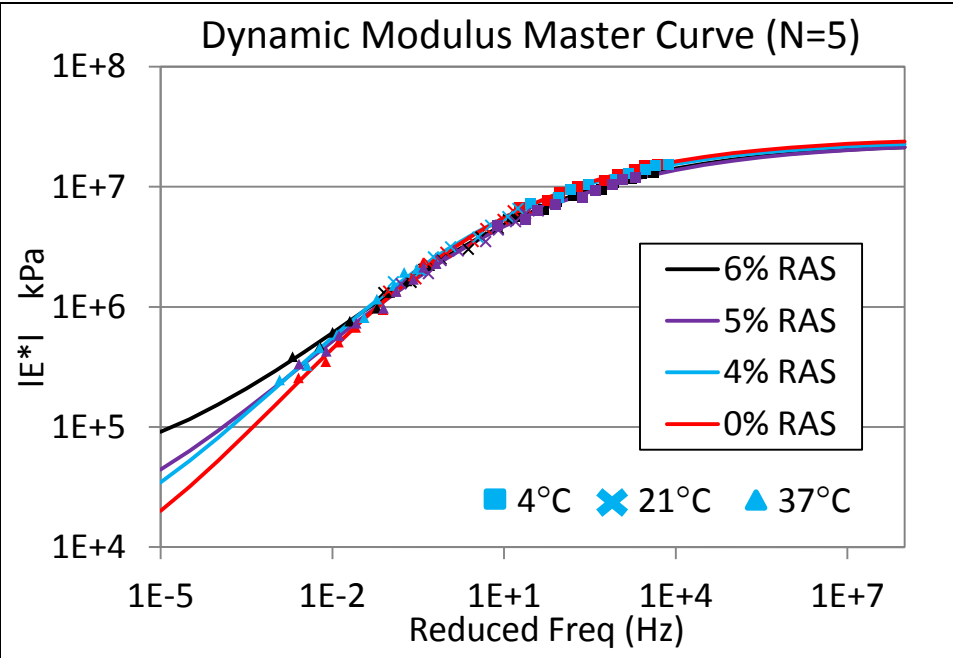
Mix Property	0% RAS	4% RAS	5% RAS	6% RAS
% RAS	0	4	5	6
% RAP	0	0	0	0
% Total AC from QC Results	5.5	5.4	5.5	5.4
% Binder Replacement	0	15.1	17.5	19.8
RAS Source	Post-Consumer	Post-Consumer	Post-Consumer	Post-Consumer
RAS Grind Size	< 12.5 mm	< 12.5 mm	< 12.5 mm	< 12.5 mm
Design Gyration	76	76	76	76
NMAS (mm)	12.5	12.5	12.5	12.5
Virgin PG Grade	58-28	58-28	58-28	58-28
High PG	73	75.8	81.3	86.1
Low PG	-19.7	-19.1	-16.7	-14.1 ^p



IADOT Mix Gradations



Iowa Mix Testing Results



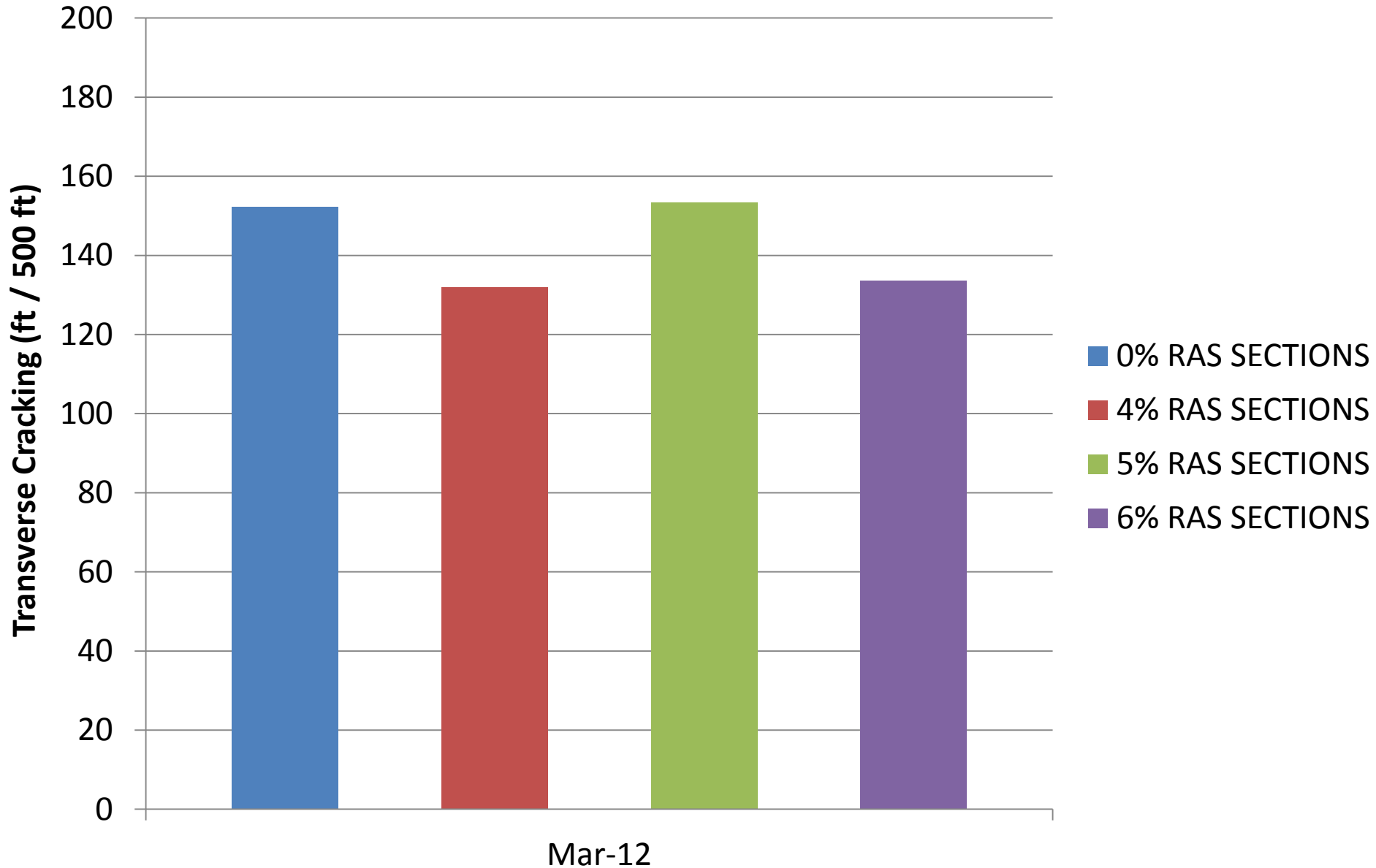






**Reflective crack from
jointed PCC pavement**

Iowa Pavement Evaluation



Minnesota

- 2008 Reconstruction of MnRoads on I-94
- Cells 5, 6, 13-23
- 5% RAS in Shoulders
- Post-Manufactured & Post-Consumer
- 30% RAP as control mix
- 12.5mm, 3" Overlay
- PG 58-28



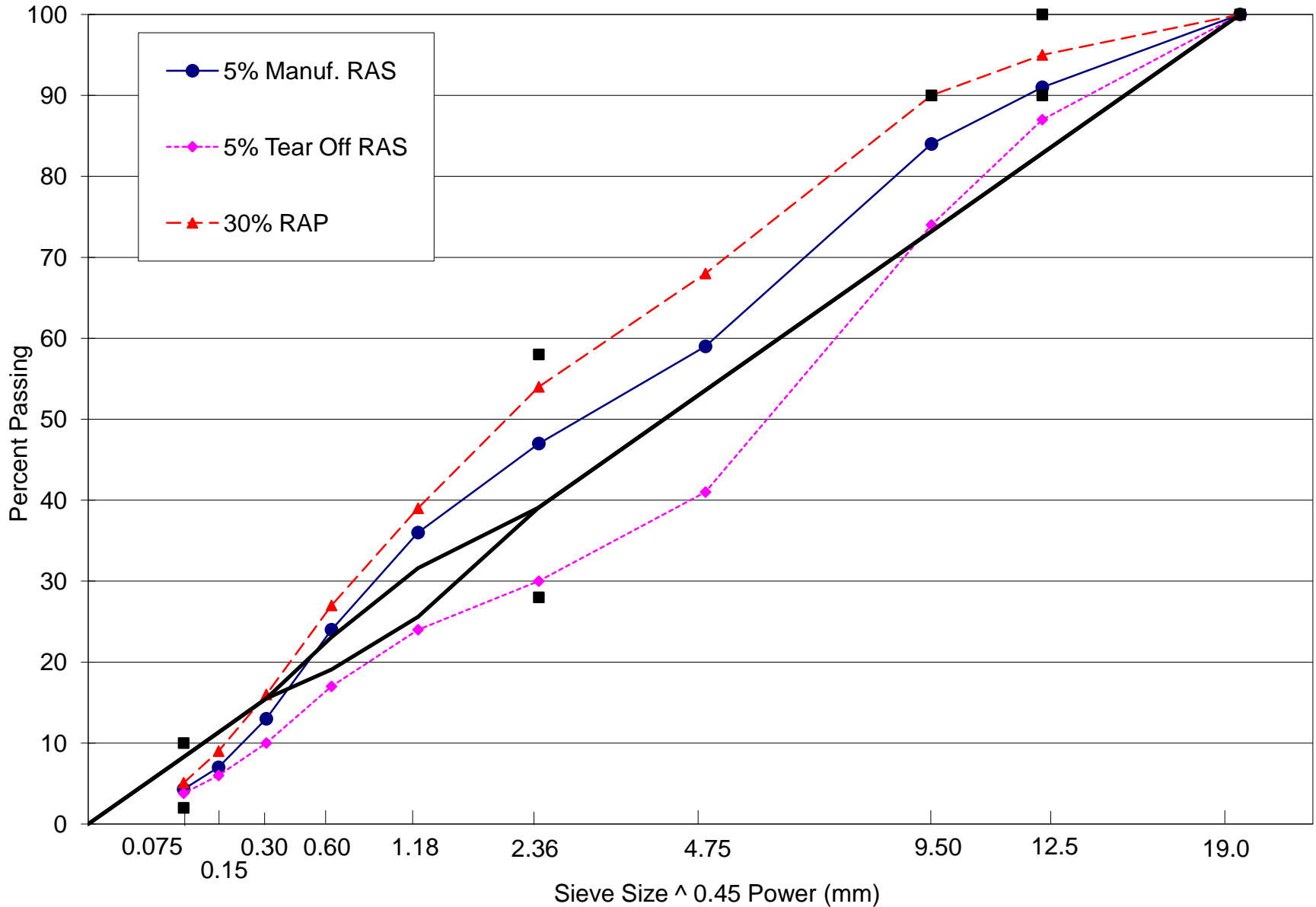


Minnesota Mix Properties

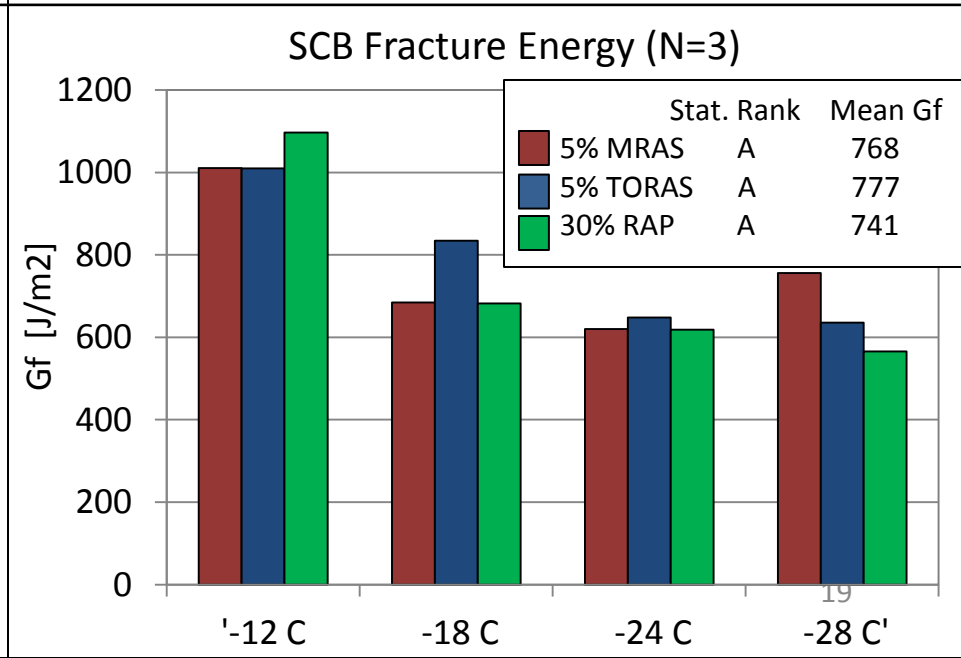
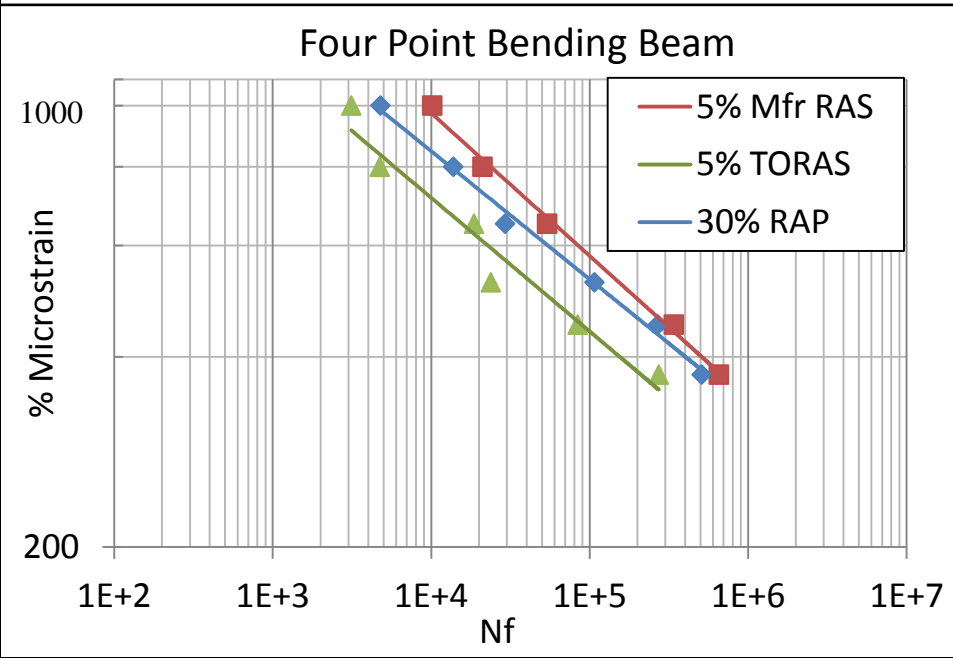
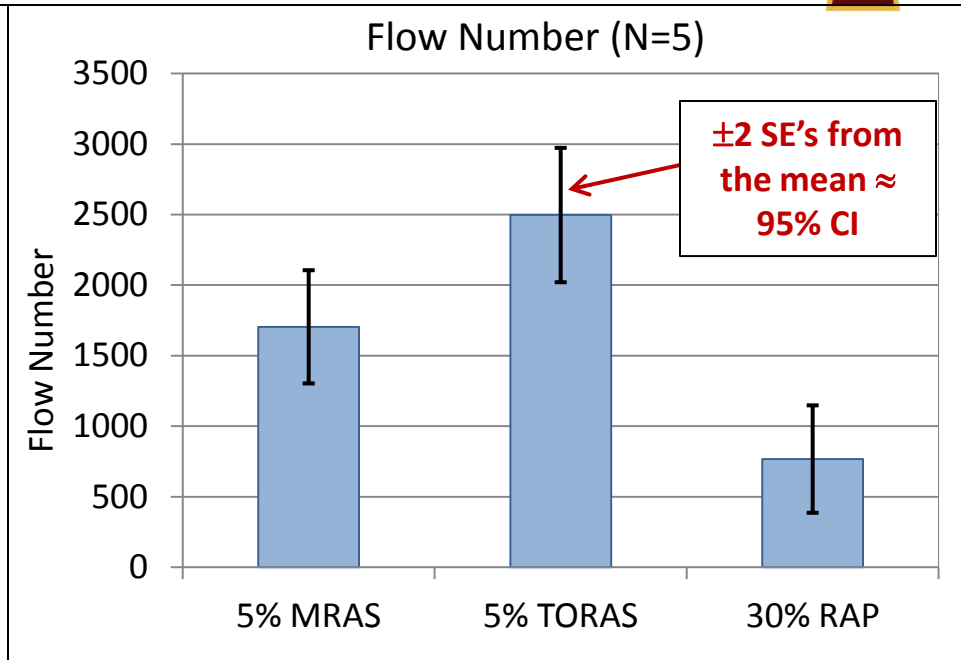
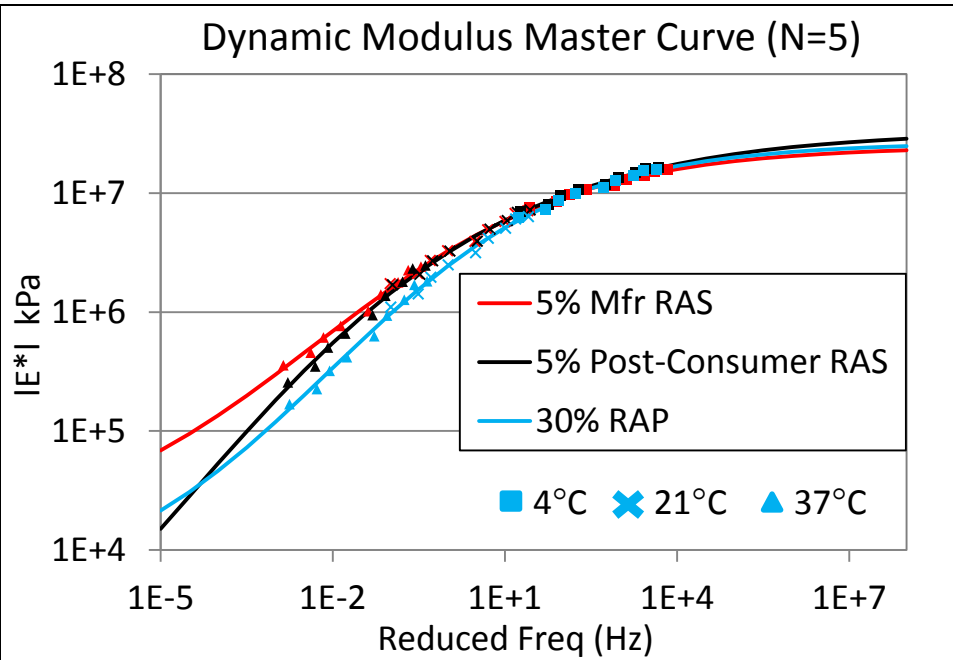
Mix Property	30% RAP	5% Mfr RAS	5% Post-Cons. RAS
% RAS	0	5	5
% RAP	30	0	0
% Total AC from QC Results	5.3	4.9	5.0
% Binder Replacement	33.4	14.9	20.5
RAS Source	-	Post-Manufacturer	Post-Consumer
RAS Grind Size	-	< 12.5 mm	< 9.5 mm
Design Gyration	90	90	90
NMAS (mm)	12.5	12.5	12.5
Virgin PG Grade	58-28	58-28	58-28
High PG	71.3	71.1	68.8
Low PG	-21.7	-21.6	-22.4 ¹⁷



MNDOT Mix Gradations



Minnesota Results



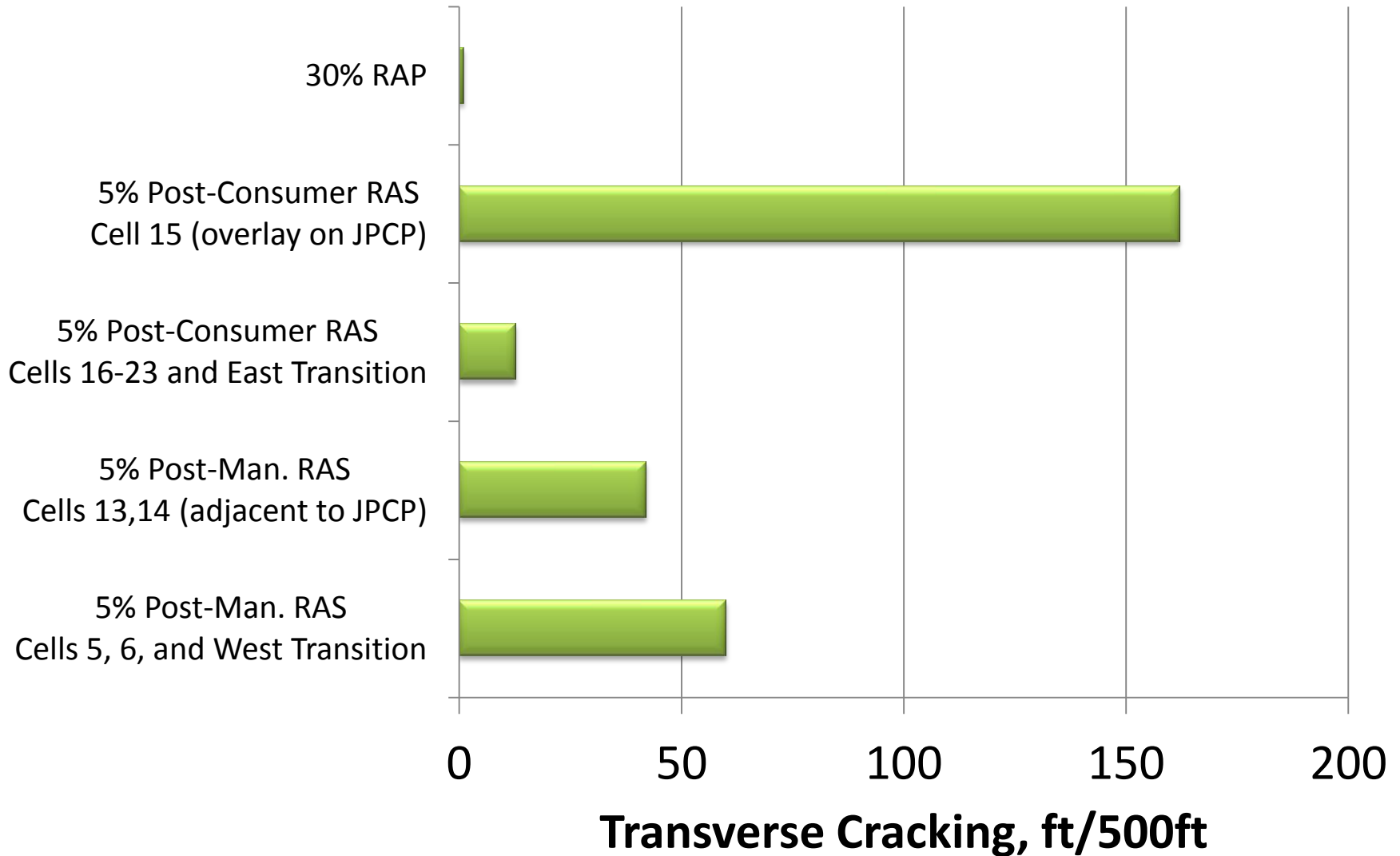


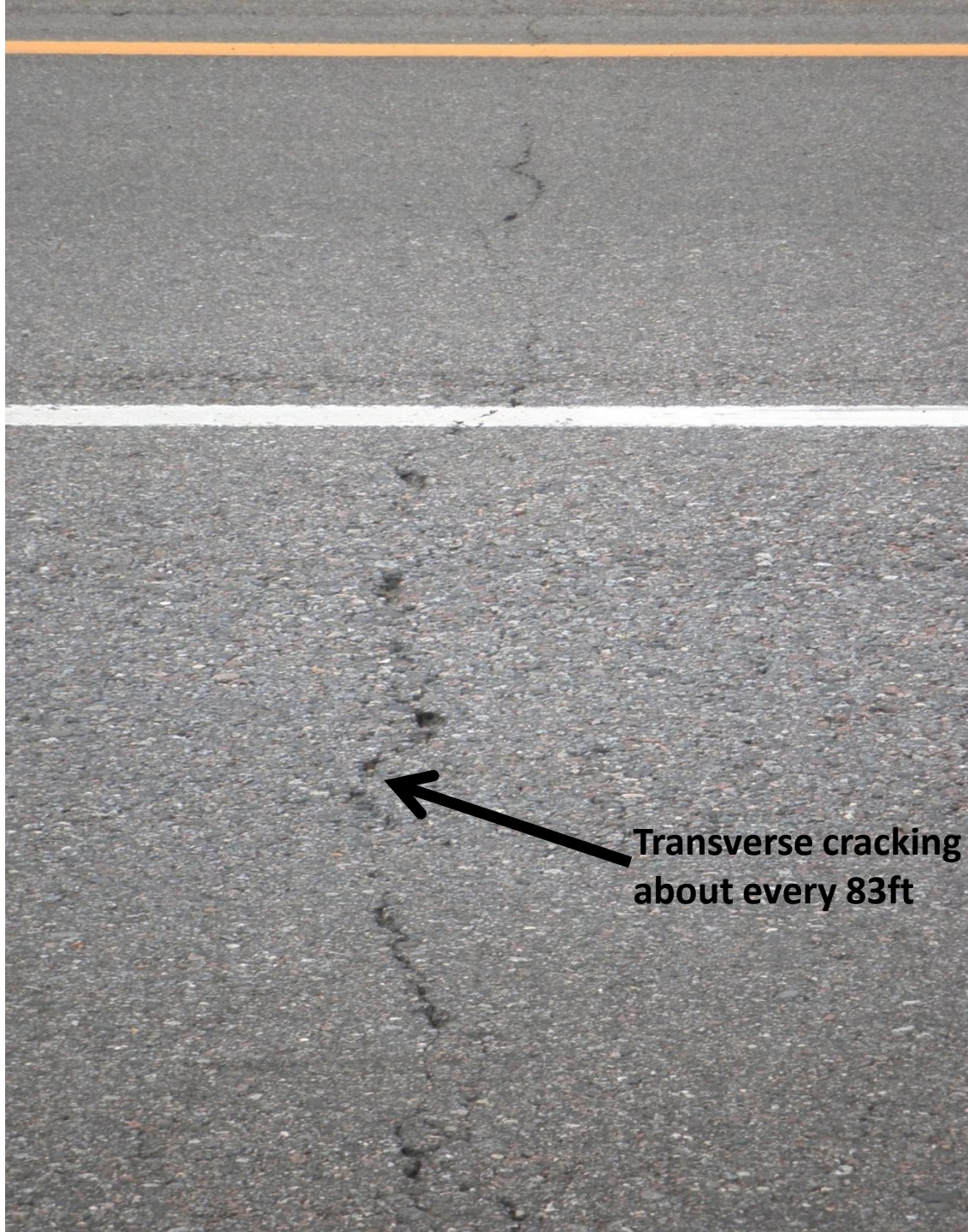
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Minnesota Pavement Evaluation

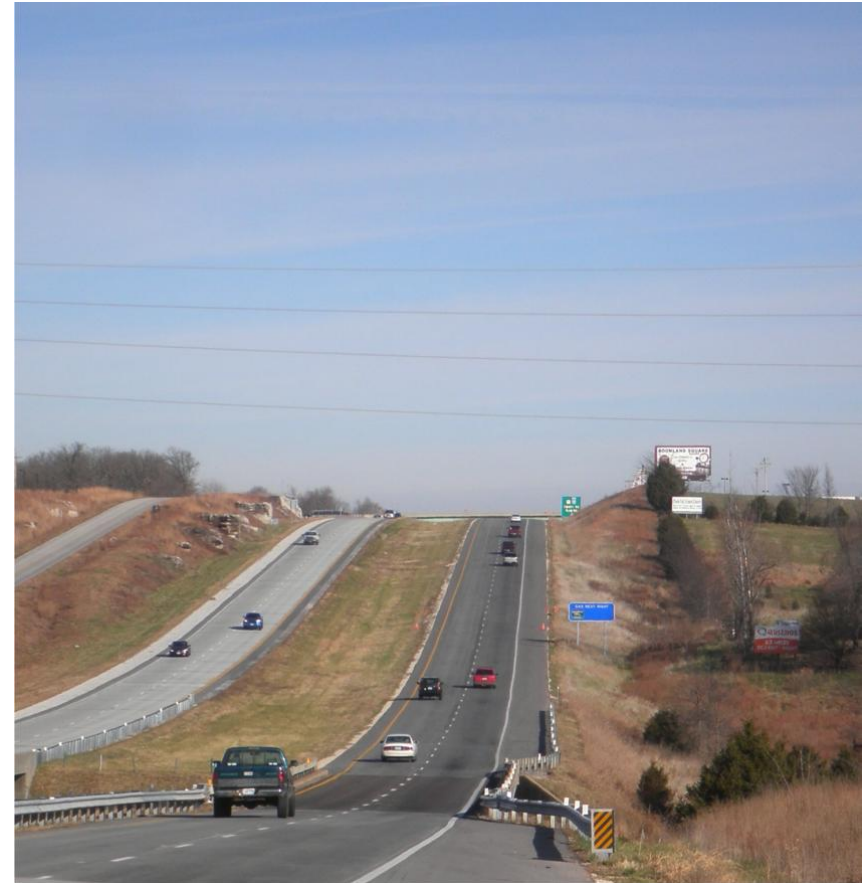




**Transverse cracking
about every 83ft**

Missouri

- US Route 65 south of Springfield
- June 2010
- Coarse vs. fine grind
- 12.5mm, 1.75" overlay
- 8.8 miles
- 26k Tons
- 3M > 30M ESALs
- PG 64-28 w/polymer & GTR



Missouri RAS

100% passing 3/8"
95% passing #4



25.0% AC

100% passing 1/2"



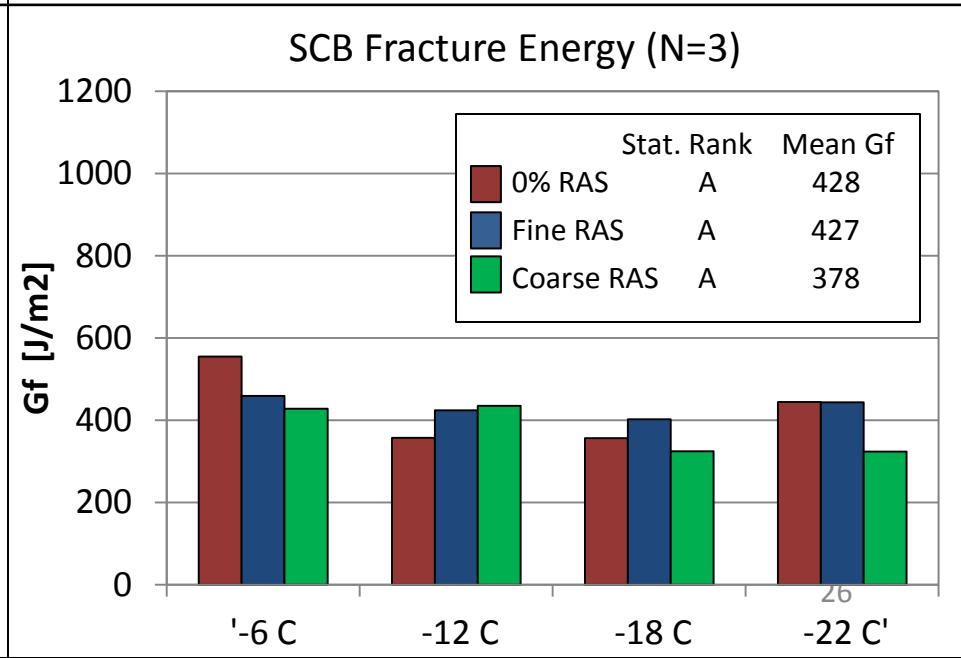
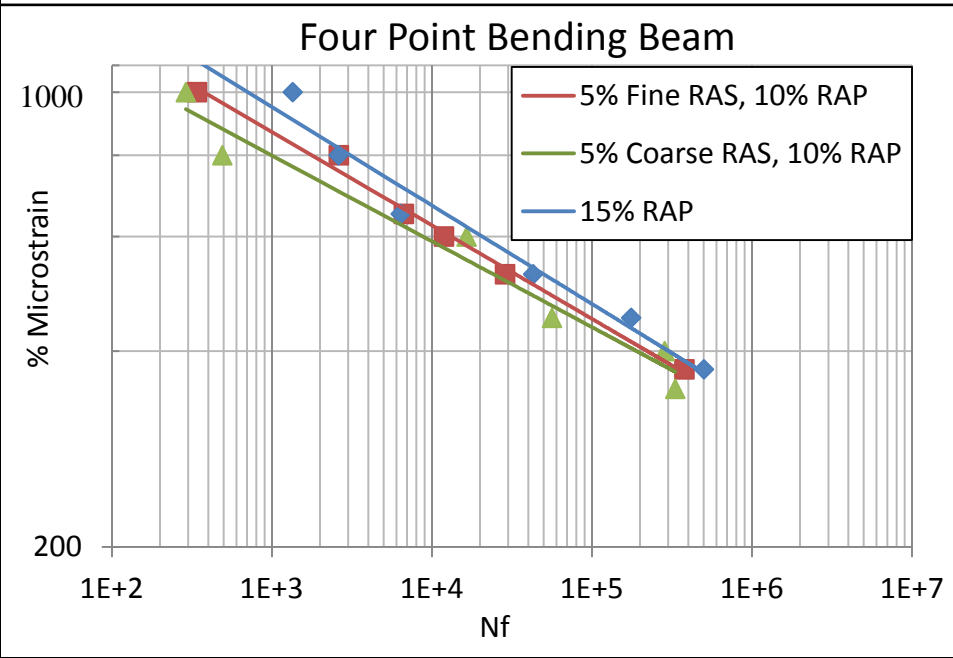
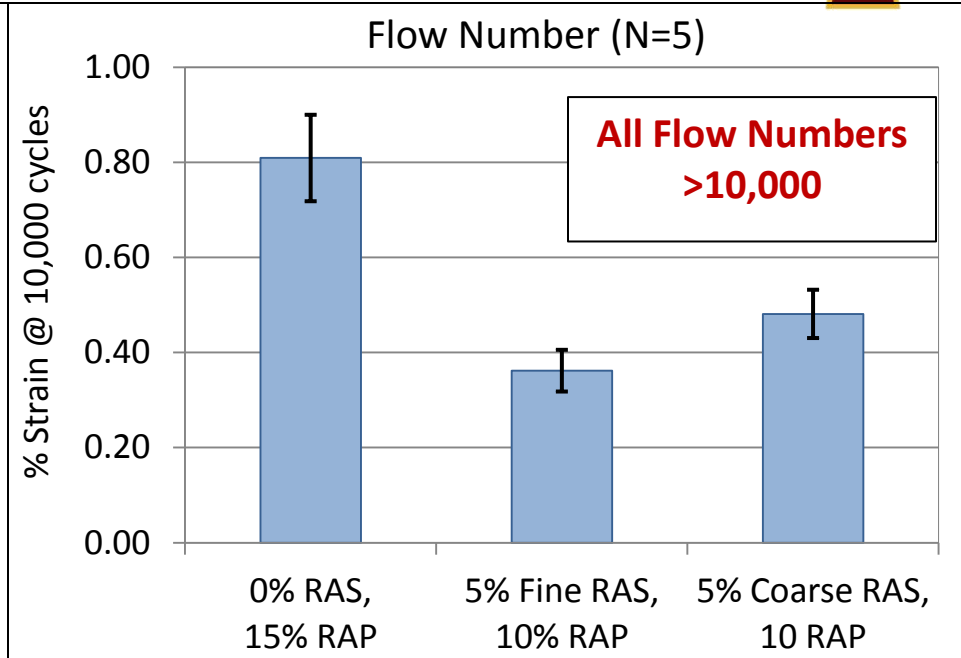
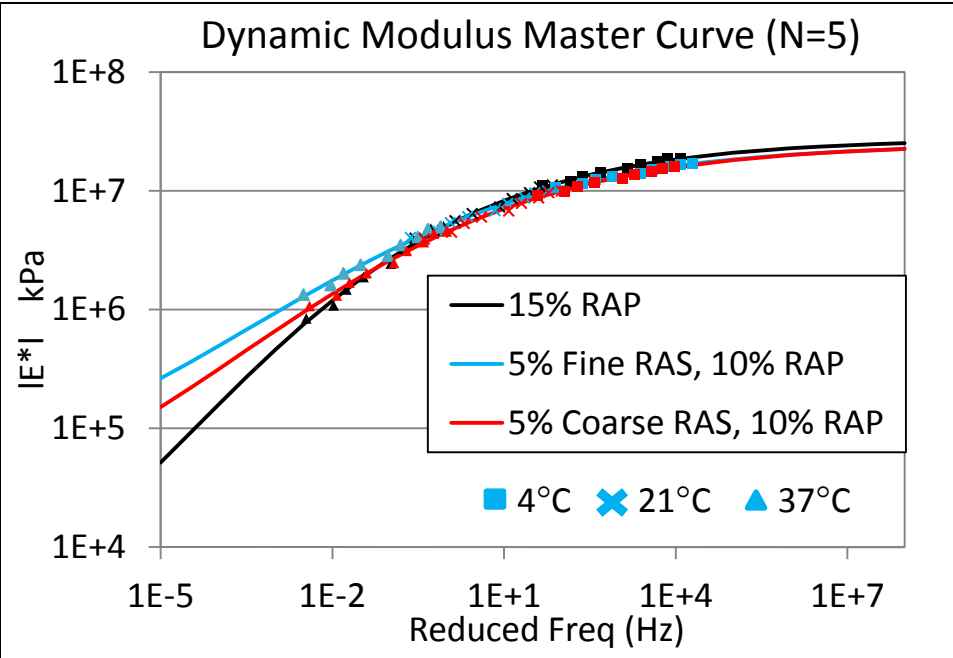
21.7% AC

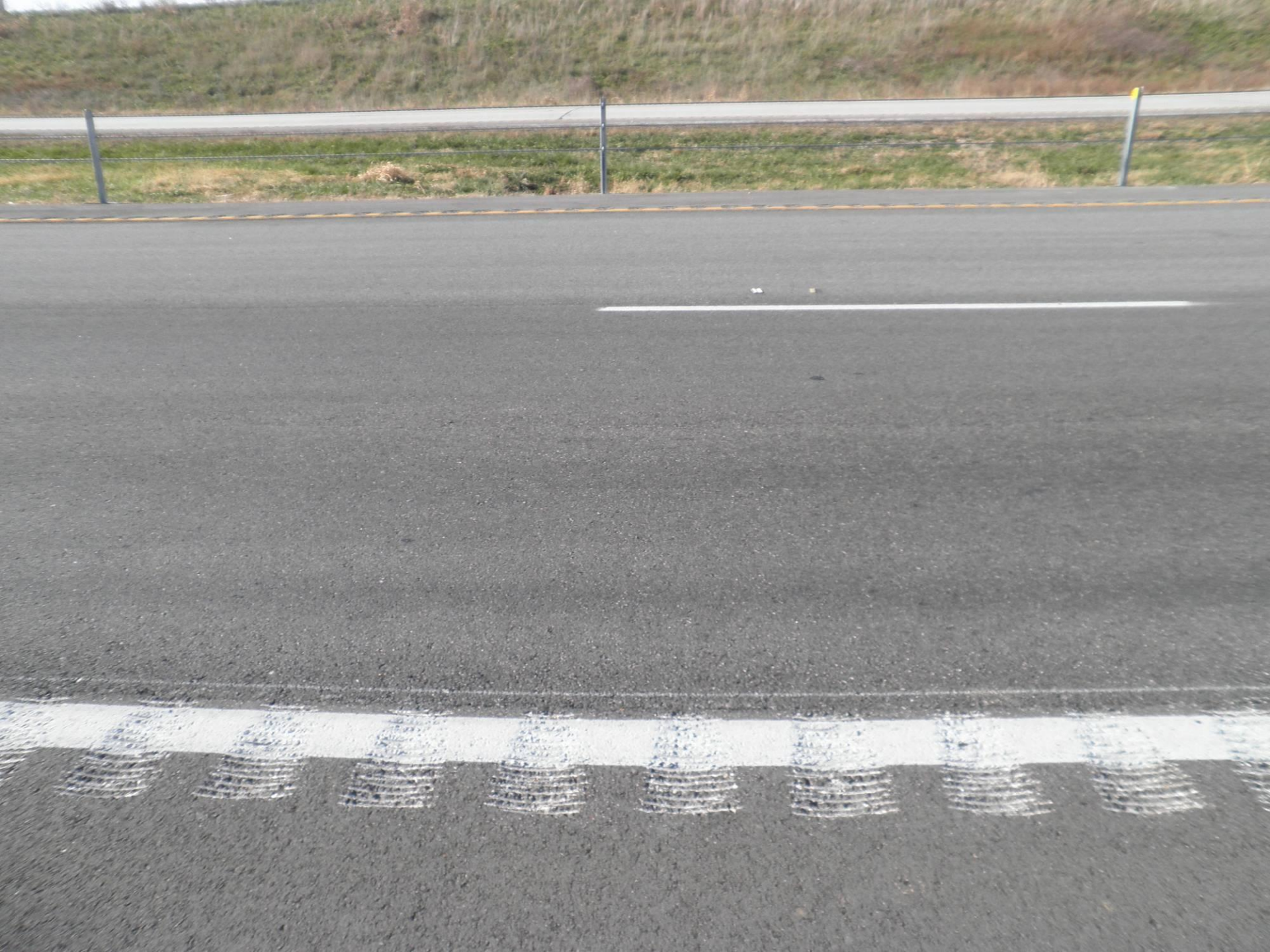


Missouri Mix Properties

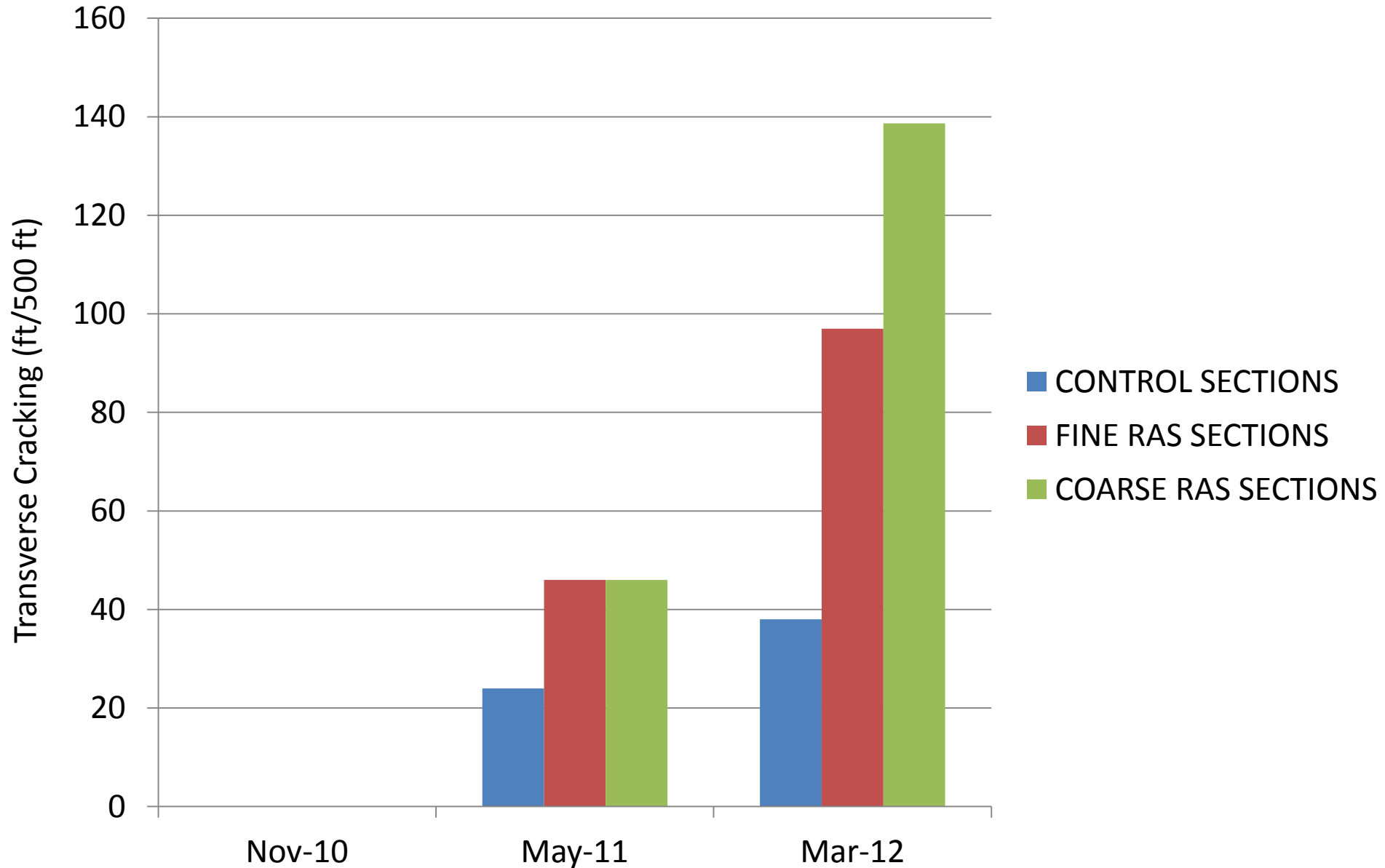
Mix Property	Control	Fine RAS Mixture	Coarse RAS
% RAS	0	5	5
% RAP	15	10	10
% Total AC from QC Results	4.7	5.3	5.3
% Binder Replacement	19.1	30.2	30.2
RAS Source	-	Post-Consumer	Post-Consumer
RAS Grind Size	-	< 9.5 mm	< 12.5 mm
Design Gyration	80	80	80
NMAS (mm)	12.5	12.5	12.5
Virgin PG Grade	64-22	64-22	64-22
% GTR by wt. of AC	10	10	10
% TOR by wt. of GTR	4.5	4.5	4.5
High PG	75.0	90.1	88.3
Low PG	-16.8	-8.4	-3.2 ²⁵

Missouri Results





Missouri Pavement Evaluation



Indiana

- US 6 in north central Indiana
- July 2009
- 9.5mm, 1.5" overlay
- Post-Consumer RAS
- Warm Mix vs. Hot Mix
- Foamed Technology
- 10M > 30M EASLs
- PG 70-22



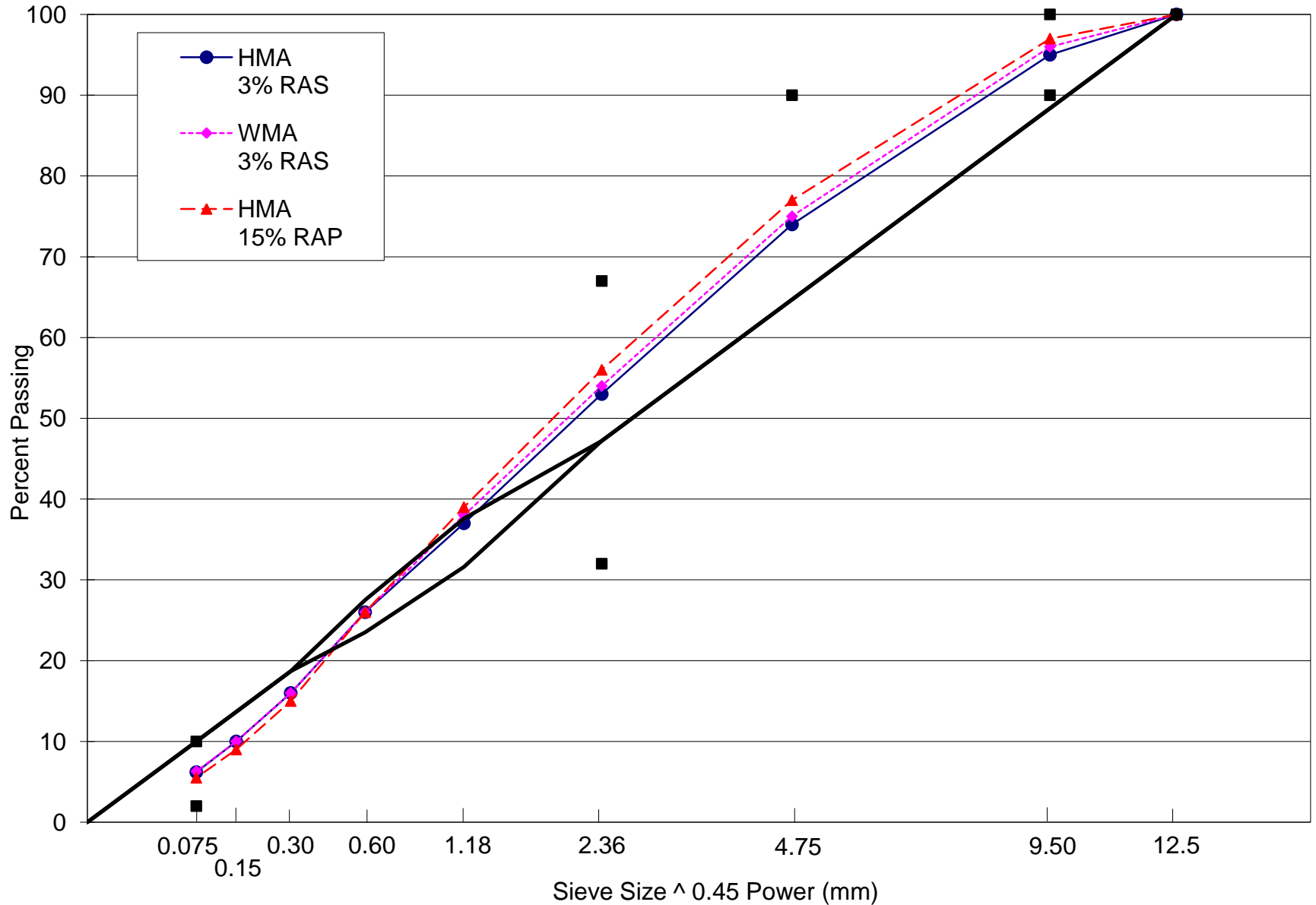


Indiana Mix Properties

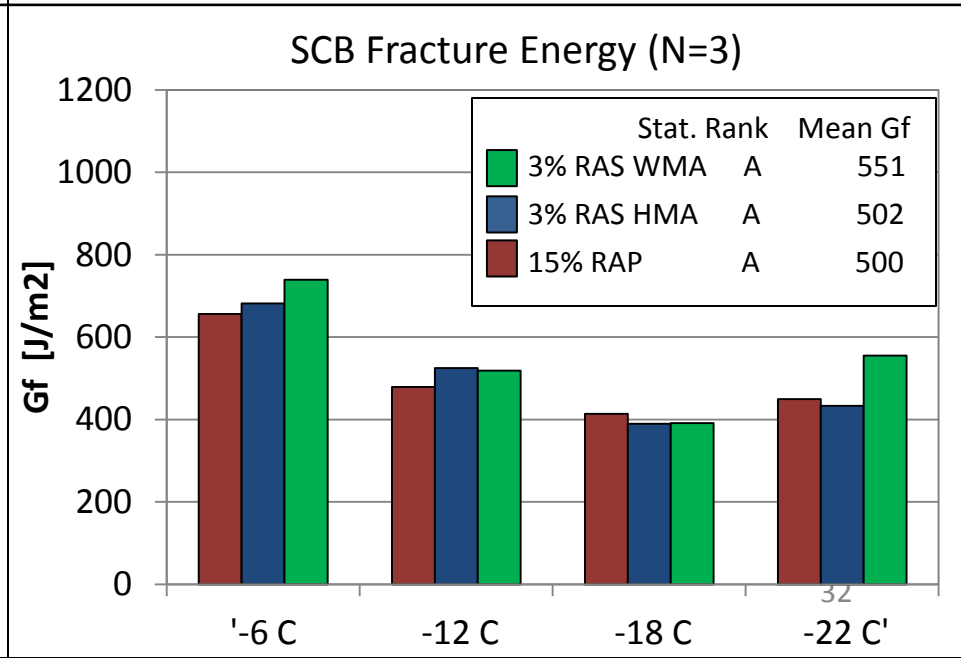
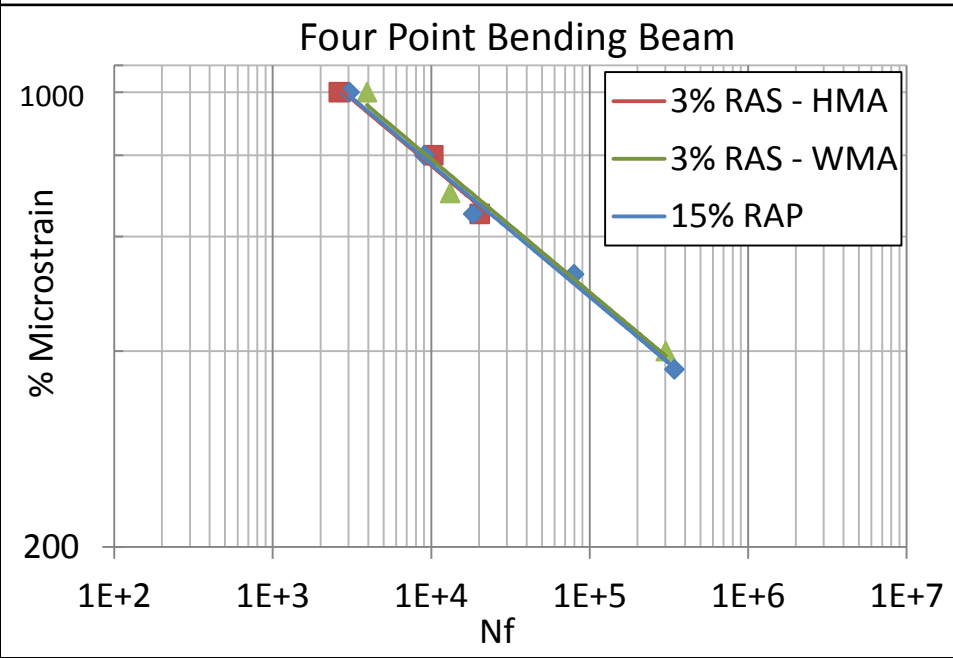
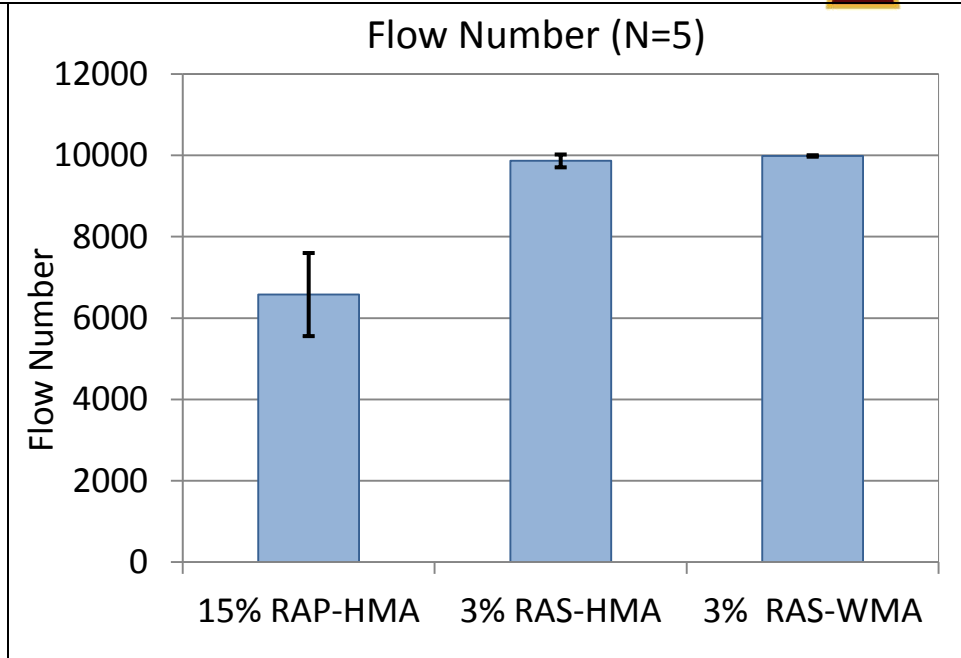
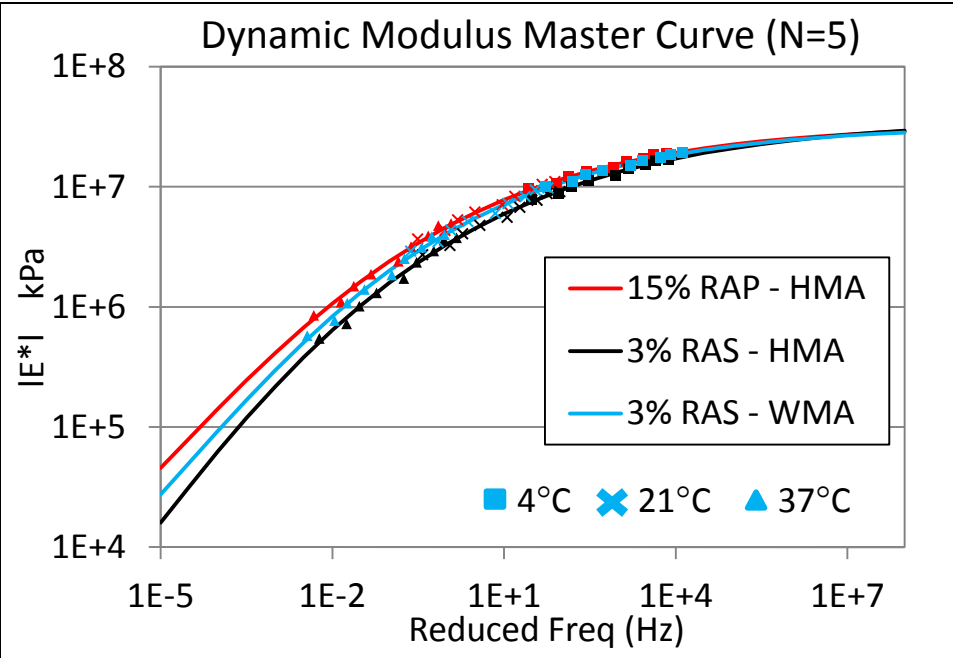
Mix Property	15% RAP	3% RAS HMA	3% RAS WMA
% RAS	0	3	3
% RAP	15	0	0
% Total AC from QC Results	5.7	6.2	6.2
% Binder Replacement	18.0	12.6	12.6
RAS Source	-	Post-Manufacturer	Post-Consumer
RAS Grind Size	-	< 12.5 mm	< 12.5 mm
Design Gyration	100	100	100
NMAS (mm)	12.5	12.5	12.5
Virgin PG Grade	70-22	70-22	70-22
Foaming Warm Mix	No	No	Yes
High PG	75.6	77.6	78.8
Low PG	-19.8	-15.3	-15.7 ³⁰



INDOT Mix Gradations



Indiana Results







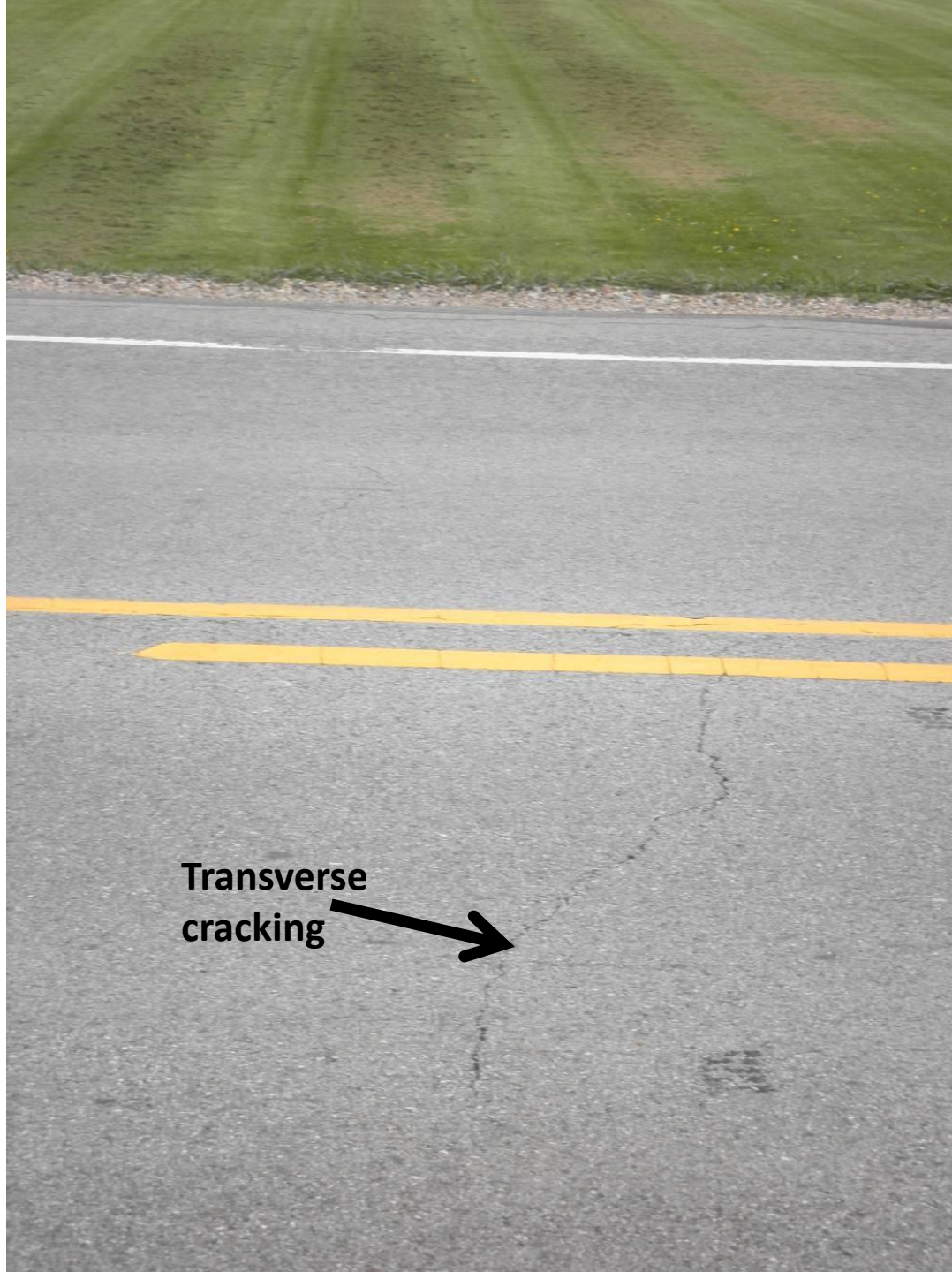
ONLY

COOP
BROS PLANS



Reflective cracking from jointed PCC pavement

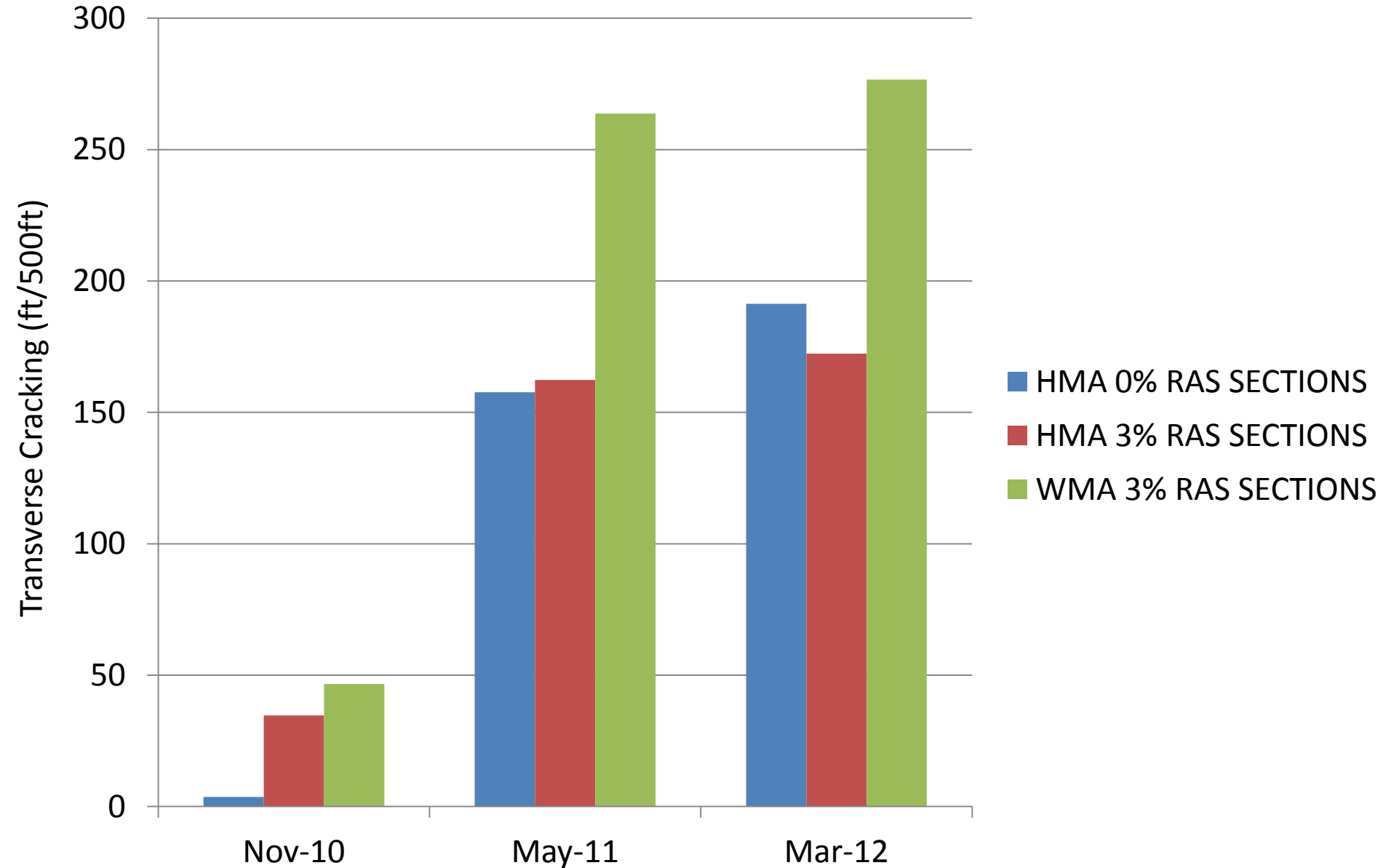
Edge cracking



Transverse
cracking

A black arrow with a white outline, pointing from the text 'Transverse cracking' towards the vertical crack in the road.

Indiana Pavement Evaluation



Colorado

- State Highway 36
- June 2011
- Between Boulder and Denver
- Post-Manufactured RAS
- Replaced 5% RAP with 3% RAS
- Maintained 70% virgin AC
- Tabs visual during laydown









Colorado Mix Properties

Mix Property	Control Mix	RAS Mix
% RAS	0	3
% RAP	20	15
% Total AC from Extraction	4.5	-
% Binder Replacement	30	30
RAS Source	-	Post-Manufacturer
RAS Grind Size	-	< 12.5 mm
Design Gyration	100	100
NMAS (mm)	12.5	12.5
Virgin PG Grade	64-28	64-28
High PG	67.6	-
Low PG	-	-

Illinois

- Interstate 80
- July 2011
- Fiber replacement in SMA
- Different PG Grades with 5% RAS
 - 70-28 Field Produced
 - 70-28 Lab Produced
 - 58-28 w/12% GTR (Lab)
- Post-Consumer RAS







Illinois SMA (Curran)

Mix Property	Lab Mix	Plant Mix	Lab Mix w/ 12% GTR
% RAS	5	5	5
% RAP	11	11	11
% Total AC	6.3	5.6	5.7
% Binder Replacement	35	35	35
RAS Source	Post-Consumer	Post-Consumer	Post-Consumer
RAS Grind Size	< 12.5 mm	< 12.5 mm	< 12.5 mm
Design Gyration	80	80	80
NMAS (mm)	12.5	12.5	12.5
Virgin PG Grade	70-28	70-28	58-28
High PG	84.4	83.9	81.8
Low PG			

Illinois SMA (D Construction)



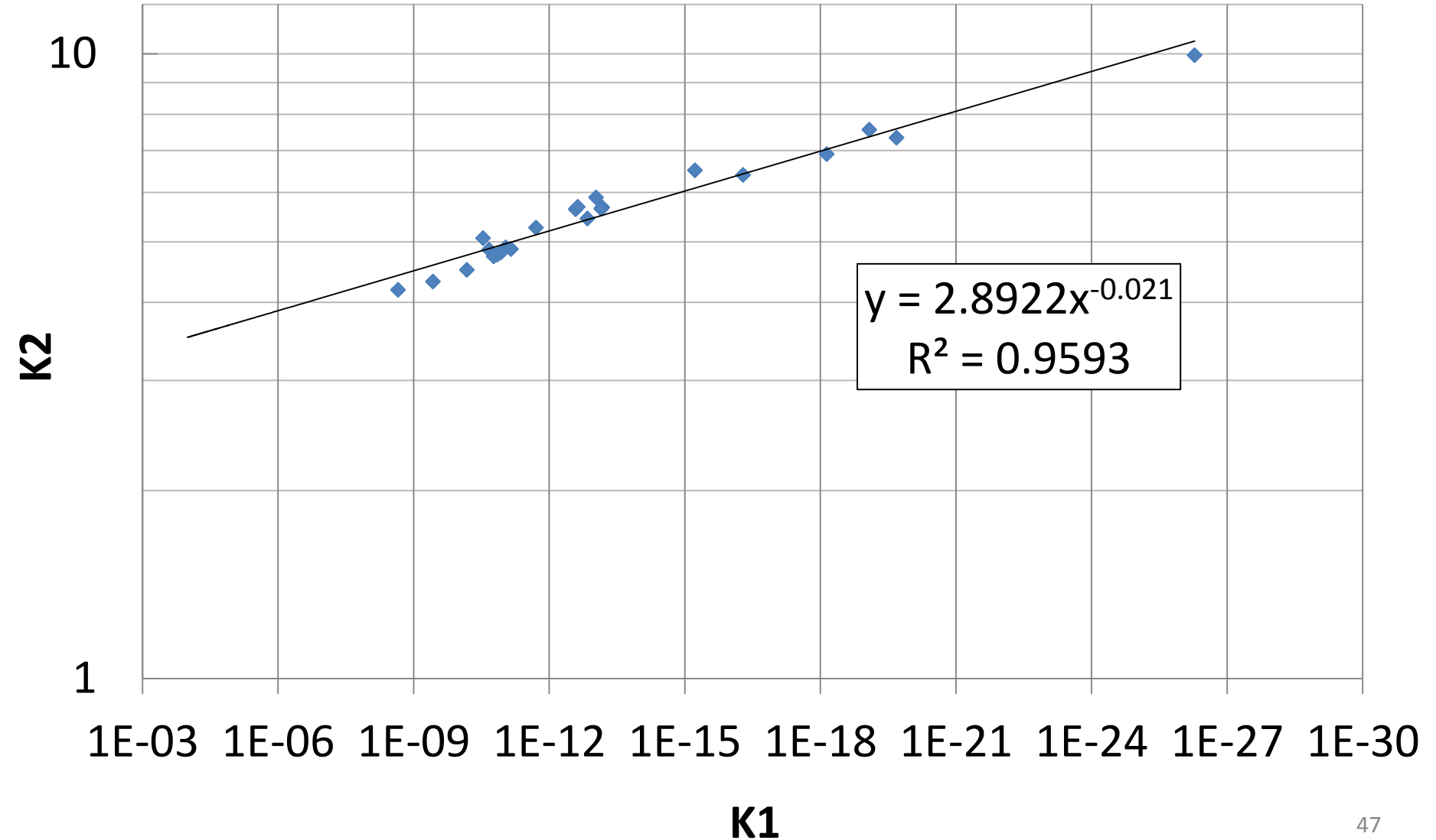
Mix Property	Lab Mix	Plant Mix	Lab Mix w/ 12% GTR
% RAS	5	5	5
% RAP	0	0	0
% Total AC	6.3	6.0	5.6
% Binder Replacement	21	21	21
RAS Source	Post-Consumer	Post-Consumer	Post-Consumer
RAS Grind Size	< 12.5 mm	< 12.5 mm	< 12.5 mm
Design Gyration	80	80	80
NMAS (mm)	12.5	12.5	12.5
Virgin PG Grade	70-28	70-28	58-28
High PG	72.7	72.8	77.8
Low PG	-	-	-



Wisconsin Mix Properties

Mix Property	No 3G Evotherm	3G Evotherm
% RAS	5	5
% RAP	13	13
% Total AC	4.8	4.7
% Binder Replacement	30	30
RAS Source	Post-Manufacturer	Post-Manufacturer
RAS Grind Size	< 12.5 mm	< 12.5 mm
Design Gyration	75	75
NMAS (mm)	12.5	12.5
Virgin PG Grade	58-28	58-28
High PG	68.5	69.5
Low PG	-	-

Four Point Bending Beam





SCB Fracture Energy (N=3)

State Agency	Rank	Treatment	Group mean G_f [J/m ²]
Iowa	A	4% RAS	674
	A/B	6% RAS	659
	B/C	5% RAS	558
	C	0% RAS	531
Minnesota	A	5% Post-Consumer RAS	777
	A	5% Post-Manufacturer RAS	768
	A	30% RAP	741
Missouri	A	0% RAS - 15% RAP	428
	A	5% Fine RAS - 10% RAP	427
	A	5% Coarse RAS - 10% RAP	378
Indiana	A	3% RAS - WMA	551
	A	3% RAS - HMA	502
	A	15% RAP - HMA	500



Continuing Work

- Continue to evaluate pavement performance
- Continue laboratory testing and analysis
- Illinois & Wisconsin demonstration projects
- Develop specification recommendations
- Technology Transfer

RAS Education

- Processing, management, plant operation
- Volumetrics
 - Binder contribution
 - VMA, VFA
- Low temperature performance
 - Done by mix testing
- Integration with other technologies

**IOWA STATE
UNIVERSITY**

Thank You!
Comments or Questions?

