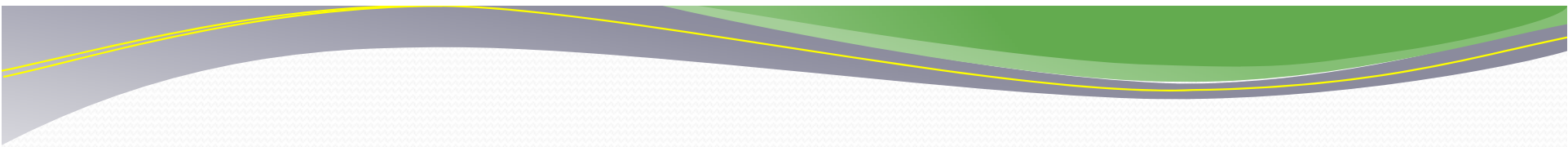


# MIX DESIGN PROCEDURES

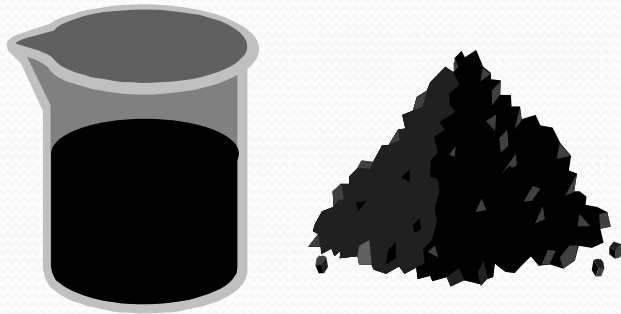
WMA Webinar  
September 25, 2012



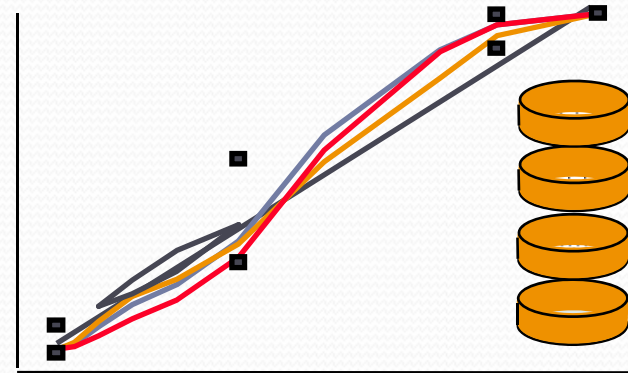
# Overview

- Similarities in mix design
- Differences in mix design
- Evolution of mix design
- Guidelines for design with WMA/RAP/RAS
- Best Practices

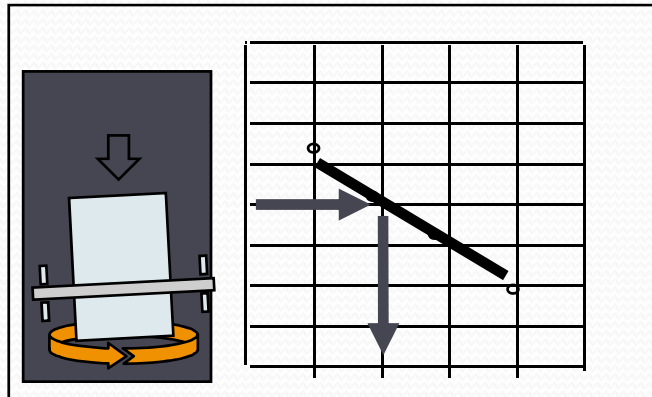
# 4 Steps in Mix Design



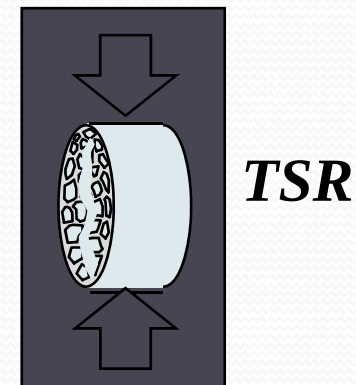
**1. Materials Selection**



**2. Design Aggregate Structure**



**3. Design Binder Content**



**4. Moisture Sensitivity**

# Adding WMA in Mix Design

- Drop-in?
- Separate mix design?
  - 2005 – 3 technologies
  - Now – 30+

# 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**

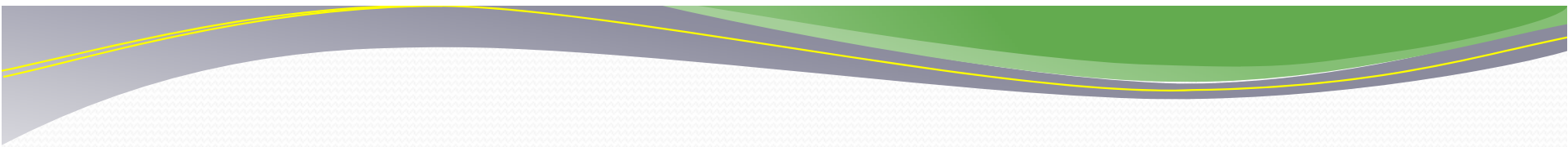
Shell: Shell **Thiopave**

Sonneborn Products: **SonneWarmix**

Stansteel: **Accu-Shear Dual Warm-Mix Additive System**

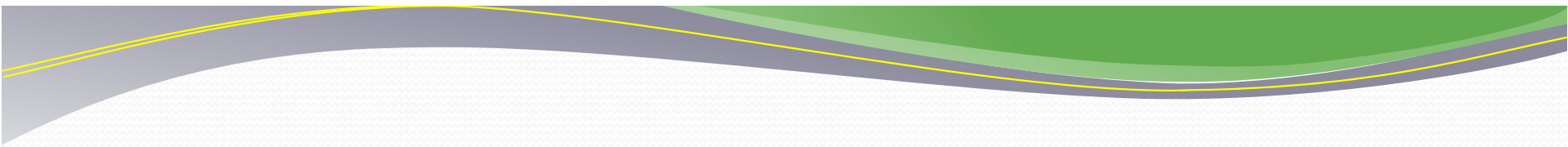
Tarmac Inc.: **Tri-Mix Warm Mix Injection**

Terex Roadbuilding: **Warm Mix Asphalt System**



# “Warm Mix” Definition

- Asphalt mixtures produced at temperatures approximately 50°F (28°C) lower than typically used for HMA
- WMA technologies may be used as coating and compaction aids without reduction in temperature



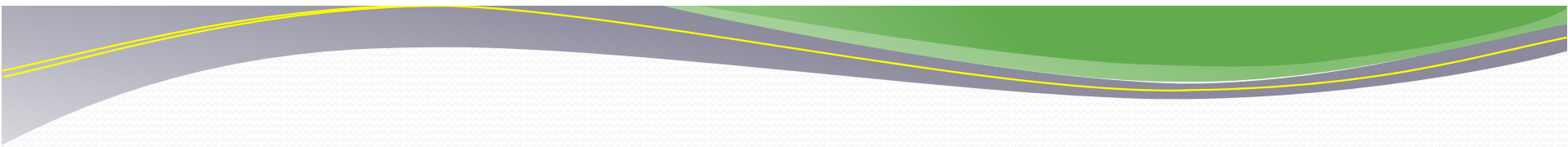
# Differences in Design Procedure

- 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 temperature and mixing time



# Planetary Mixers

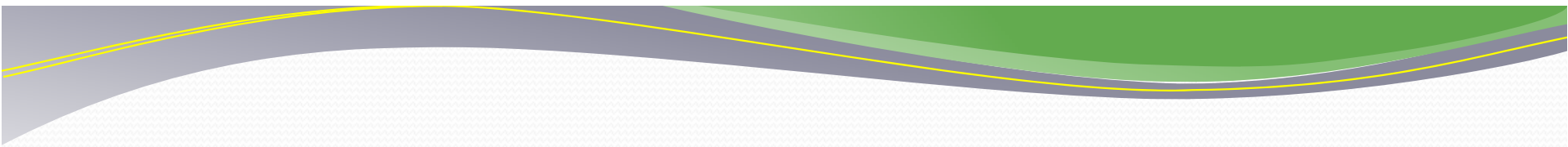
- Used for NCHRP 9-43 (20 Quart capacity)
- Mixing times used in AASHTO R35

# Differences Needing More Research

## Asphalt Foaming Devices

- Does lab foaming simulate field devices





# 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

Two WMA focused NCHRP projects for 2012:

- NCHRP 9-52 “Short-Term Laboratory Conditioning of Asphalt Mixtures”
- NCHRP 9-53 “Asphalt Foaming Characteristics for Warm Mix Asphalt Applications”

Proposed WMA NCHRP project for 2013:

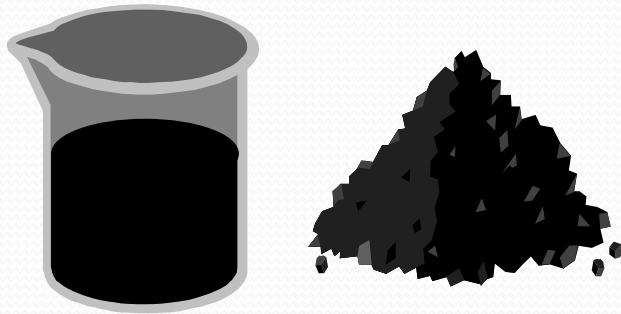
- “Recycled Asphalt Shingles (RAS) and Reclaimed Asphalt Pavement (RAP) in HMA/WMA Mixtures”

Courtesy: Matt Corrigan, FHWA

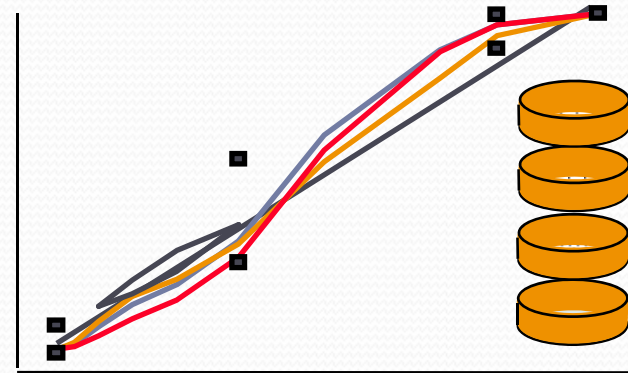
# WMA Mix Design Guidelines

- Additives added to the asphalt binder
- Additives added to the mixture during production
- Wet aggregate mixtures
- Plant foaming process

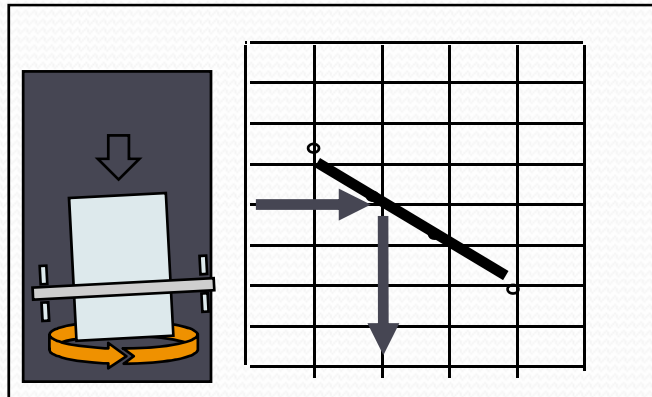
# 4 Steps in Mix Design



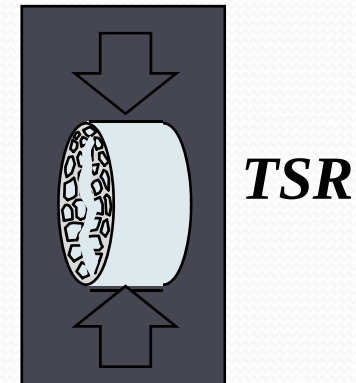
**1. Materials Selection**



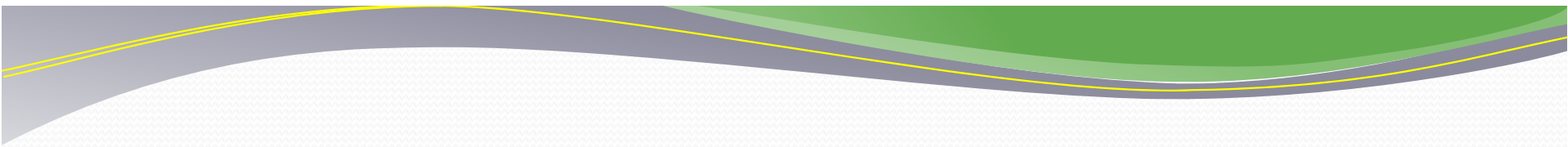
**2. Design Aggregate Structure**



**3. Design Binder Content**



**4. Moisture Sensitivity**



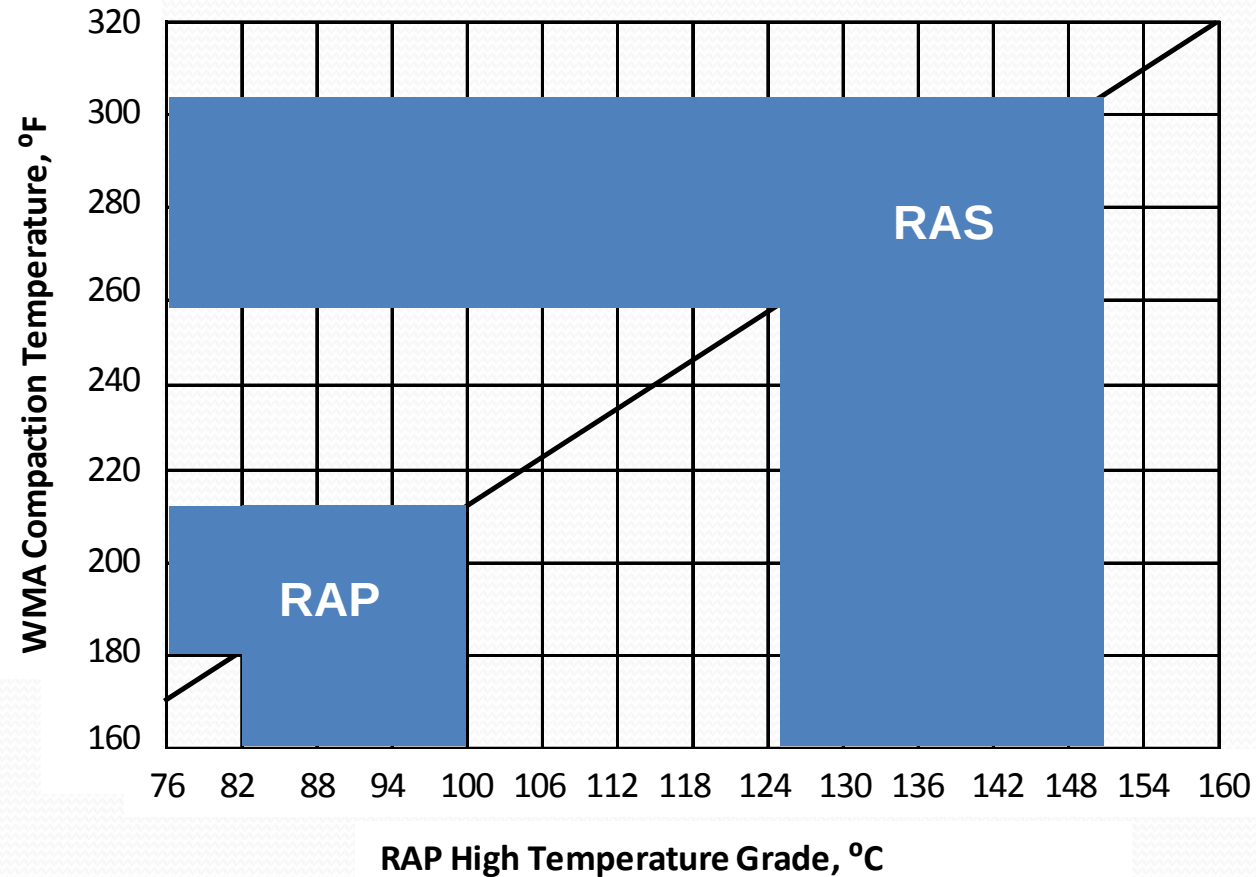
# Binder Selection

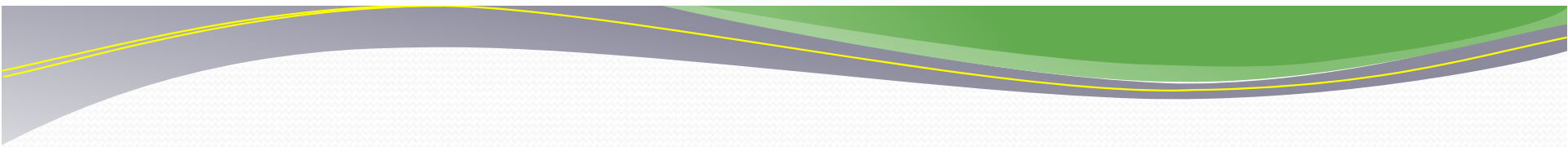
- Use same grade normally used for HMA \*
- Consider environment and traffic at project site

\* If WMA is 100°F (56°C) lower than HMA, increase high temperature one grade.

# RAP & RAS in WMA

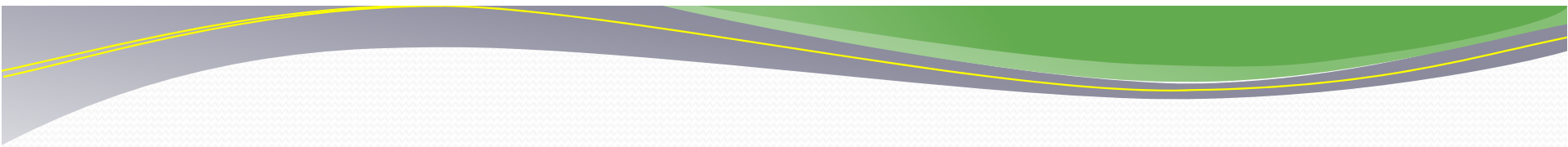
Criteria: High grade of RAP  $\leq$  planned field compaction temperature





# How much RAP can I use?

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

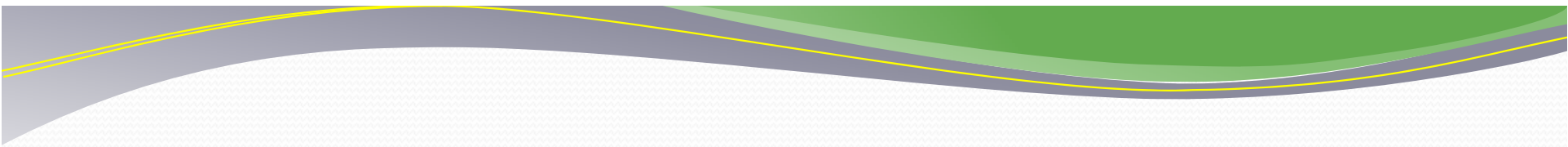


# % Rap Binder (of Blend)

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

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

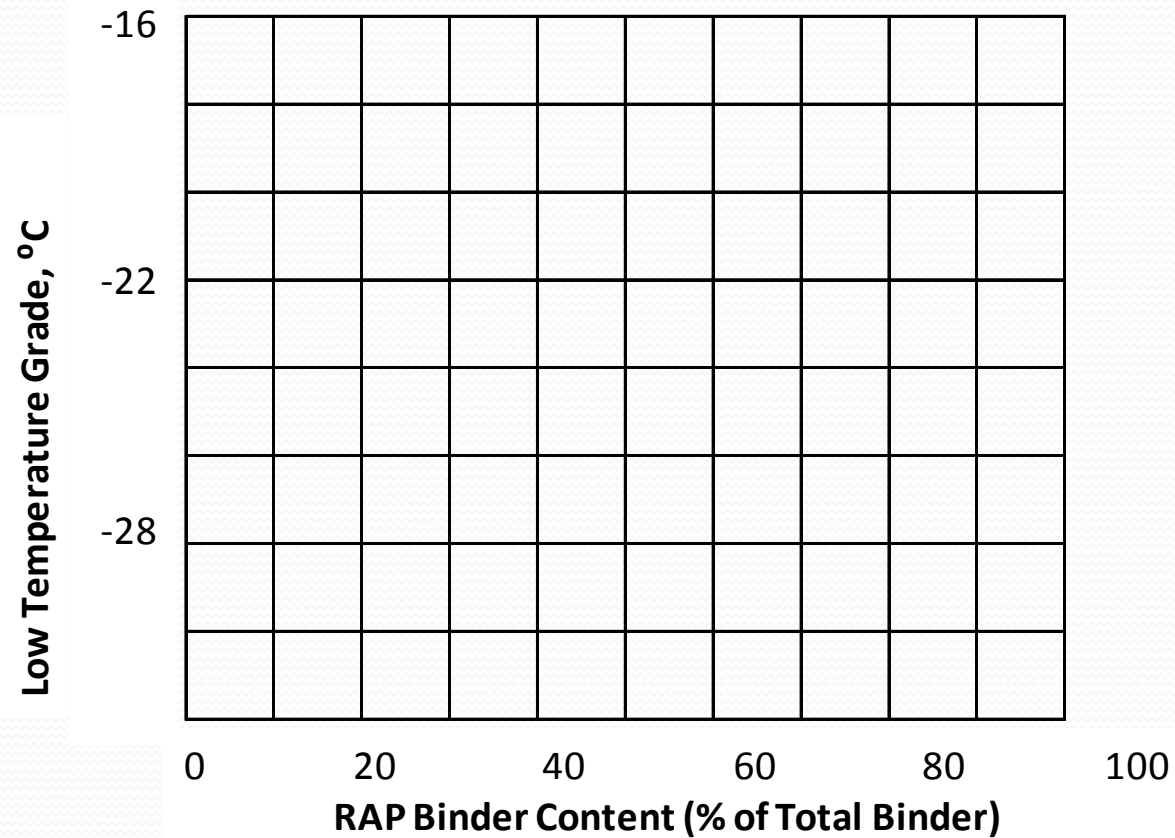
$$= \frac{1.8}{6.3} \times 100 = 28.6\%$$



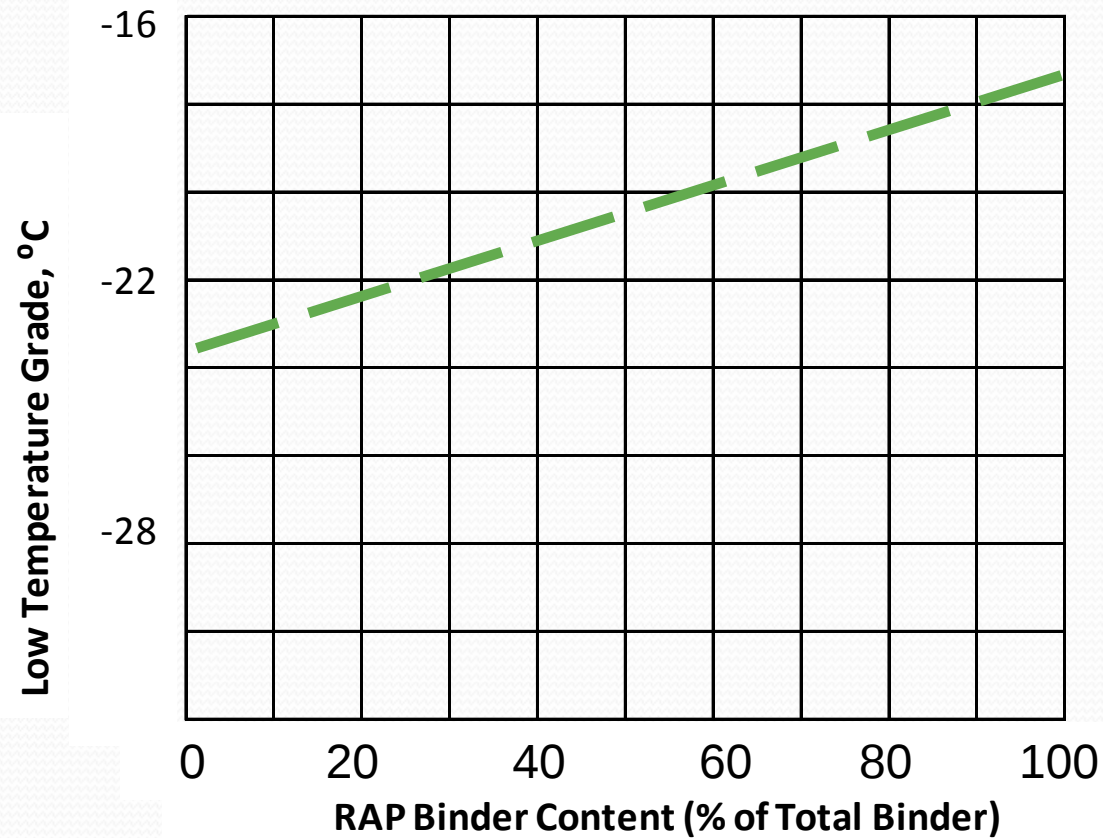
# Maximum % RAP

- $$\text{Max. \% RAP} = 100 \times \frac{\% \text{ RAP binder of Blend} \times \% \text{ Total AC}}{\% \text{ binder in RAP}}$$
$$= 100 \times \frac{28.6\% \times 5.5\%}{5.0\%} = 31.5\% \text{ RAP}$$

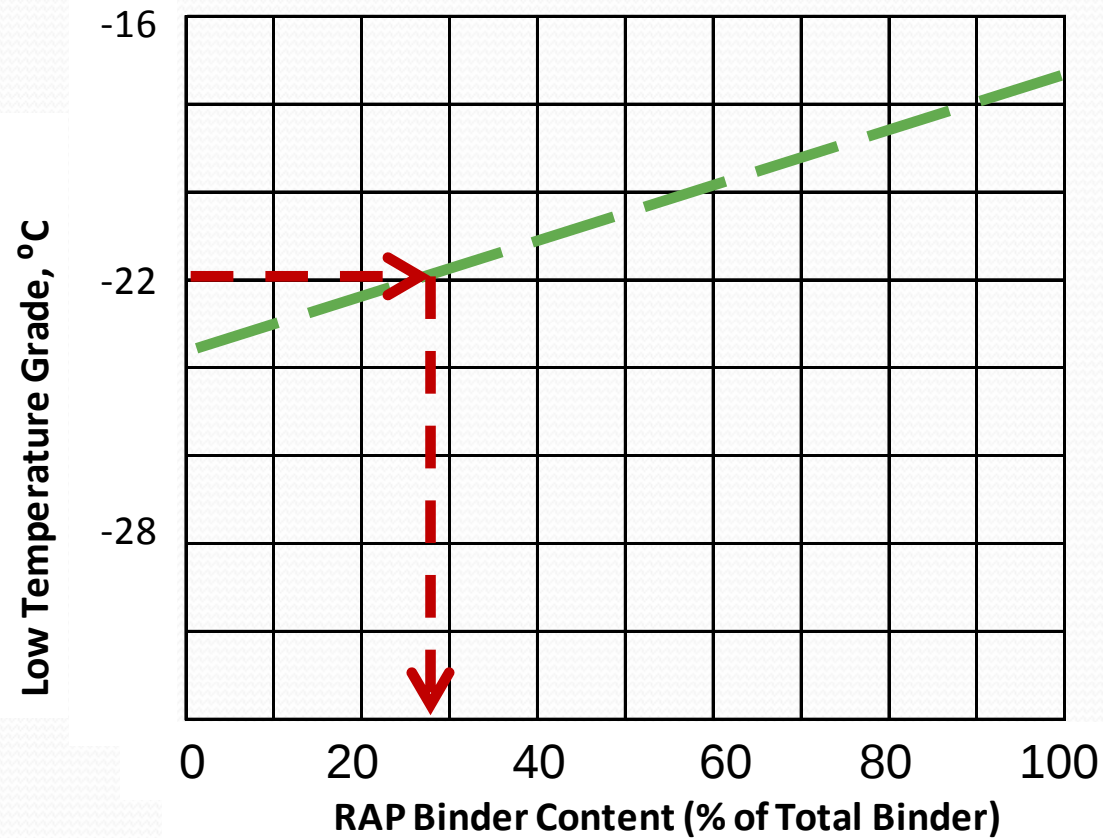
# Effect of WMA on RAP



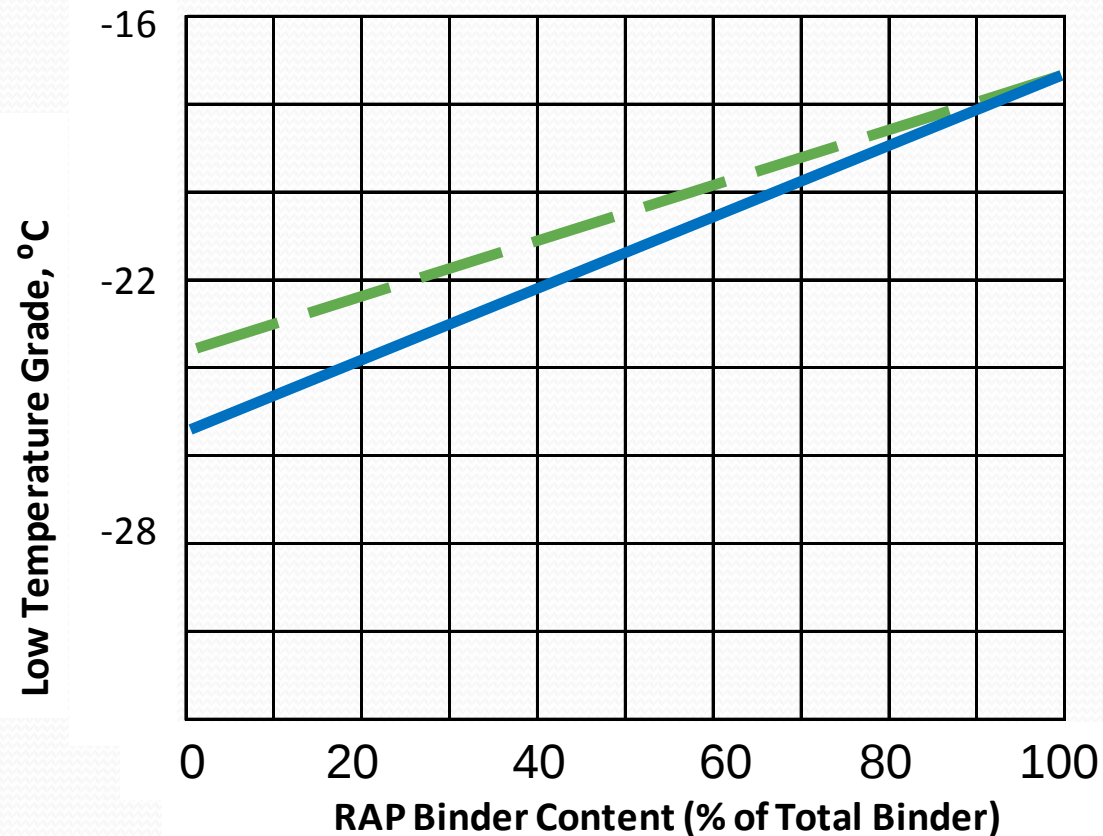
# Effect of WMA on RAP



# Effect of WMA on RAP

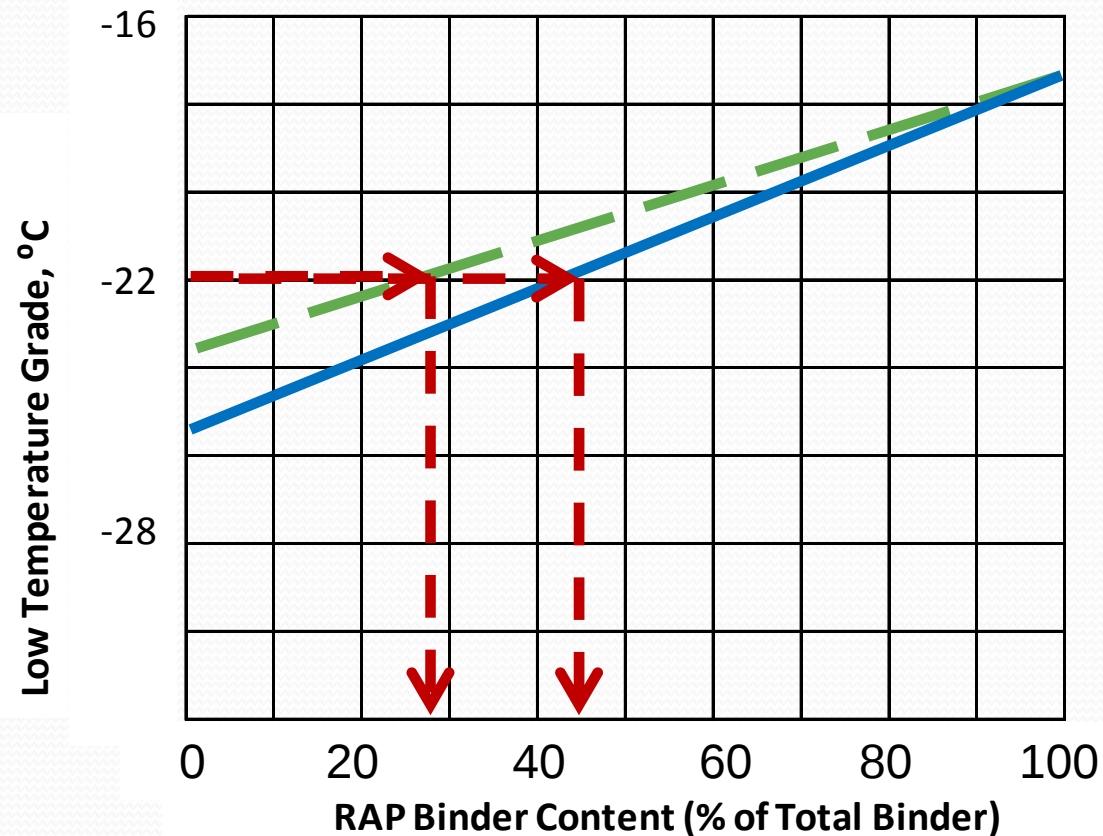


# Effect of WMA on RAP

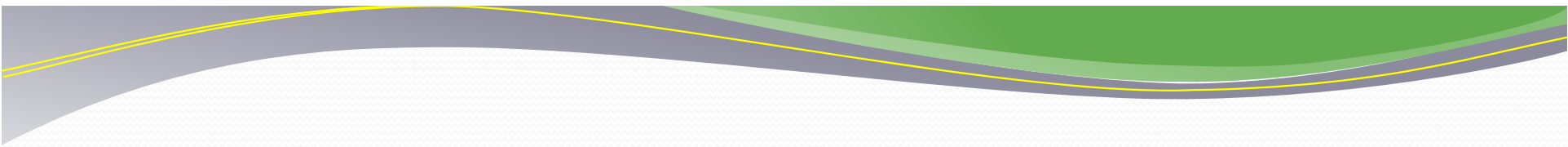


Assume WMA  
technology  
reduces low  
temp by 2°C

# Effect of WMA on RAP



Assume WMA  
technology  
reduces low  
temp by 2°C

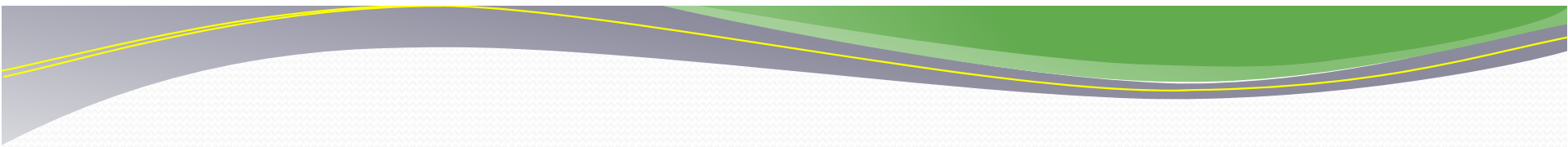


# RAP in WMA

- 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
    - $5.5\% \times 28.6\% = 1.57\%$  AC from RAP; 3.93% new AC
  - Example 2: 75% blending with 5.5% Total AC
    - $5.5\% \times 28.6\% \times 75\% = 1.18\%$  AC from RAP; 4.32% new AC

# Number of Specimens

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



# Temperatures

- Aggregate - 15°C higher than planned production temperature
- RAP- heat with aggregate; limit to 2 hours
- Binder- heat to planned production temperature
- Short-term conditioning- heat to planned compaction temperature

# WMA Additives Added to Binder



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

# 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

# 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°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°C (194-212°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

# Mixture Coating

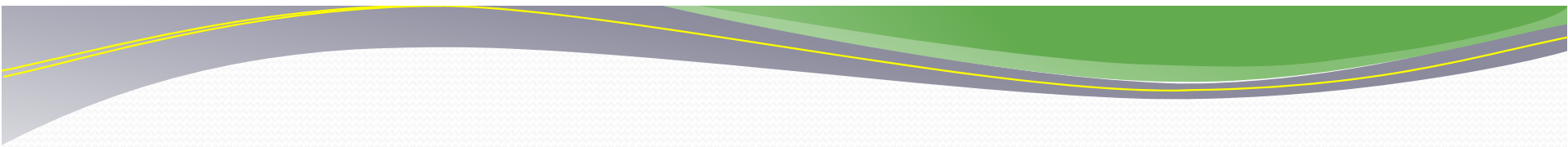
- Prepare samples according to WMA method used
  - Do NOT short-term condition the mixture
- Separate Coarse Aggregate
  - $\geq 12.5\text{mm}$  NMAS, use 9.5 mm sieve
  - $\leq 9.5\text{ mm}$  NMAS, use 4.75 mm sieve
  - Minimum of 200 particles
- Evaluate per AASHTO T195
- Criteria:  $\geq 95\%$  fully coated

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

# Compactibility

- Prepare four gyratory samples including short-term conditioning for 2 hours
- 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 °C below planned field compaction temperature
  - Determine gyrations to 92% of  $G_{mm}$
- Criteria: Ratio  $\leq 1.25$

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



# 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

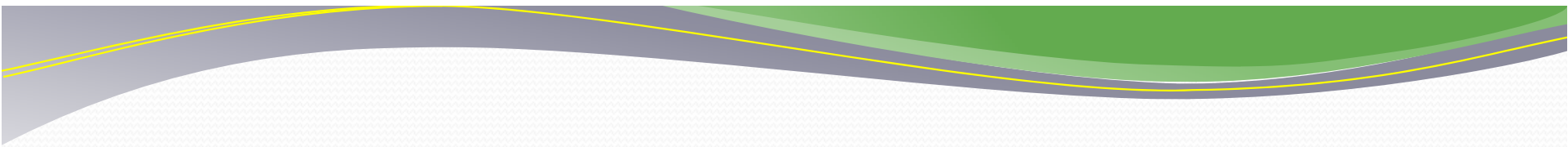
Gmb = 2.469

| Height, mm (T-30°C) |             |             |         |       |
|---------------------|-------------|-------------|---------|-------|
| 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 250°F (121°C) = 21 gyrations

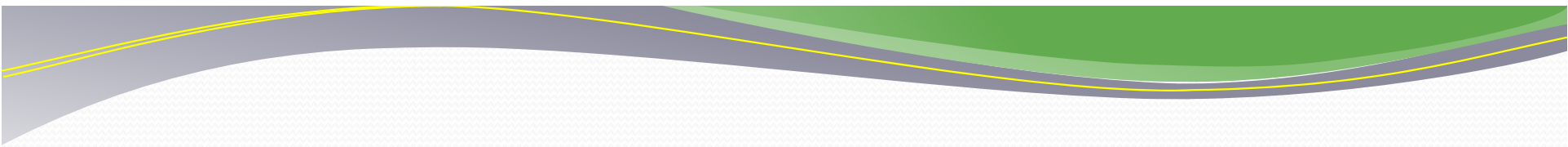
92% Gmm at 196°F (91°C) = 25 gyrations

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



# Compactibility

- If recovered RAP binder grade = PG82-xx
  - Minimum compaction temperature = 82°C (180°F)



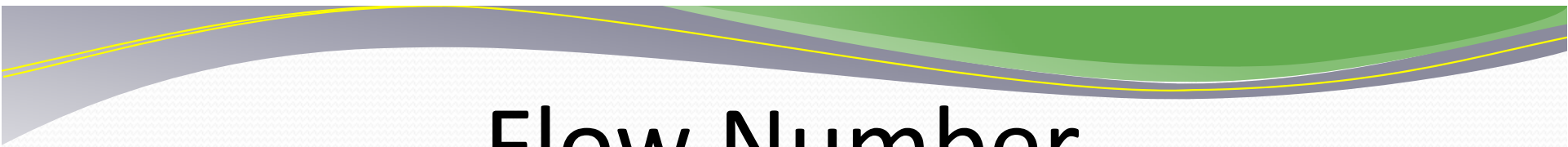
# Moisture Susceptibility

- WMA with anti-strip: TSR  $\geq$  in 67% of mixes
- WMA without anti-strip: TSR  $\leq$  in 79% of mixes
- Compact to  $7.0 \pm 0.5\%$  Va
- TSR  $> 0.80$
- No visual stripping

# 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)



# Flow Number

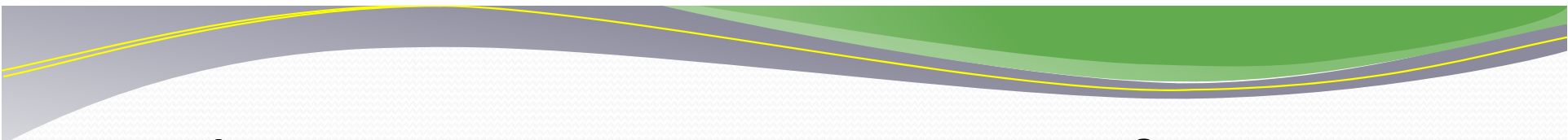
## Test Conditions from AASHTO TP 79

- $V_a = 7.0 \pm 1.0\%$
- Temperature = 50% Reliability @ high pavement temperature per LTPP Bind v 3.1
  - Surface = 20 mm depth
  - Other layers = Top of layer
  - No adjustments for traffic or speed
- Unconfined
- 600 kPa (87 psi) Repeated Deviator Stress
- 30 kPa (4 psi) Contact Deviator Stress

# Rutting Resistance

## AASHTO T 79, Flow Number

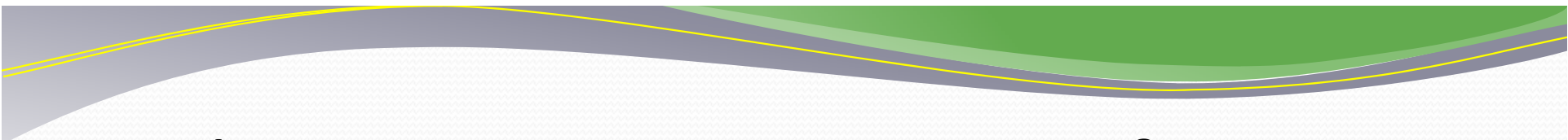
| Traffic Level,<br>Million ESALs | Flow Number,<br>Minimum |
|---------------------------------|-------------------------|
| < 3                             | N/A                     |
| 3 to < 10                       | 30                      |
| 10 to < 30                      | 105                     |
| $\geq 30$                       | 415                     |



# 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

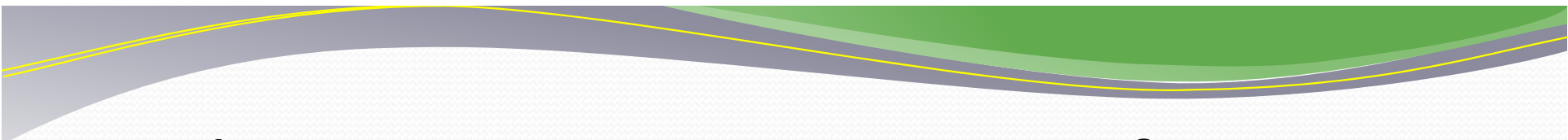
Rutting Resistance:

- 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

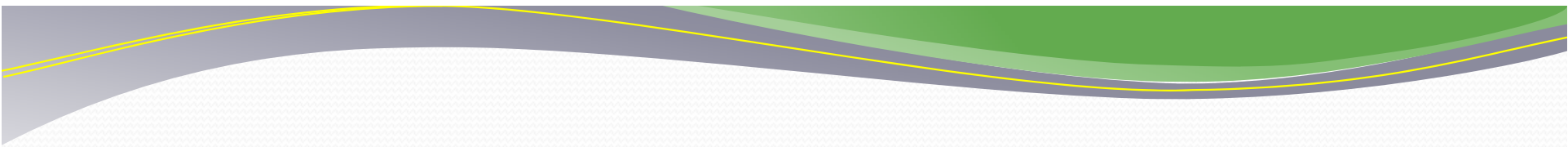
## Rutting Resistance:

- 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

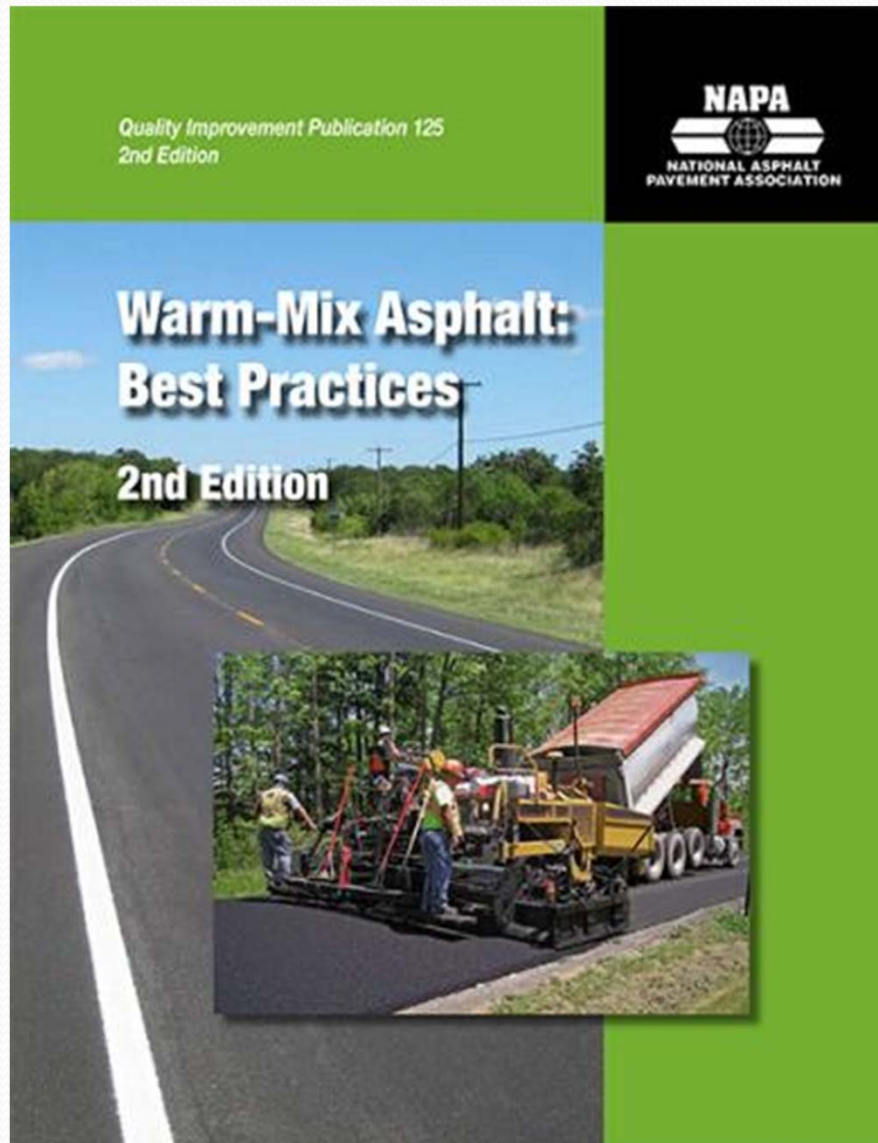
## Rutting Resistance:

- 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

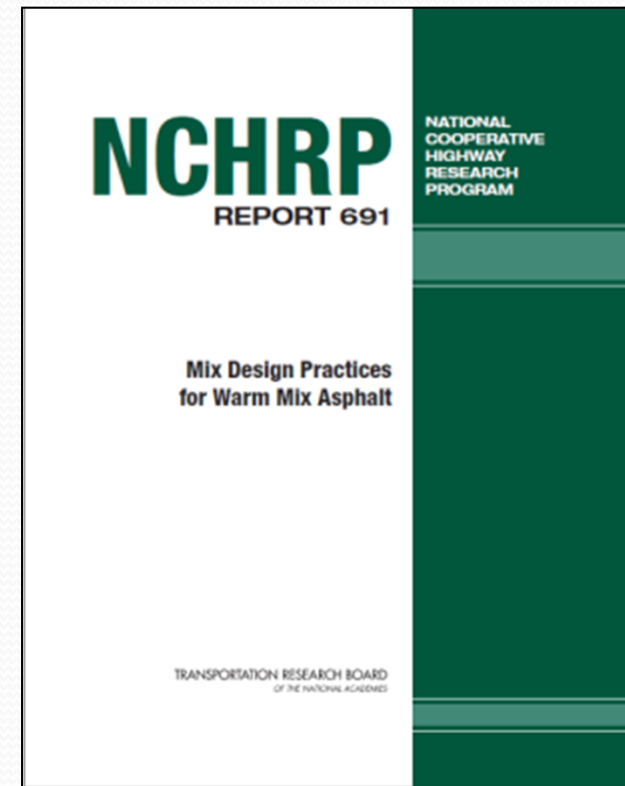
- Check WMA mixes for:
  - Coating
  - Compactibility
  - Moisture Sensitivity
  - Rutting Resistance
- Be sure whether additive rate based on binder weight or total mix weight



# Available Resource

# National Research Initiatives

- NCHRP 9-43 “Mix Design Practices for Warm Mix Asphalt”
- NCHRP Report 691
- Appendix 2 to AASHTO R35



# 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

- Advanced Mix Design – January 29-31, 2013



**National Center for  
Asphalt Technology**

**NCAT**

**AUBURN UNIVERSITY**



[www.ncat.us](http://www.ncat.us)

