WARM MIX PLUS RAP

Everett Crews, Ph.D.
Technical Development Manager
MeadWestvaco Corporation

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OUTLINE

- Recap of Key Issues in RAP Use in HMA
- The Question of Binder “Activation” & Blending
- Results of Lab-Made, Lab-Molded RAP WMA Mixes
- Case Studies with WMA RAP Mixes
- Conclusions
- Future Work

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BACKGROUND ON RAP USE IN HMA

Current National Research:
Increasing the RAP Content

Rebecca McDaniel
North Central Superpave Center

Special Joint Conference
January 10, 2008

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BACKGROUND ON RAP USE IN HMA

"Big Ten" ~~Top Ten~~ Research Needs

1. Performance test for evaluating RAP
2. Best practices manual
3. Solventless method to characterize RAP
4. Binder grade changes necessary?
5. Degree of blending of binders
6. Field performance of high RAP mixes
7. Replicating plant heating in lab
8. Guidance for states to allow higher RAP
9. Identification of RAP variability
10. Guidance for processing/fractionating RAP

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BACKGROUND ON RAP USE IN HMA

Today's presentation will touch on these three issues in WMA

"Big Ten" ~~Top Ten~~ Research Needs

1. Performance test for evaluating RAP
2. Best practices manual
3. ~~Solventless method to characterize~~ RAP
4. Binder grade changes necessary?
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BACKGROUND ON RAP USE IN HMA

"Big Ten"

~~Top Ten~~ Research Needs

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8. ~~Guidance for states to allow higher RAP~~
9. Identification of RAP variability
10. ~~Guidance for processing/fractionating~~ RAP

The issue of RAP variability - closer to resolution

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RAP CAN BE MANAGED FOR HIGH UNIFORMITY

RAP QC Statistics

Recycled Hot-Mix Asphalt Concrete in Florida: A Variability Study
ICAR – 401-1/98

RAP property	n	Average (%)	Standard Deviation (%)	
			Average	Range
Asphalt Content	20	5.4	0.30	0.1 to .55
% Passing Median Sieve	20	47.9	3.11	1.29 to 5.66
% Passing 75 micron Sieve	20	9.1	0.93	0.45 to 2.22

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www.eng.auburn.edu/center/ncat/**RAP/Past%20RAP%20ETGs/10-08/***Summary%20of%20NCAT%20Survey.ppt*

RAP CAN BE MANAGED FOR HIGH UNIFORMITY

RAP QC Statistics

Recycled Hot-Mix Asphalt Concrete in Florida: A Variability Study

		Average (%)	Standard Deviation (%) Average	Range
Asphalt Content	20	5.4	0.30	0.11 to .55
% Passing #8 Sieve	20	47.9	3.11	41.29 to 53.06
% Passing #200 Sieve	20	9.1	0.93	0.45 to 2.22

- "…increasing the percentage of RAP does not increase the CV of the mix...in the RAP range of 15-40%..."
- from stockpile analyses: "…RAP had a lower variation [CV] than virgin aggregates"
- from stockpile analyses: "…no significant difference between any of the materials: HMAC, RAP, or virgin aggregate."

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www.eng.auburn.edu/center/ncat/**RAP/Past%20RAP%20ETGs/10-08/***Summary%20of%20NCAT%20Survey.ppt*

KEY ISSUE: "BLENDING" OF RAP & VIRGIN BINDERS

- Recent work applying Hirsch models:
  - Mix dynamic modulus, E* = f (G*, VMA, VFA)
  - "Blending" is occurring in tested HMA systems

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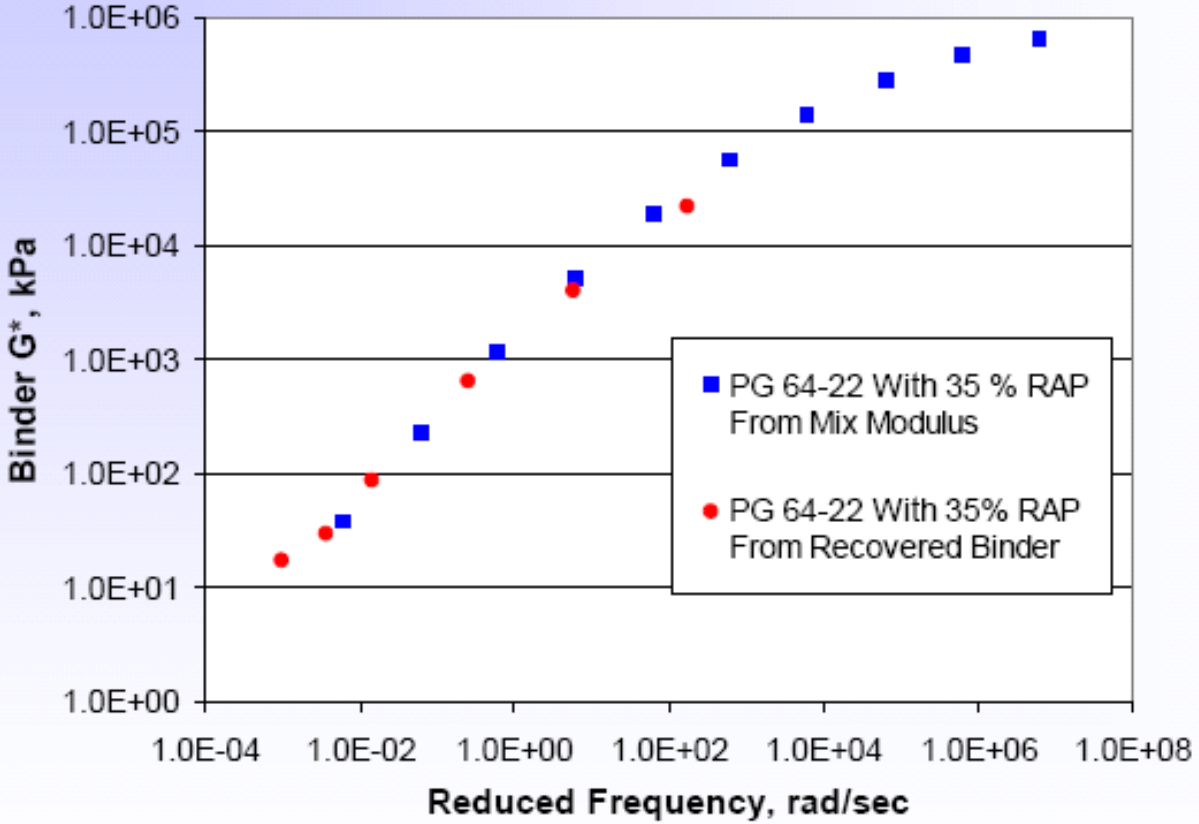
KEY ISSUE: "BLENDING" OF RAP & VIRGIN BINDERS

-

9.5 mm With PG 64-22 + 35 % Fractionated RAP, Double Barrel



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"Engineering Services for the Asphalt Industry"

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KEY ISSUE: "BLENDING" OF RAP & VIRGIN BINDERS

- "Blending" of virgin & oxidized binder more of an issue in Warm Mixes?
- Does the oxidized asphalt in the RAP "blend" with the virgin binder if we lower mix temperatures 50°F? 80°F?
- RAP asphalt (from Maryland to Indiana) are characterized as PG 88-xx to PG 94-xx
- Softening points of PG 88-xx to PG 94-xx asphalts are likely less than 100 C*

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*** Blown roofing asphalts have softening points ranging from 85 to 115 C**

"BLENDING" OF RAP & VIRGIN BINDERS IN EVOTHERM MIXES

- Evotherm mixes evaluated at 120 C
  - One aggregate: 12.5-mm NMAS, very low absorption granite with same gradation in both mixes below, A & B
  - One set of mixes (A): made with pre-blended binder composed of two binders, a PG 64-22 & and Type III in ratios of 100:0, 80:20, 60:40, & 40:60
  - One set of mixes (B): made with lab-made RAP based on the same virgin aggregate & the Type III binder

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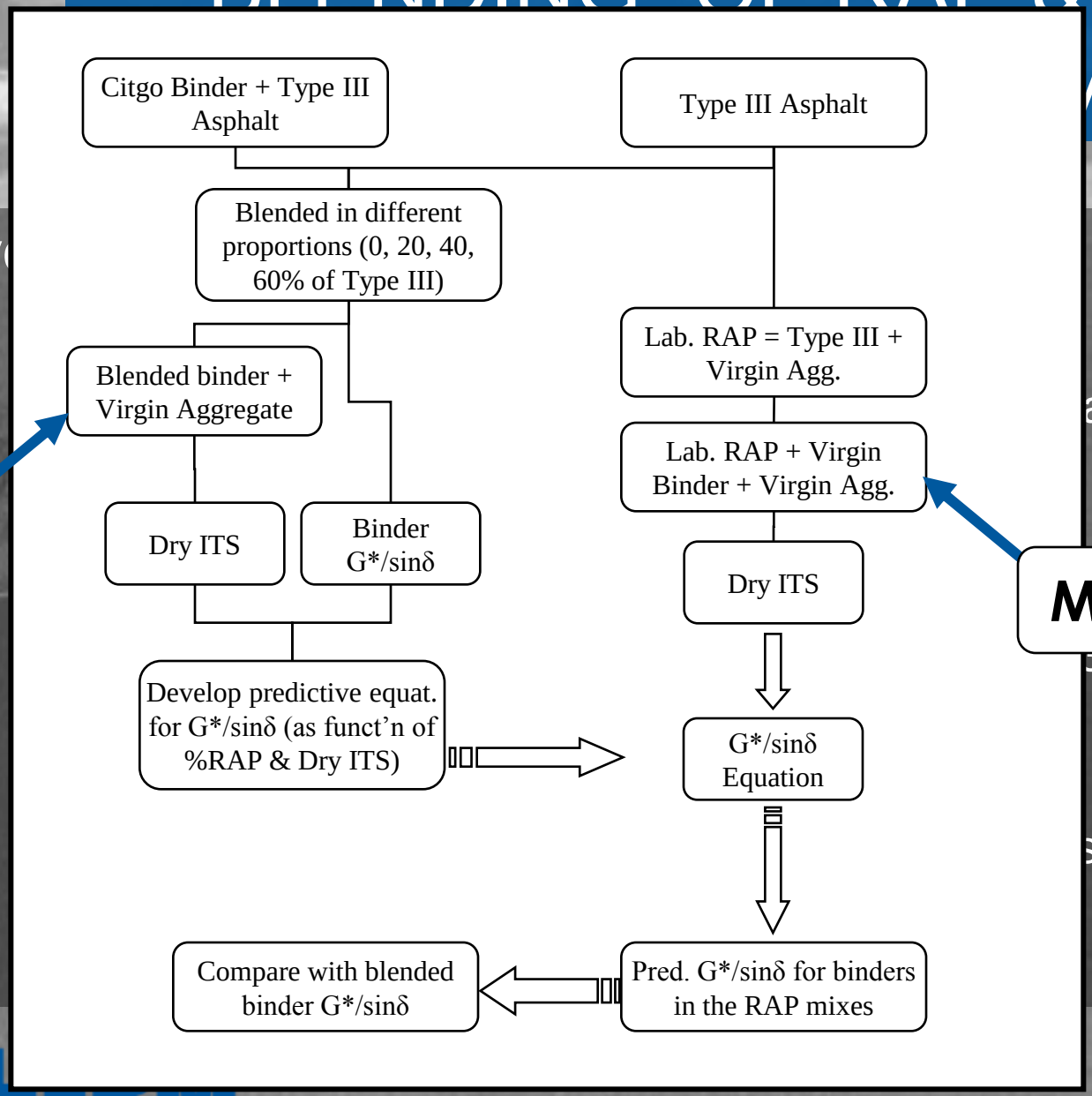
"BLENDING" OF RAP & VIRGIN M MIXES



Mix A

Mix B

- Evo
  - anite with
  - sed on

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Evotherm DAT
MODELING PROPERTY VARIATION

EVOTHERM DAT SUMMARY ANALYSIS		
%Type III in binder blend	Mixes A: 100% blended PG 64-22 & Type III binders	
	Measured	
	G*/sin δ	Dry ITS
0	3.553	134.5
20	9.087	177
40	14.585	183.5
60	22.415	181.5

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Evotherm DAT
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0	3.553	134.5
20	9.087	177
40	14.585	183.5
60	22.415	181.5

Analysis of the variation of G*/sinδ and Dry ITS with with %Type III in binder blend yields Equation 1.

Eq. 1: $G^*/\sin\delta = 0.346(\%RAP) - 0.048(\text{Dry ITS}) + 10.16$

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Evotherm DAT
TESTING MODEL EQUATION

EVOTHERM DAT SUMMARY ANALYSIS			
%Type III in binder blend or %Type III RAP	Mixes A: 100% blended PG 64-22 & Type III binders		Mixes B: Type III RAP + virgin agg. + PG 64-22
	Measured G*/sin δ	Dry ITS	Dry ITS
0	3.553	134.5	134.5
20	9.087	177	169
40	14.585	183.5	178.5
60	22.415	181.5	199

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Evotherm DAT
TESTING MODEL EQUATION

EVOTHERM DAT SUMMARY ANALYSIS			
%Type III in binder or %Type III RAP	Mixes A: 100% blended		Mixes B: Type III RAP + virgin agg. + PG 64-22
			Dry ITS
0			134.5
20			169
40	14.580	165.5	178.5
60	22.415	181.5	199

Use Equation 1 to Calculate the G*/sinδ value of the binder in Mixes B, the Type III RAP + virgin agg. + PG 64-22

Eq. 1: $G^*/\sin\delta = 0.346(\%RAP) - 0.048(\text{Dry ITS}) + 10.16$

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Evotherm DAT
TESTING MODEL EQUATION

EVOTHERM DAT SUMMARY ANALYSIS				
%Type III in binder blend or %Type III RAP	Mixes A: 100% blended PG 64-22 & Type III binders		Mixes B: Type III RAP + virgin agg. + PG 64-22	
	Measured		Predicted	
	G*/sin δ	Dry ITS	G*/sin δ	Dry ITS
0	3.553	134.5	3.734	134.5
20	9.087	177	8.998	169
40	14.585	183.5	15.462	178.5
60	22.415	181.5	21.398	199

Eq. 1: $G^*/\sin\delta = 0.346(\%RAP) - 0.048(\text{Dry ITS}) + 10.16$

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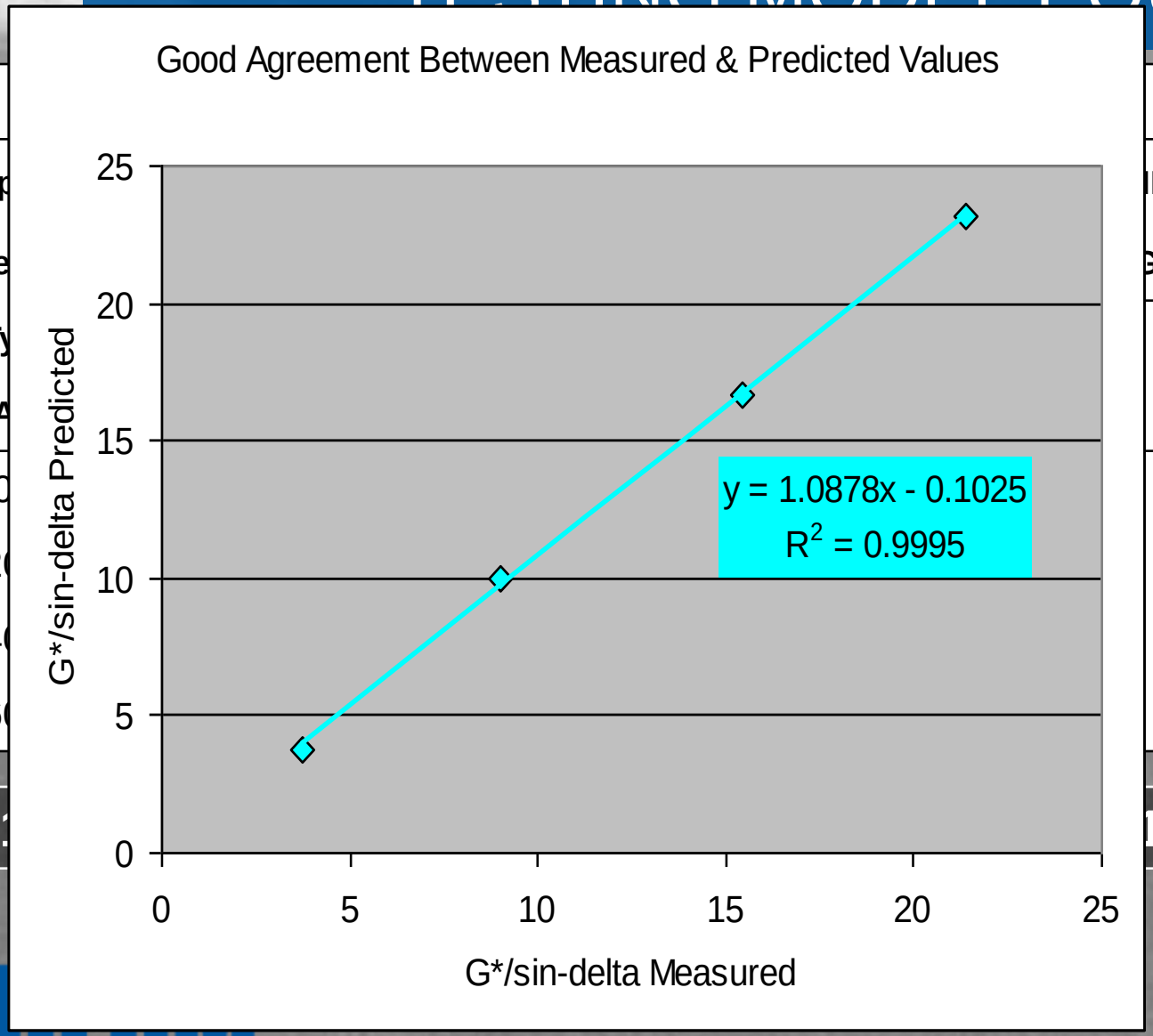
Evotherm DAT TESTING MODEL EQUATION



%Typ	ll RAP
in binde	G 64-22
or %Ty	
RA	Dry ITS
0	134.5
2	169
4	178.5
6	199

Eq. 1 ... 10.16

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Evotherm 3G
SIMILAR MODEL

EVOTHERM 3G SUMMARY ANALYSIS				
%Type III in binder blend or %Type III RAP	Mixes A: 100% blended PG 64-22 & Type III binders		Mixes B: Type III RAP + virgin agg. + PG 64-22	
	Measured		Predicted	
	G*/sin δ	Dry ITS	G*/sin δ	Dry ITS
0	3.553	134.5	3.332	134.5
20	9.087	175	9.012	167
40	14.585	173.5	14.968	188
60	22.415	170.5	21.476	186

Eq. 2: $G^*/\sin\delta = 0.323(\%RAP) - 0.024(\text{Dry ITS}) + 6.56$

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HMA Control
SIMILAR MODEL

HMA SUMMARY ANALYSIS				
%Type III in binder blend or %Type III RAP	Mixes A: 100% blended PG 64-22 & Type III binders		Mixes B: Type III RAP + virgin agg. + PG 64-22	
	Measured		Predicted	
	G*/sin δ	Dry ITS	G*/sin δ	Dry ITS
0	3.553	153	3.384	153
20	9.087	205.5	8.379	240.5
40	14.585	245.5	15.585	227.5
60	22.415	248.5	21.372	279

Eq. 3: $G^*/\sin\delta = 0.346(\%RAP) - 0.022(\text{Dry ITS}) + 6.75$

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CASE STUDIES: MISSOURI RT 44 HIGH-RAP WMA

- Route 44 Overlay
- Pace Construction mix producer & paving contractor
- Conoco Phillips PG 70-22 binder (total Pb = 5.5%)
- N_{-des} =100,12.5-mm NMAS Superpave
- Bussen #3 limestone (Antire Quarry)
- RAP from Pace's Overland, MO, site (Pb = 4.8%)

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CASE STUDIES: MISSOURI RT 44 HIGH-RAP WMA

High RAP Warm Mix Asphalt

- 20% RAP Control HMA
- 20% RAP WMA
- 28% RAP WMA
- 35% RAP WMA

- Approximately 1,000 Tons/Mix Type

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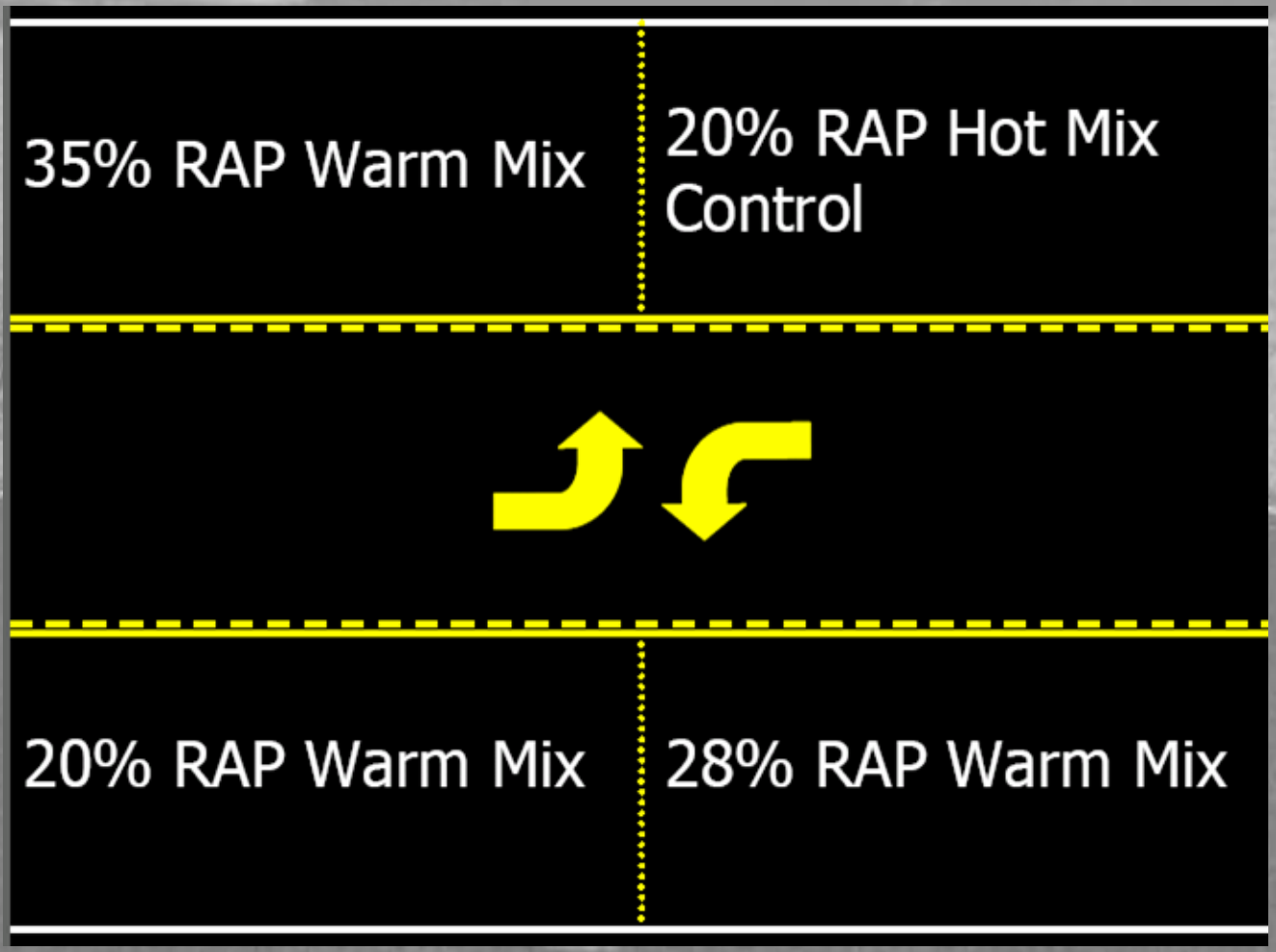
Data presented by Dale Williams, MO DOT Mat'ls Eng, at MS&T 51st Asphalt Conference, Dec. 9-10, '08

CASE STUDIES: MISSOURI RT 44 HIGH-RAP WMA



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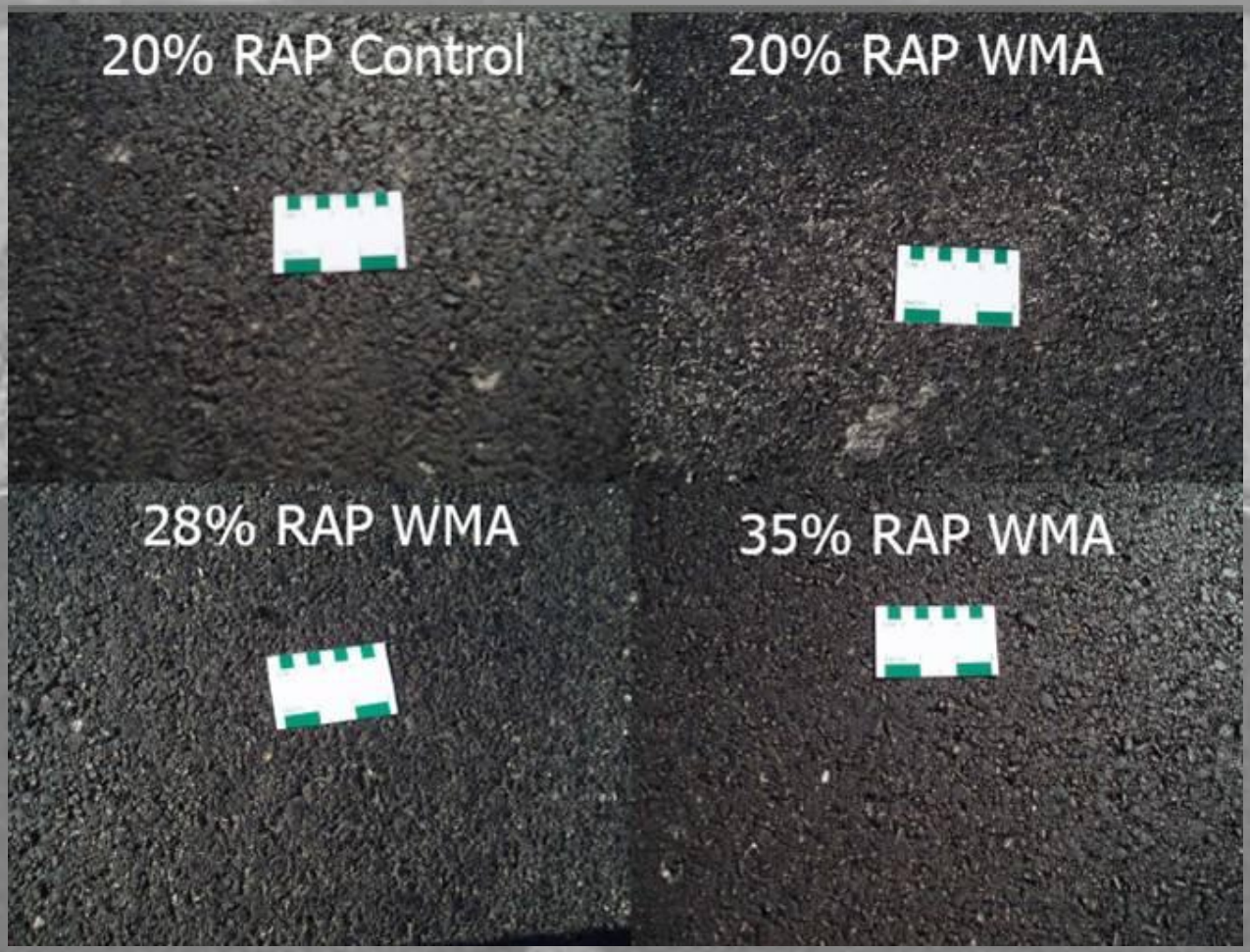

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CASE STUDIES: MISSOURI RT 44 HIGH-RAP WMA

High RAP Warm Mix Asphalt

	Control	20% RAP	28% RAP	35% RAP
Pen	29	39	32	28
Viscosity	25,920	16,087	16,738	23,470
Ductility	38	79	54	42
DSR 64	7.35	4.39	5.74	7.56
MSCR	26	42	37	32
DSR 70	3.48	2.11	2.91	3.59
BBR -12	0.394	0.437	0.406	0.393

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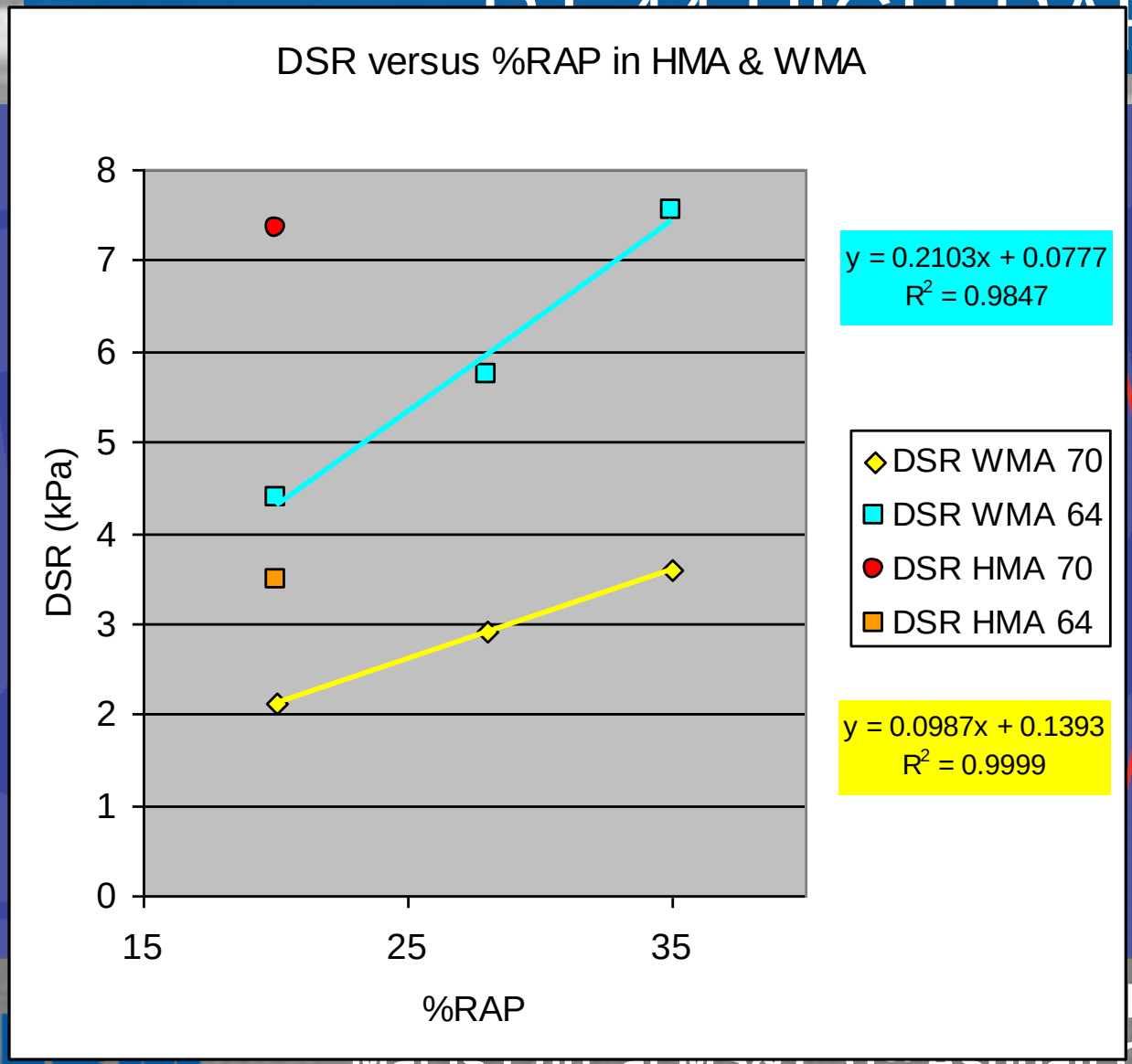
CASE STUDIES: MISSOURI



MO DOT

Conference,

Dec. 9-10, '08

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CASE STUDIES: MISSOURI RT 44 HIGH-RAP WMA

Cost Savings Associated with RAP Usage

- Assume RAP Pb = 5.0%
- Assume asphalt cost is $450/ton
- Assume aggregate cost is $13/ton

RAP Value = $450*0.05 + $13*0.95 ≈ $35 / ton

Ignoring other costs (milling, WMA additive, etc.), every 1% RAP lowers cost by $0.35/ton

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CASE STUDIES: DEC. 8, ‘08
40% RAP EVOTHERM AT <26 C

- Queens Borough mill & overlay
- Peckham Materials was mix producer (Astec Dbl Bar)
- NYC DOT was paving contractor
- Conoco Phillips PG 64-22 binder (total Pb = 5.9%)
- NYC 6FHD,12.5-mm NMAS Superpave, 40% RAP

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CASE STUDIES: DEC. 8, '08
40% RAP EVOTHERM AT <26 C

Evotherm DAT portable solution tote

Evotherm metered directly into the asphalt line

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CASE STUDIES: DEC. 8, ‘08
40% RAP EVOTHERM AT <26 C

Ground temperature
at 7 a.m. was < 20 F

Mix temperature behind
the screed

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CASE STUDIES: DEC. 8, ‘08
40% RAP EVOTHERM AT <26 C

Icicles hanging from the back of the Hyster steel wheel compactor

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CASE STUDIES: DEC. 8, ‘08
40% RAP EVOTHERM AT <26 C

Air voids > 92% of Gmm

Excellent joint compaction

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CASE STUDIES: NOV. 08, RAP USE IN I-90 WMA PROJECT

I-90 Illinois Tollway

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Ross Bentsen, Illinois Tollway, NCAUPG 2008

CASE STUDIES: NOV. 08, RAP IN WMA ON I-90 TOLLWAY

N_{des} 120 GTR PG 76-22 w/ 15% RAP in SMA w/ trap rock

Evotherm mix made at 150 C and 120 C; Control HMA at 175°C

Rock Road Co., mix & paving contractor

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CASE STUDIES: NOV. 08, RAP IN WMA I-90 TOLLWAY

HMA Standard, Va = 3.2%
150 C Evotherm, Va = 2.8%
120 C Evotherm, Va = 3.5%

S.T.A.T.E. Testing, L.L.C.

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CASE STUDIES: I-78 NEW JERSEY, NOV. 08

Mist & rain at the Traprock Industries mix plant.

N_{des} 100, 12.5 mm NMAS, NuStar Energy PG 76-22, with 25% RAP

Dry 1 hr away at the job site.

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CASE STUDIES:
I-78 NEW JERSEY, NOV. 08

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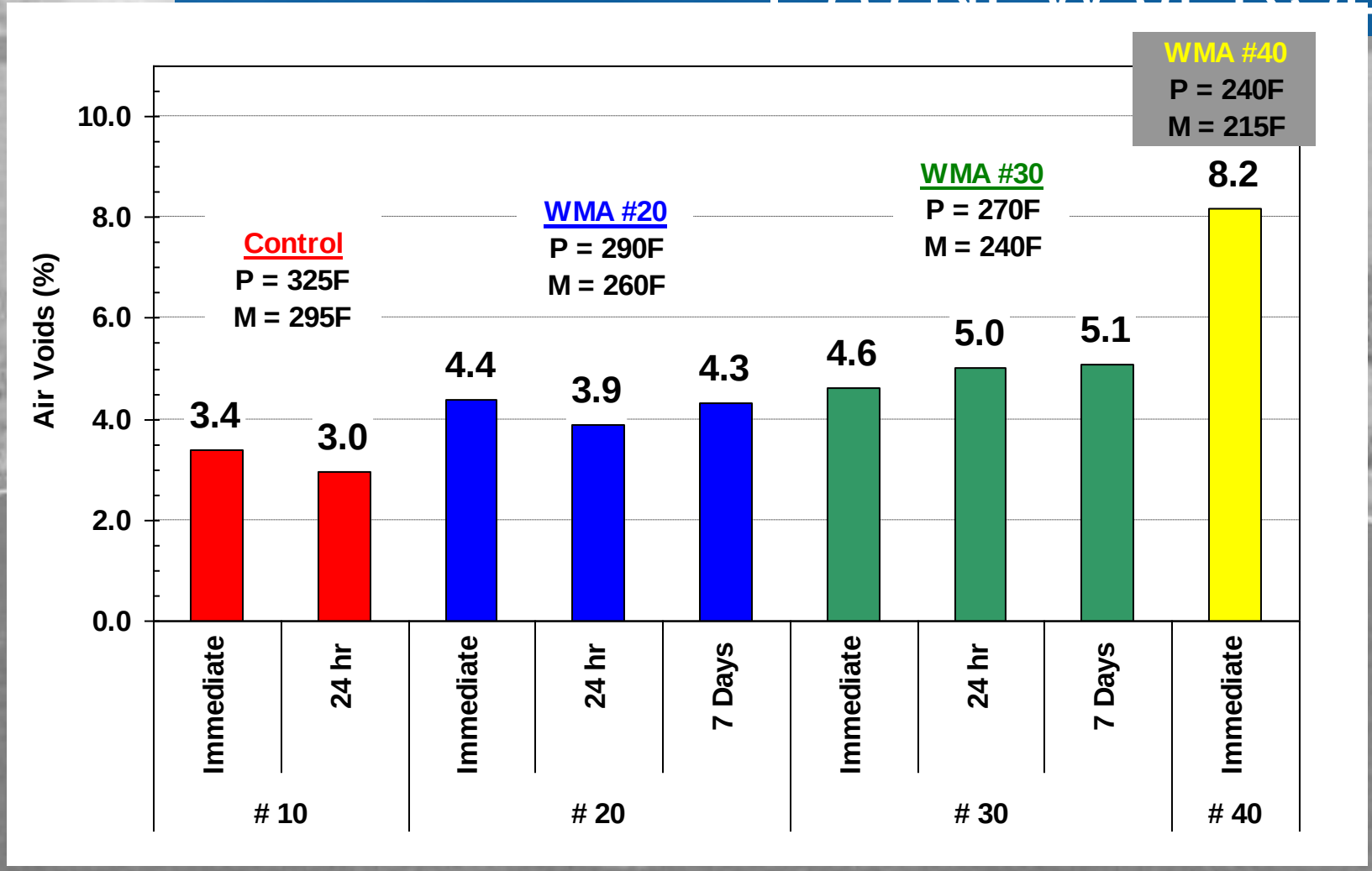
CASE STUDIES: I-78 NEW JERSEY



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Results of Thomas Bennert, Rutgers University Asphalt Paving Laboratory

CONCLUSIONS

- Lab analysis of field mixes (MO Rt 44) showed the reduced oxidation of WMA binder allowed higher RAP contents than HMA control mixes at same binder stiffness
- “Blending” of oxidized & virgin binders was demonstrated in WMA lab study by comparing mixes made with virgin & Type III binder blends versus mixes made with RAP based on the Type III binder
- Results of numerous field projects demonstrate viability of high-RAP mixes using WMA can be controlled

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FUTURE WORK

- Larger high-RAP WMA projects are needed for
  - a more thorough analysis mix performance
  - a more accurate cost analysis
  - an analysis of plant emissions & job site fumes
- Other field performance evaluations of high-RAP WMA are warranted (e.g., accelerated loading)
- Dynamic mechanical analysis on both lab & field samples of high-RAP WMA versus HMA controls
  - new tiers, e.g,, 20, 20-30, >35%, for %RAP in WMA mixes versus 15, 16-25, >25% in HMA

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