MIX DESIGN PROCEDURES

WMA Webinar

September 18, 2013

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1

Overview

- Present guidelines for design with WMA/RAP/RAS
- Identify WMA processes for various WMA technologies
- Identify differences in HMA/WMA mix design
- Discuss evolution of WMA mix design
- Review Best Practices

“Warm Mix” Definition

A. Asphalt mixtures produced at temperatures approximately 50^{o}F lower than for HMA?
B. Technologies used as coating and compaction aids without reduction in temperature?
C. Technologies that allow reduced temperature for producing, placing, and compacting asphalt mixtures?

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Four Categories of WMA Technologies

- Organic Additives
- Chemical Additives
- Foaming Processes
- Hybrid Processes

Four Categories of WMA Technologies

- Additive added to the binder

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Four Categories of WMA Technologies

- Additive added to the binder
- Additive added to the mix

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Four Categories of WMA Technologies

- Additive added to the binder
- Additive added to the mix
- Wet aggregate mix

Four Categories of WMA Technologies

- Additive added to the binder
- Additive added to the mix
- Wet aggregate mix
- Foamed mix

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Adding WMA in Mix Design

- Drop-in HMA design
  - Risks
    - Less binder absorption
    - Less aging (May change binder properties, rutting)
    - Moisture susceptibility
- Separate mix design?
  - 2005 – 3 technologies
  - Now – 30+

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WMA Technologies

Advanced Concepts Engineering Co.: **LEA-CO**
AESCO/Madsen: **Eco-Foam II**
Akzo Nobel: **Rediset WMX**
All States Materials Group: **ECOBIT**
Arkema Group: **CECABASE RT**
Aspha-min: **Aspha-min Online**
Astec Industries: **Double Barrel Green System**
Engineered Additives: **BituTech PER**
Gencor Industries: **Green Machine**
Herman Grant Company: **HGrant Warm Mix System**
Iterchimica: **Qualitherm**
Kumho Petrochemical and Korea Institute of Construction Technology: **LEADCAP**
Maxam Equipment Inc.: **Aquablack Warm Mix Asphalt**

McConnaughay Technologies: **Low Emission Asphalt**
MeadWestvaco Asphalt Innovations: **Evotherm**
Meeker Equipment Corp. Inc.: **Meeker Warm Mix**
PQ Corporation: **Advera WMA**
Sasol Wax North America Corporation: **Sasobit**
Shell: Shell **Thiopave**
Sonneborn Products: **SonneWarmix**
Stansteel: **Accu-Shear Dual Warm-Mix Additive System**
Tarmac Inc.: **Tri-Mix Warm Mix Injection**
Terex Roadbuilding: **Warm Mix Asphalt System**

Differences in Design Procedure

- Only minor changes to AASHTO R35
  - Appendix 2
  - Specimen Fabrication
  - Coating & Compactibility for mixing and compaction temperatures
- Simulating plant foaming process
- Compactibility, stripping, & rutting may be different

Differences Needing More Research

- WMA mixing with bucket mixers
  - Less efficient, but more available
  - Coating as a function of mixing time

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Planetary Mixers

- Used for NCHRP 9-43
- Mixing times used in AASHTO R35

Differences Needing More Research

Asphalt Foaming Devices

- Does lab foaming simulate field devices
- Is all foam equal
- How long is foam effective?

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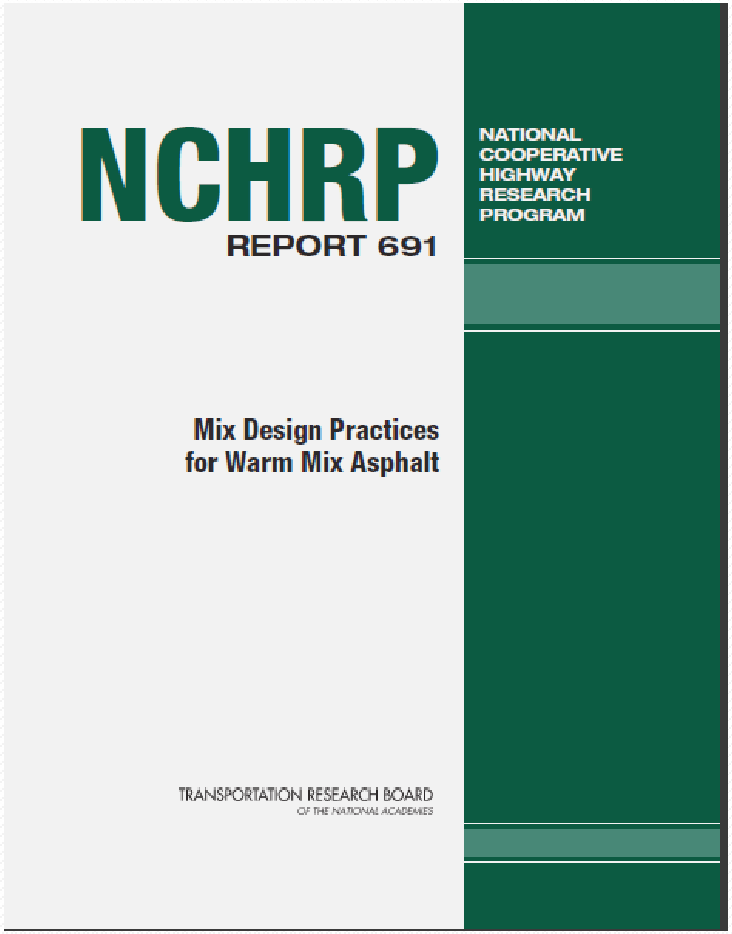
Differences Needing More Research

- STOA for moisture susceptibility & rutting resistance
  - HMA=4 hours @ 275F
  - WMA=2 hours @ compaction temp
  - Two-step conditioning

National Research Initiatives

NCHRP 9-43, Mix Design Practices for Warm Mix Asphalt



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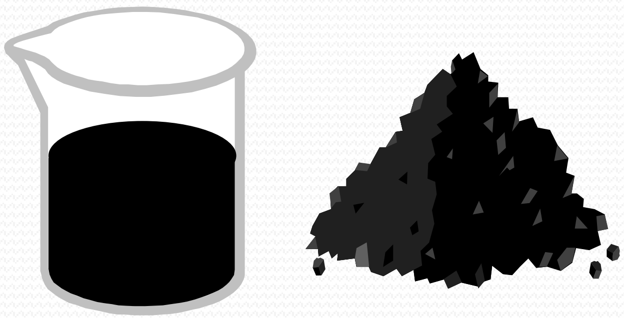
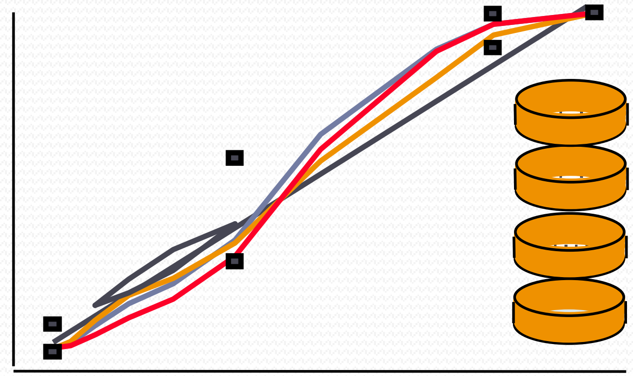
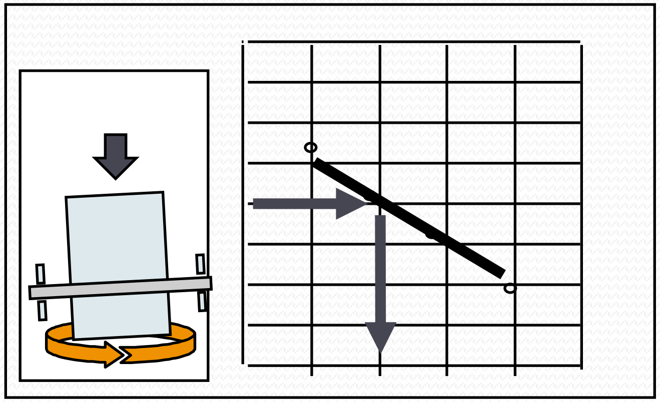
4 Steps in Mix Design



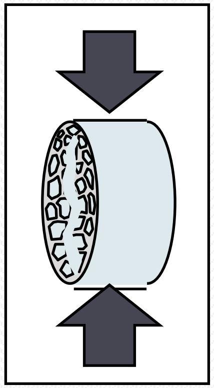
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Performance Testing

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Materials Selection

1. Select the process to be used

2. Binder Selection

- Use same grade normally used for HMA *

* If WMA is 100ºF lower than HMA, increase high temperature one grade.

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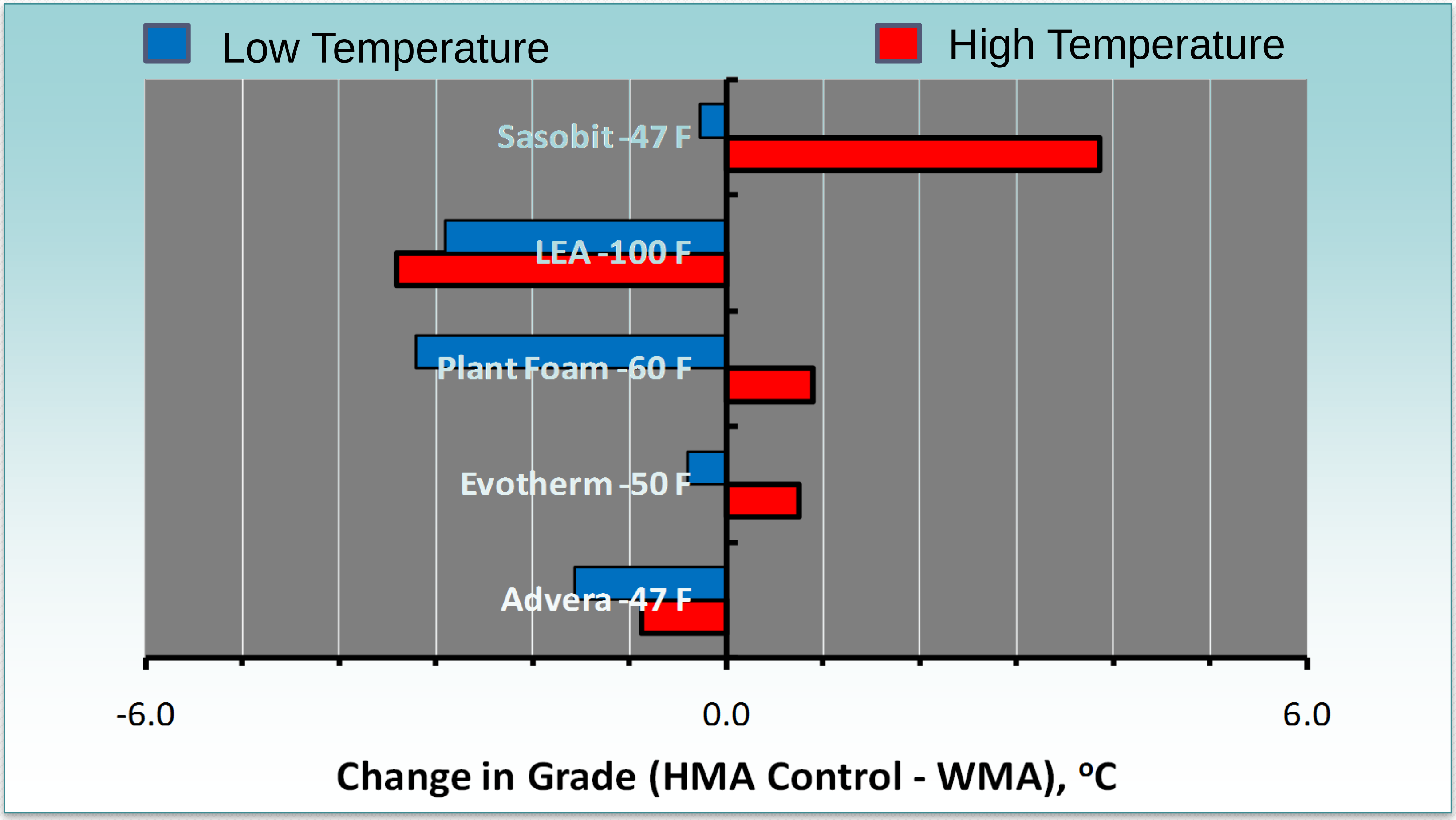
Effect of Technology on Binder Grade



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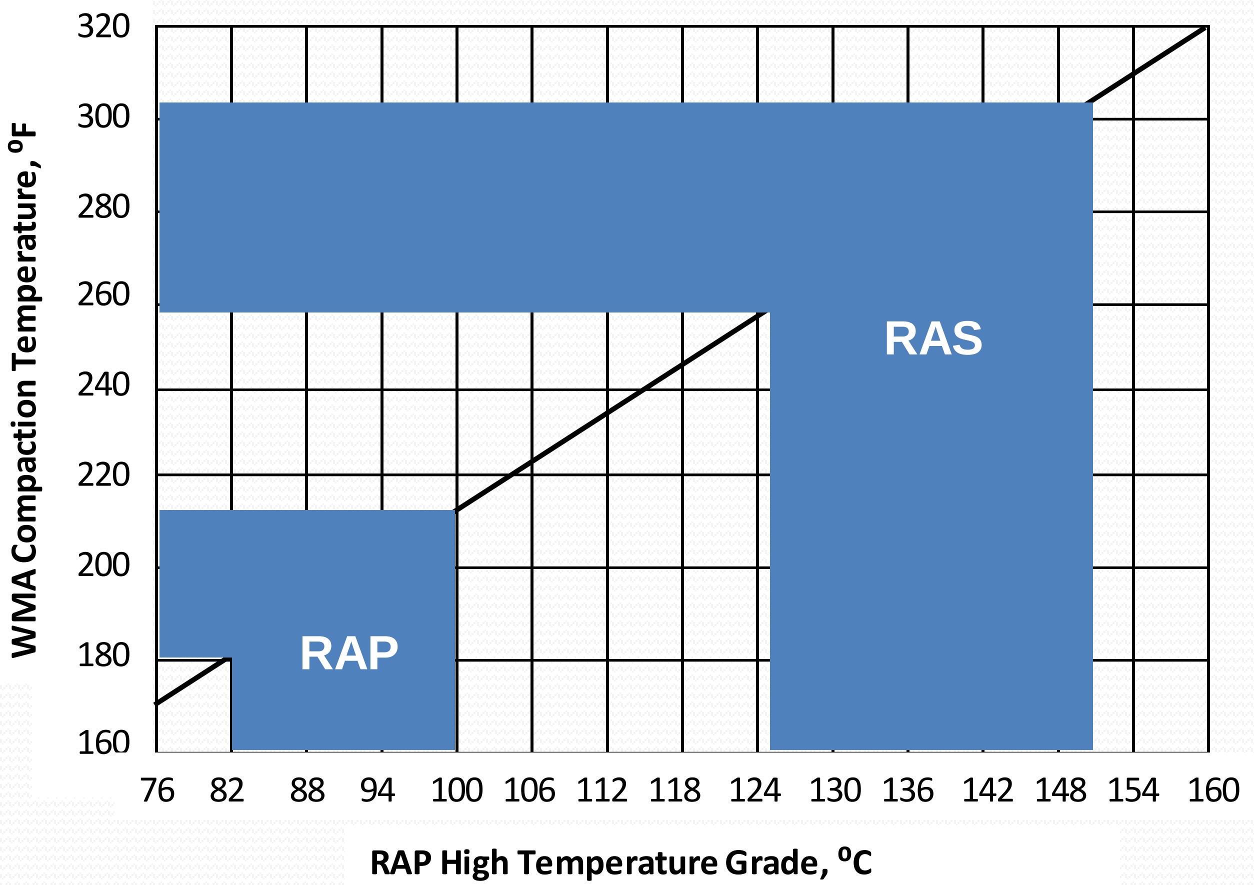
RAP & RAS in WMA

Criteria: High grade of RAP/RAS must be ≤ planned field compaction temperature



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How much RAP can I use?

- Anticipated optimum asphalt content = 5.5%
- RAP has 5.0% asphalt
- RAP low temp grade = -17.5^{o}C
- Virgin AC low temp grade = -23.8^{o}C
- Desired blend low temp grade = -22^{o}C
- Assume WMA technology reduces low temp by 2^{o}C

% Rap Binder (of Blend)

- % RAP Binder (of blend) = $\left(\frac{T_{blend} - T_{virgin}}{T_{RAP} - T_{virgin}}\right) \times 100$

$$= \left(\frac{-22 - (-23.8)}{-17.5 - (-23.8)}\right) \times 100$$

$$= \frac{1.8}{6.3} \times 100 = 28.6\%$$

Maximum % RAP

- Max. % RAP = $100 \times \frac{\% \, RAP \; binder \; of \; Blend \times \% \, Total \; AC}{\% \, binder \; in \; RAP}$

$$= 100 \times \frac{28.6\% \times 5.5\%}{5.0\%} = 31.5\% \text{ RAP}$$

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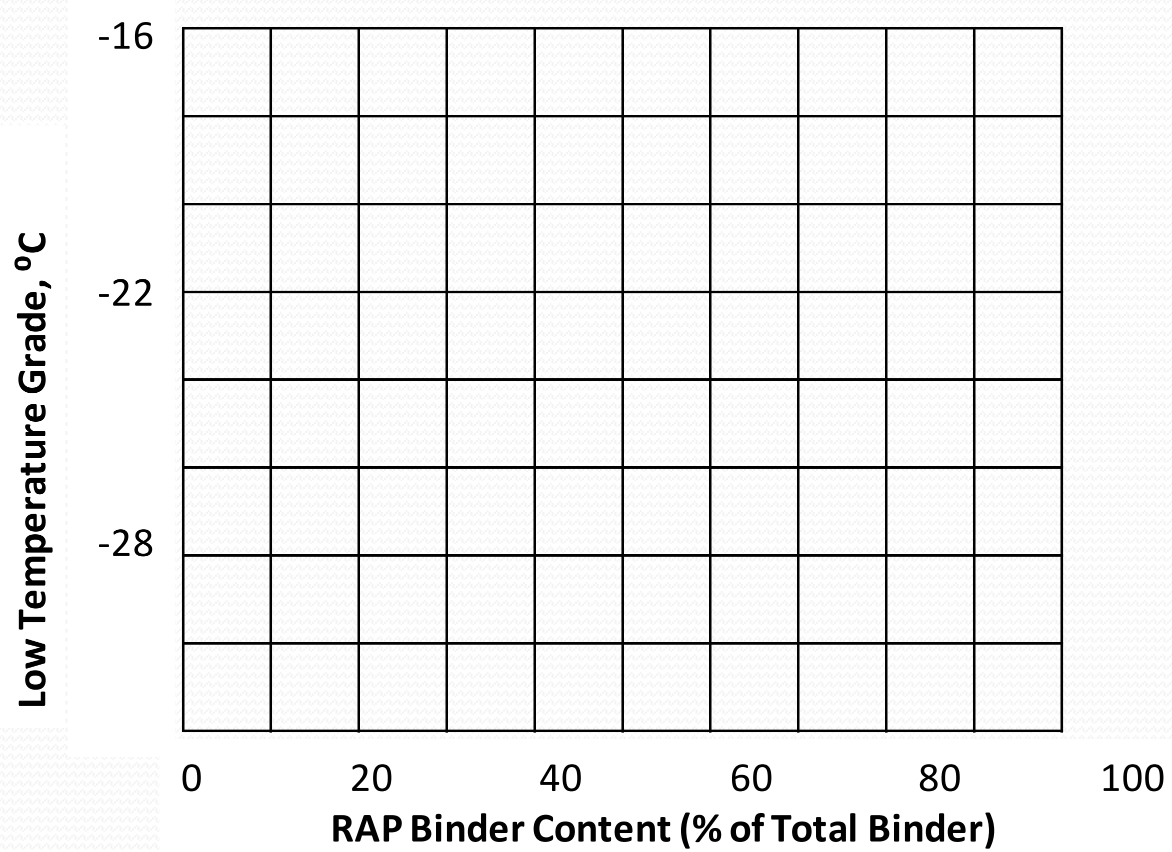
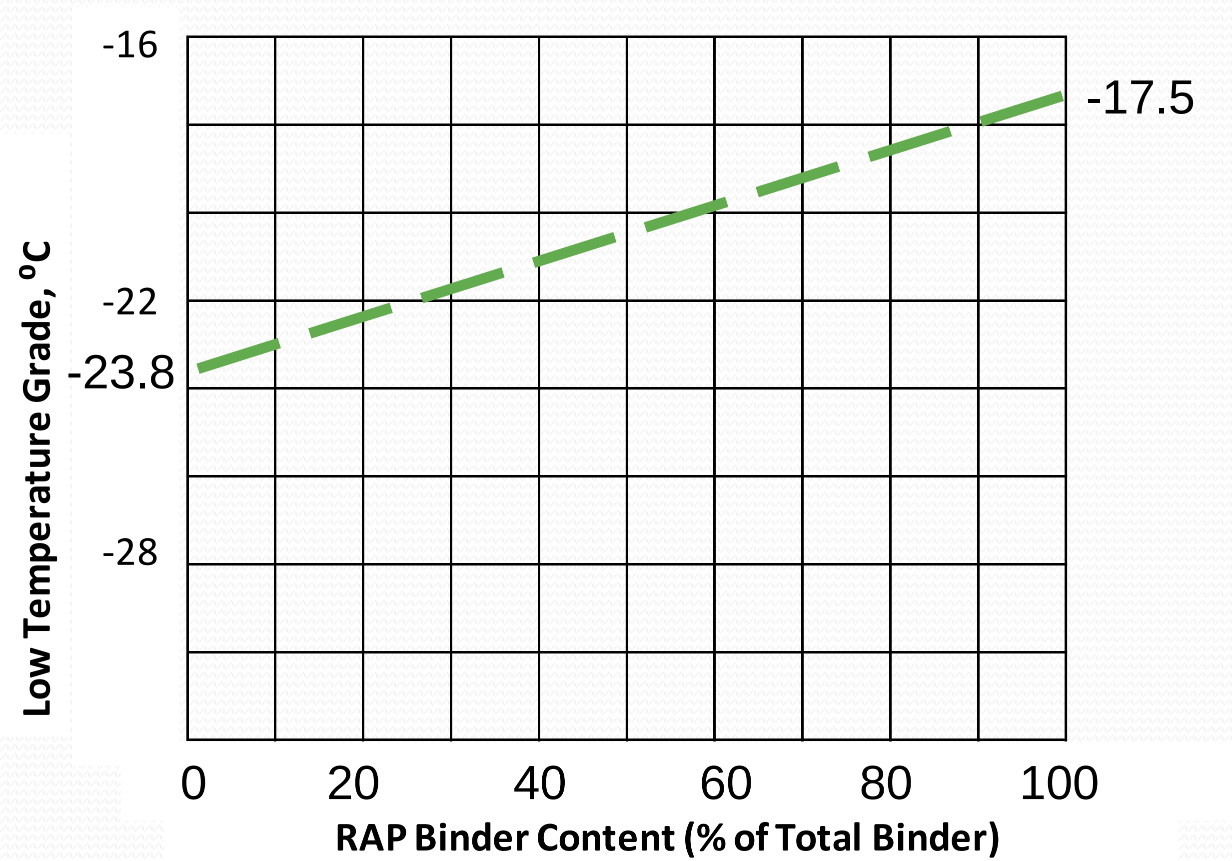
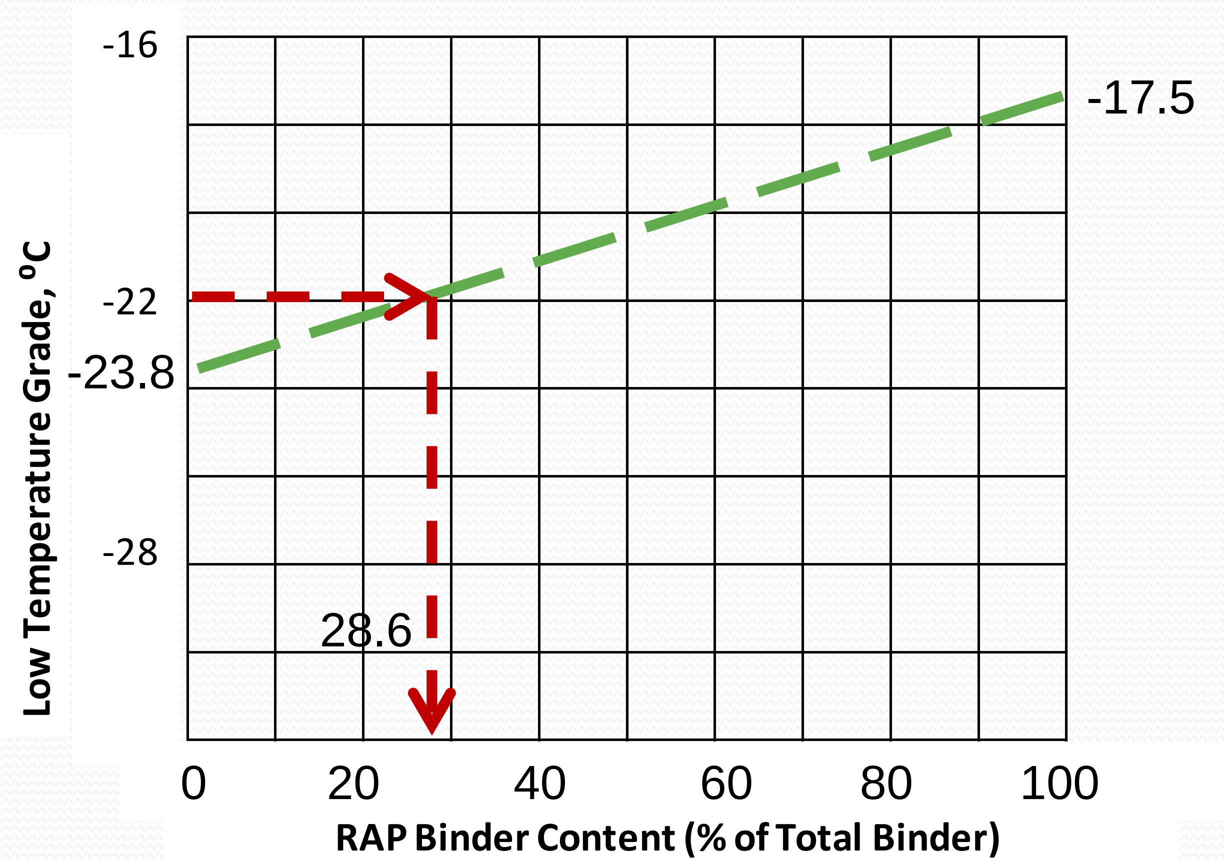
Effect of WMA on RAP



Effect of WMA on RAP



Effect of WMA on RAP



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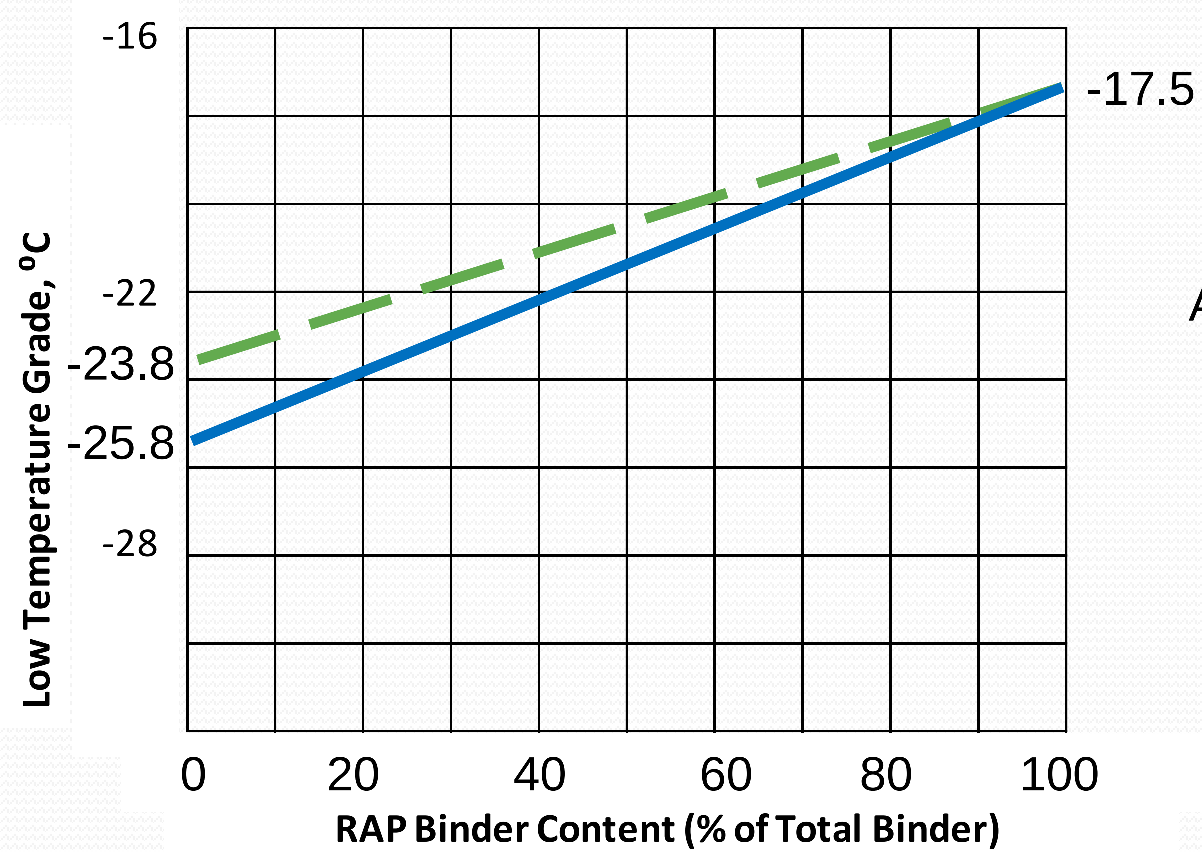
Effect of WMA on RAP



Assume WMA technology reduces low temp by 2ºC

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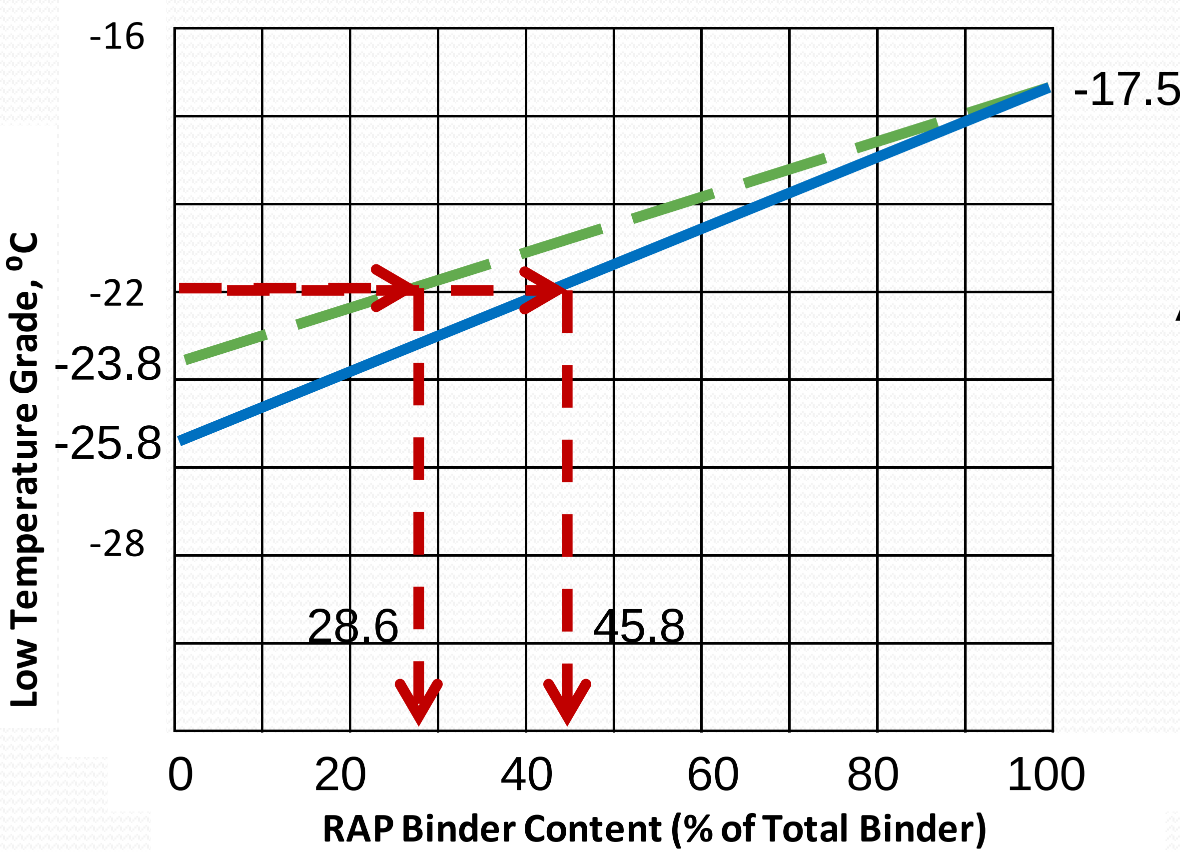
% Rap Binder (of Blend)

- % RAP Binder (of blend) = $\left(\frac{T_{blend} - T_{virgin}}{T_{RAP} - T_{virgin}}\right) \times 100$

$$= \left(\frac{-22 - (-25.8)}{-17.5 - (-25.8)}\right) \times 100$$

$$= \frac{3.8}{8.3} \times 100 = 45.8\%$$

Effect of WMA on RAP



Assume WMA technology reduces low temp by 2ºC

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Maximum % RAP

- Max. % RAP = $100 \times \frac{\% \, RAP \; binder \; of \; Blend \times \% \, Total \; AC}{\% \, binder \; in \; RAP}$

$$= 100 \times \frac{45.8\% \times 5.5\%}{5.0\%} = 50.4\% \text{ RAP}$$

RAP in WMA

- Planned field compaction temp > recovered high temp grade of RAP binder
- Some agencies assume < 100% blending
  - Example 1: 100% blending with 5.5% Total AC
    - RAP AC = 28.6% of total AC
    - 5.5% × 28.6% = 1.57% AC from RAP; 3.93% new AC
  - Example 2: 75% blending with 5.5% Total AC
    - 5.5% × 28.6% × 75%= 1.18% AC from RAP; 4.32% new AC

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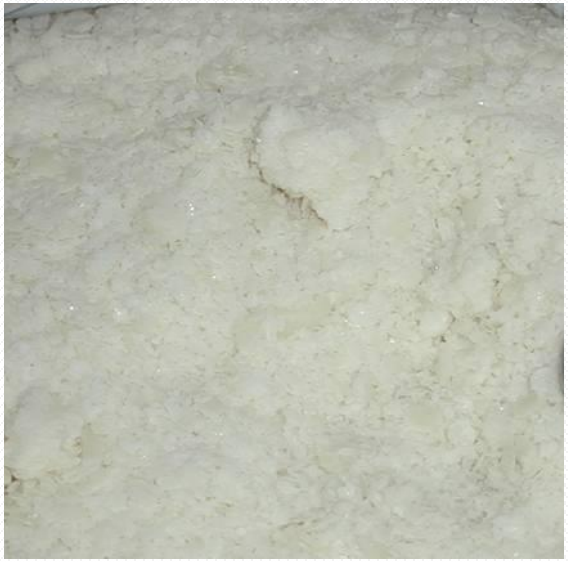
Number of Specimens

Specimen Type	Size	Approx. Mass	Number Required
G_{mm}	N/A	500-6,000 g (depends on NMAS)	2 per trial, 8 for design, 1 for compactibility
Volumetrics	150 mm diameter × 115 mm high	4,700 g	2 per trial, 8 for mix design
Coating	N/A	500-6,000 g (depends on NMAS)	1 at optimum
Compactibility	150 mm diameter × 115 mm high	4,700 g	4 at optimum
Moisture Susceptibility	150 mm diameter × 95 mm high	3,800 g	6 at optimum
Flow Number	150 mm diameter × 175 mm high	7,000 g	4 at optimum

Temperatures

- Aggregate - 15^{o}C higher than planned production temperature
- RAP- heat with aggregate; limit to 2 hours
- Binder- heat to planned production temperature
- Short-term conditioning- heat 2 hours at planned compaction temperature

WMA Additives Added to Binder



- Weigh required additive (by wt. of binder) into small container
- Heat covered binder in 135ºC oven until able to pour
- Add additive to binder and stir
- Store in covered container at room temperature until ready to use

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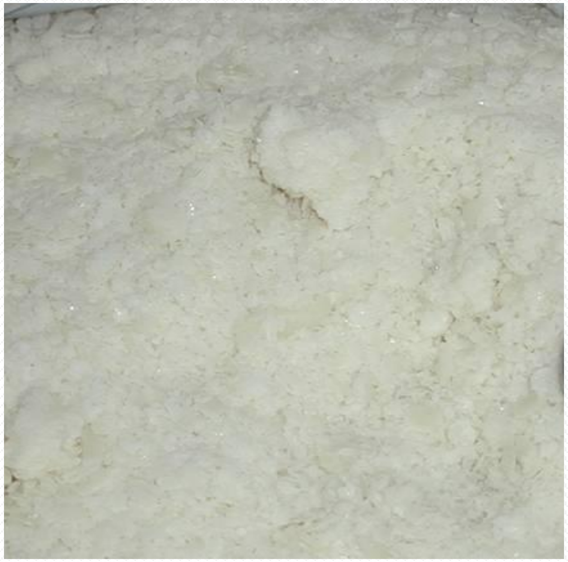
WMA Additives Added to Binder



- Prepare Specimens:
  - Heat to previous mentioned temp
  - Add liquid anti-strip to binder (if required)
  - Dry mix hot aggregate and RAP
  - Form crater and add binder
  - Mix 90 seconds
  - 2 hour aging at planned field compaction temp

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WMA Additives Added to Mixture

- Weigh required additive into small container
  - Based on Total AC, or Total mix?
- Add liquid anti-strip to binder (if required)
- Dry mix hot aggregate and RAP
- Form crater and add binder
- Pour WMA additive into pool of new binder
- Mix 90 seconds
- 2 hour aging At planned field compaction temp

WMA with Wet Aggregate Fraction

- Weigh required additive into small container
  - By weight of binder
- Heat covered binder in 135^{o}C oven until able to pour
- Add additive to binder and stir
- Add moisture to wet aggregate fraction; mix, cover and let stand for 2 hours

WMA with Wet Aggregate Fraction

- Prepare Specimens:
  - Dry mix hot dry aggregate portion and RAP
  - Add additive to binder immediately before mixing
  - Form crater and add binder
  - Mix 30 seconds
  - Add wet aggregate fraction; mix for 60 more seconds
  - Mix shall be between 90-100^{o}C (194-212^{o}F)
  - 2 hour aging at planned field compaction temp

WMA Foamed Mixtures

- Add liquid anti-strip additive to binder, if required
- Prepare foamed binder per supplier's instructions
- Dry mix hot aggregate and RAP
- Form crater and add foamed binder
- Mix 90 seconds
- 2 hour aging at planned field compaction temp

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Mixture Coating

- Mixing Times in AASHTO R35
- Separate Coarse Aggregate
  - ≥ 12.5mm NMAS, use 9.5 mm sieve
  - ≤ 9.5 mm NMAS, use 4.75 mm sieve
  - Minimum of 200 particles
- Evaluate per AASHTO T195
- Criteria: ≥ 95%

$$\%\ \text{Coated Particles} = \left(\frac{No.\,of\ fully\ coated\ particles}{No.\,of\ total\ particles}\right) \times 100$$

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Compactibility

- Compact 2 specimens @ optimum AC to N_d at planned field compaction temperature
  - Determine gyrations to 92% of G_{mm}
- Compact 2 specimens @ optimum AC to N_d at 30 ^oC below planned field compaction temperature
  - Determine gyrations to 92% of G_{mm}
- Criteria: Ratio ≤ 1.25

$$\text{Ratio} = \frac{(N_{92})T-30}{(N_{92})T} \leq 1.25$$

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Calculate % G_{MM} for Each Gyration

$$\% \; G_{mm} = 100 \times \left(\frac{G_{mb} \times hd}{G_{mm} \times hn} \right)$$

Compactibility

Gmm = 2.572

Gmb = 2.469

	Height, mm (T-30ºC)			
Gyrations	Specimen #1	Specimen #2	Average	% Gmm
:	:	:	:	:
22	116.7	116.8	116.8	91.7
23	116.6	116.6	116.6	91.8
24	116.4	116.5	116.4	91.9
25	116.2	116.2	116.2	92.1
26	116.0	116.0	116.0	92.3
:	:	:	:	:
100	111.4	111.6	111.5	96

92% Gmm at 250ºF (121ºC) = 21 gyrations

92% Gmm at 196ºF (91ºC) = 25 gyrations

$$\text{Ratio} = \frac{25}{21} = 1.19, \ \leq 1.25$$

Compactibility

- If recovered RAP binder grade = PG 82-xx
  - Minimum compaction temperature = $82^{o}C$ ($180^{o}F$)

Moisture Susceptibility

- WMA with anti-strip: TSR ≥ HMA in 67% of mixes
- WMA without anti-strip: TSR ≤ HMA in 79% of mixes

- Compact to 7.0 ± 0.5% Va
- TSR ≥ 0.80
- No visual stripping

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Flow Number

Test Conditions from AASHTO TP 79

- Compact prepared samples after 2 hour short-term conditioning at compaction temp
- Core 100 mm diameter by 150 mm high sample from 150 mm diameter by 175 mm high sample (AASHTO PP60)

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Flow Number

Test Conditions from NCHRP 9-33

- Va = 7.0 ± 0.5%
- Temperature = 50% Reliability @ high pavement temperature per LTPPBind v 3.1
  - Surface = 20 mm depth
  - Other layers = Top of layer
  - No adjustments for traffic or speed
- Unconfined
- 600 kPa Repeated Deviator Stress
- 30 kPa Contact Deviator Stress

Rutting Resistance

AASHTO T 79, Flow Number

Traffic Level, Million ESALs	Flow Number, Minimum
< 3	N/A
3 to < 10	30
10 to < 30	105
≥ 30	415

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Adjusting Mix to Meet Specifications

Consult WMA Technology Supplier for issues with:

- Coating
- Compactibility
- Moisture Sensitivity

Adjusting Mix to Meet Specifications

Rutting Resistance:

- Change binder grade (+1 high grade = factor of 2)

Adjusting Mix to Meet Specifications

Rutting Resistance:

- Change binder grade (+1 high grade = factor of 2)
- Add RAP (25-30% RAP = +1 high grade)

Adjusting Mix to Meet Specifications

Rutting Resistance:

- Change binder grade (+1 high grade = factor of 2)
- Add RAP (25-30% RAP = +1 high grade)
- Increase filler content (+ 50 fineness modulus = factor of 2)

Adjusting Mix to Meet Specifications

Rutting Resistance:

- Change binder grade (+1 high grade = factor of 2)
- Add RAP (25-30% RAP = +1 high grade)
- Increase filler content (+ 50 fineness modulus = factor of 2)
- Decrease VMA (-1% = factor of 1.2)

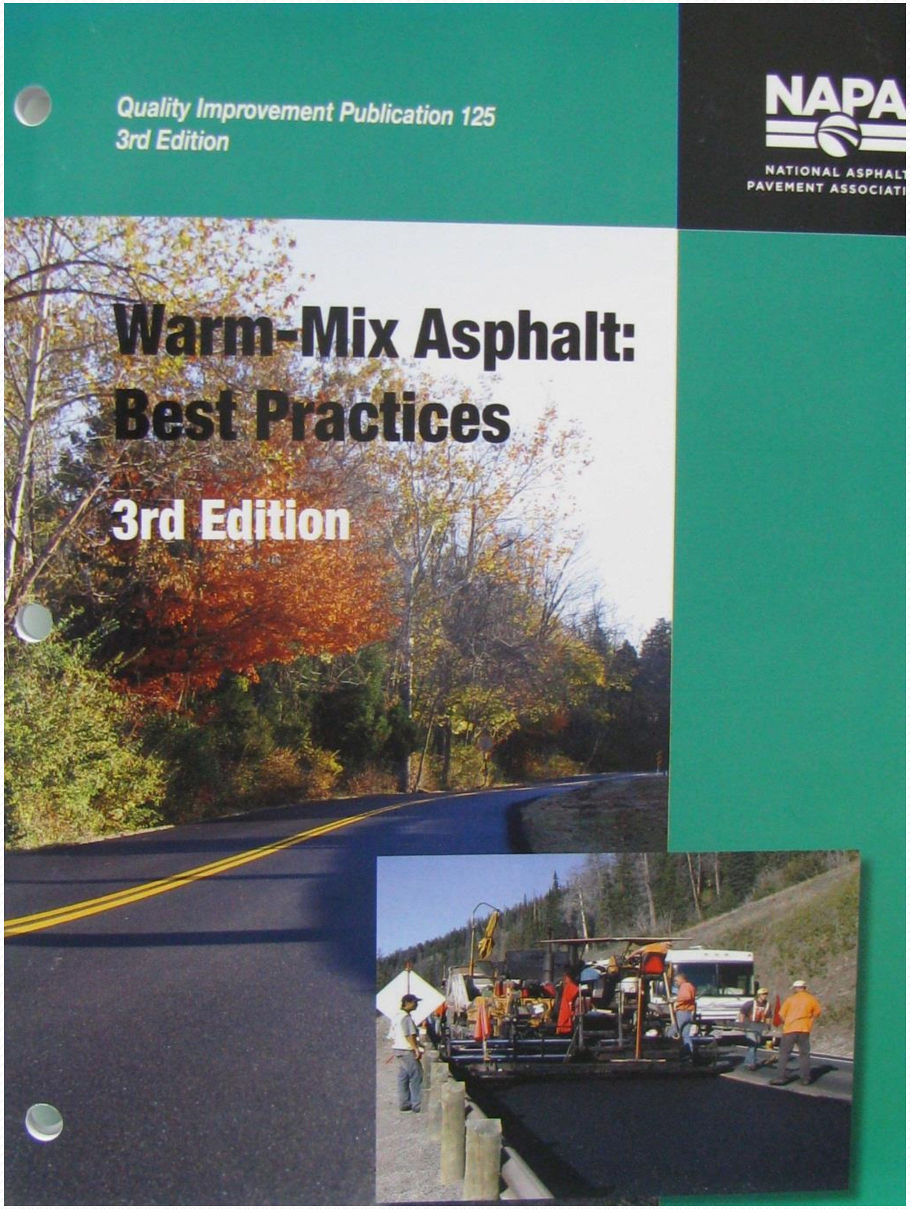
Adjusting Mix to Meet Specifications

Rutting Resistance:

- Change binder grade (+1 high grade = factor of 2)
- Add RAP (25-30% RAP = +1 high grade)
- Increase filler content (+ 50 fineness modulus = factor of 2)
- Decrease VMA (-1% = factor of 1.2)
- Increase N_d (+1 level = factor of 1.2)

Summary

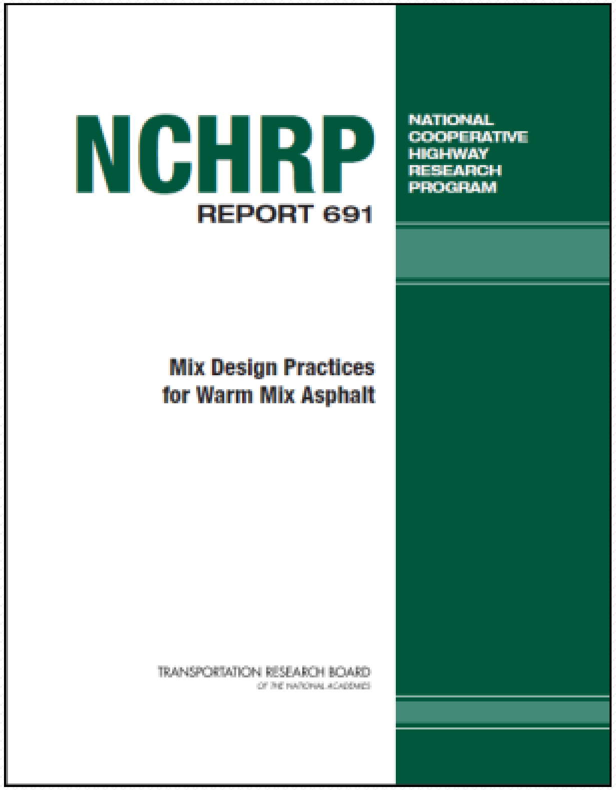
- Check WMA mixes for:
  - Coating
  - Compactibility
  - Moisture Sensitivity
  - Rutting Resistance
- Be sure whether additive rate based on binder weight or total mix weight



Available Resource

National Research Initiatives

- NCHRP 9-43 “Mix Design Practices for Warm Mix Asphalt”
- NCHRP Report 691
- Appendix to AASHTO R35



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Course Number: FHWA-NHI-131137

Special Mixture Design Considerations and Methods for Warm Mix Asphalt - WEB-BASED

PROGRAM AREA: Pavements and Materials

COURSE NUMBER: FHWA-NHI-131137

CALENDAR YEAR	LENGTH	CEU	FEE
2011	2 Hours	0 Units	$0 Per Participant
2012	2 Hours	0 Units	$0 Per Participant

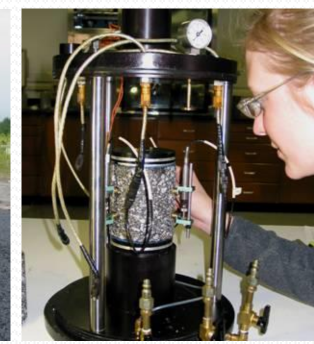
TRAINING LEVEL: Basic

CLASS SIZE: Minimum:1; Maximum:1

DESCRIPTION:

Highway transportation agencies are exploring the use of warm mix asphalt (WMA) for pavement projects. One of their main questions, particularly for agency mixture design technicians and engineers, is how WMA design differs from hot mix asphalt (HMA) design. "Mixture Design for Warm Mix Asphalt" is a Web-based training that presents the modifications to the current Superpave volumetric design procedure, as described in AASHTO R35, that are needed to complete a WMA mixture design. The training highlights key differences in WMA and HMA design procedures, and provides an opportunity to apply the AASHTO R35 standard practice to a WMA design modification.

Courtesy: Matt Corrigan, FHWA



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