



# INNOVATIONS IN WARM MIX ASPHALT

Minnesota Asphalt Contractors' Workshop  
March 6, 2013



# ECONOMICS AND THE ENVIRONMENT

- Primary drivers of innovation today.
- Sustainability
  - Of materials
  - Of pavements
  - Of energy
  - Of funding
  - Of market share

# WMA BENEFITS

- Reduced fuel used for heating (15 to 30% reduction)
- Reduced greenhouse gases
- Construction benefits (compaction aid)
- May facilitate longer haul distances
- May allow colder weather paving
- May allow higher recycled contents (RAP, RAS)



# LONGER HAUL DISTANCES

- WMA cools slower than HMA
  - Cooling rate proportional to difference between mix and air temperatures
- Compaction achieved at lower temps
- May be able to haul longer, farther and still achieve good compaction and performance
- Many successful examples of 1–3 hour hauls

# EMERGENCY PAVING STUDY

- Recovering from natural disasters
- Plants in area may be shut down
- How far can you haul mix using WM technology at hot temperatures?
- Mississippi State study tested plant mix hauled from 1 to 10.5 hours
- Conclusion – 1 to 8 hour haul times feasible

# EMERGENCY PAVING STUDY

- $G_{mm}$  and  $P_{ba}$  increased as haul time increased
  - Could add 0.1 to 0.2% binder to counteract (*check with your materials*)
- Haul times of up to 8.4 hours acceptable with foam or additive
  - At 10.5 hrs, Additive mix had low temp grade 5.2°C warmer, high temp grade 4.4°higher
- No unusual molecular changes with aging
- Mixes remained workable after long haul



May need to use WMA as compaction aid  
at “normal” production temperatures

# COLD WEATHER PAVING

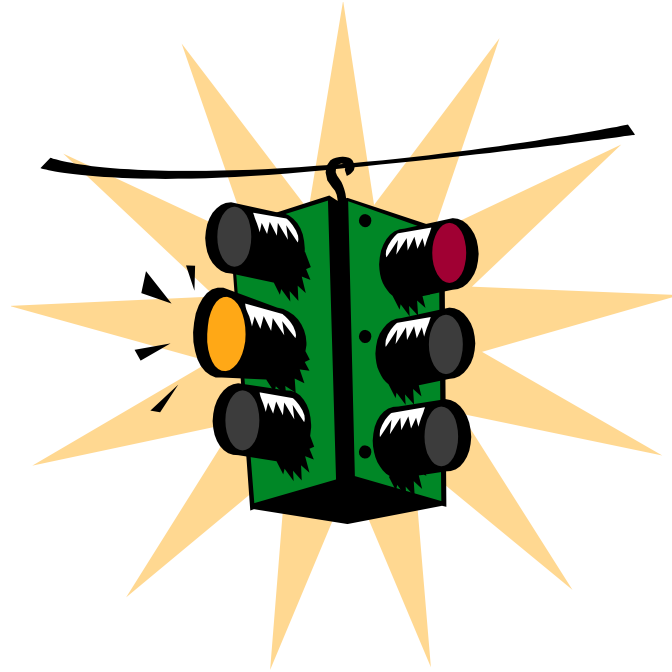
- Lower rate of cooling
- Density obtainable at lower temperatures
- WMA may help extend paving season.





# EXAMPLES OF COLD WEATHER PAVING

- Examples from Europe, New York, South Carolina, and others show good density can be achieved
- Road in China paved after earthquake
  - High altitude, low temp ( $\sim 5^{\circ}\text{C}$  ( $40^{\circ}\text{F}$ ))
  - Densities of 98–99% of Marshall density achieved



Again, may need to produce at “normal” temperatures for cold weather paving.

# HIGHER RAP CONTENTS



- RAP used since 1970s
  - Spurred by high prices, Arab Oil Embargo
  - Development of milling technology
- Today – strong incentives to use higher amounts of RAP in more mixes
  - High prices again
  - Helps contractors stay competitive
  - Helps asphalt compete with concrete



## RECLAIMED BINDER

- RAP increases mix stiffness
  - Negligible at low RAP contents
  - More important at high RAP contents
  - Could increase cracking – thermal, fatigue and reflective
- Especially true for RAS?

# RAS = RECYCLED ASPHALT SHINGLES

- High binder contents, as high as 30%.
  - Greatly reduces demand for new binder
  - Hard, angular fine aggregate and fibers
- But, binder is very stiff (oxidized)
  - More likely to crack???
- Allowable shingle content is about 20–25% as high as allowable RAP content.

# WARM MIX ASPHALT

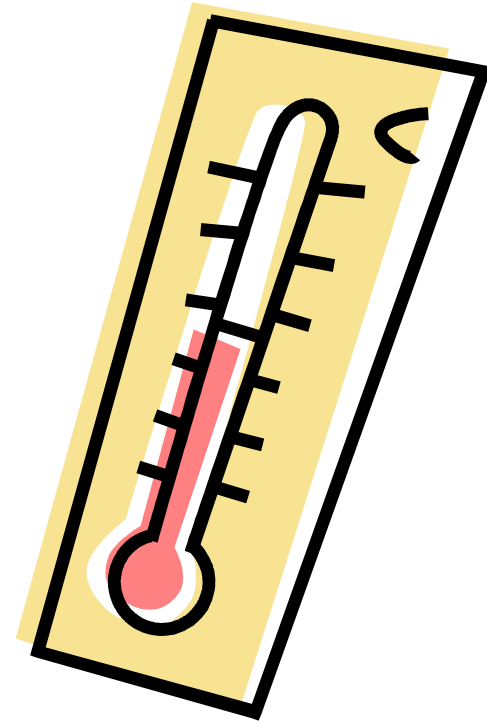
- Energy Savings
- Decreased Emissions
  - Visible and Non-Visible
- Decreased Fumes
- Extended Paving Season
- Compaction Aid
- *Decreased Binder Aging*
- *Potential for Increased RAP/RAS Usage*



# BINDER AGING

Function of:

- Temperature
- Time at elevated temperature
  
- Less aging at WMA temps may help with reclaimed binders



# WMA + RAP AND/OR RAS

- RAP contents of 50% with WMA
  - Improved rut resistance
  - Better resistance to moisture damage
  - Little to no effect on cracking
- Do they blend?
  - NCHRP 9-43 found RAP will if production temperature > high PG grade of recovered binder
  - Other work shows effect of RAP on high PG > effect on low PG



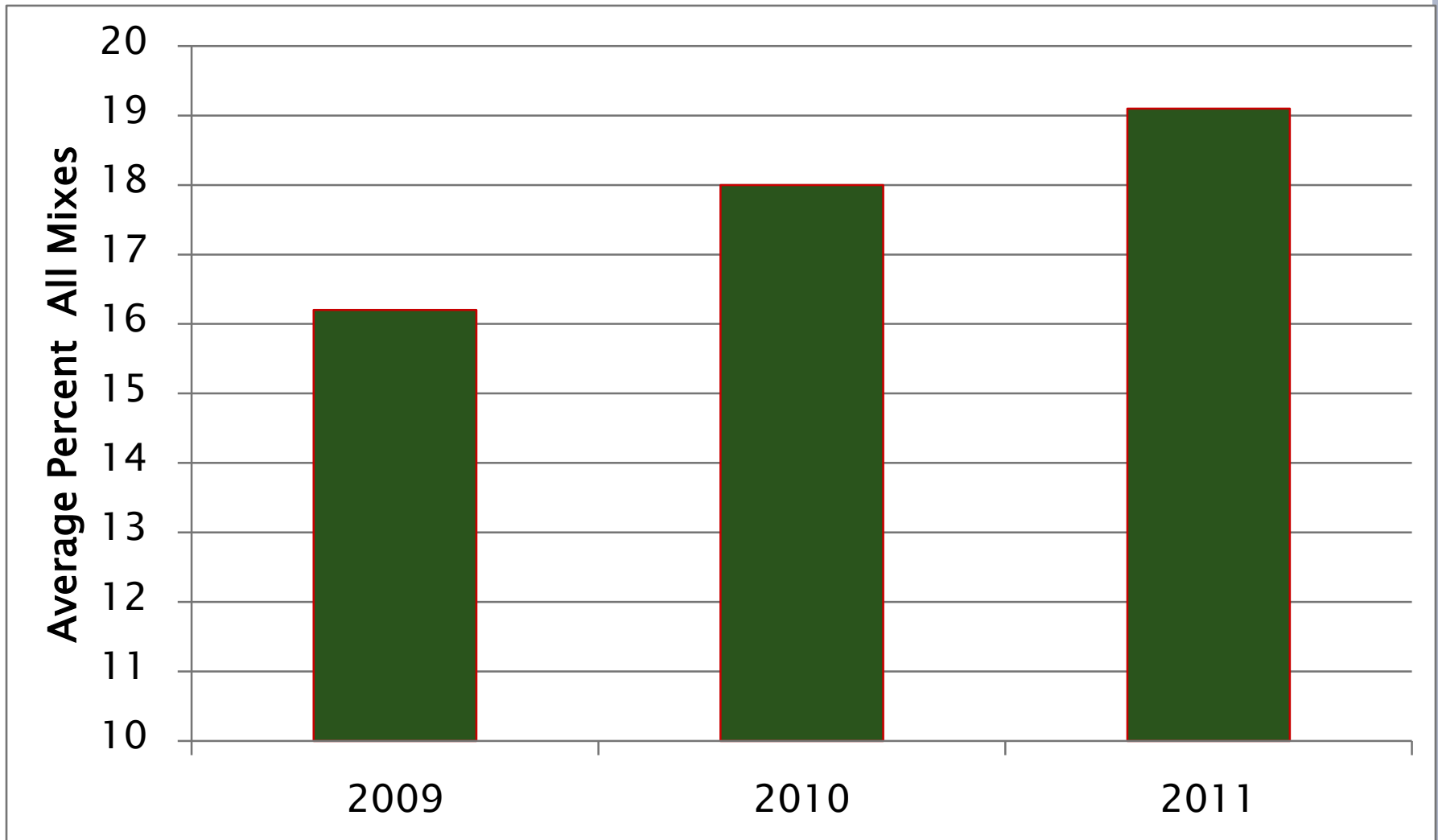
# NCHRP RESEARCH

- 9-43, WMA Mix Design (completed)
- 9-46, High RAP Mix Design and Management (final deliverables in review)
- 9-47 WMA Emissions, Properties (completed)
- 9-47A, Properties and Performance of WMA (2013)
- 9-49, WMA Moisture Susceptibility (2013)
- 9-49A, Long-Term Field Performance (2016)
- 9-53, Properties of Foamed WMA (2014)
- 9-55, Shingles and RAP/RAS in WMA (2016)

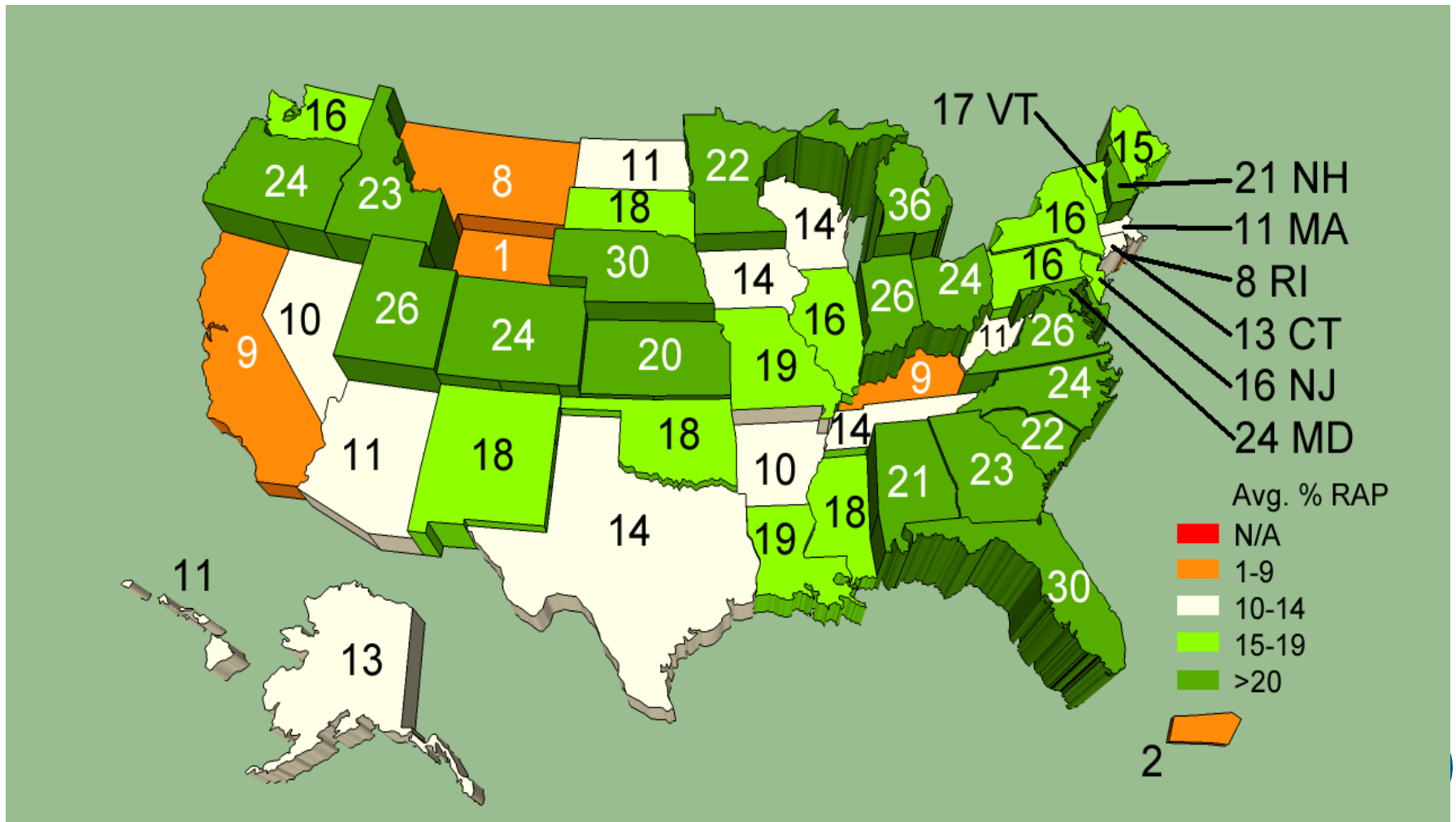
# HOW MUCH IS USED?

- FHWA/NAPA survey of producers
  - About 200 companies with over 1000 plants
- Compared usage in 2009, 2010, 2011
- Thanks to Audrey Copeland and NAPA for slides and data

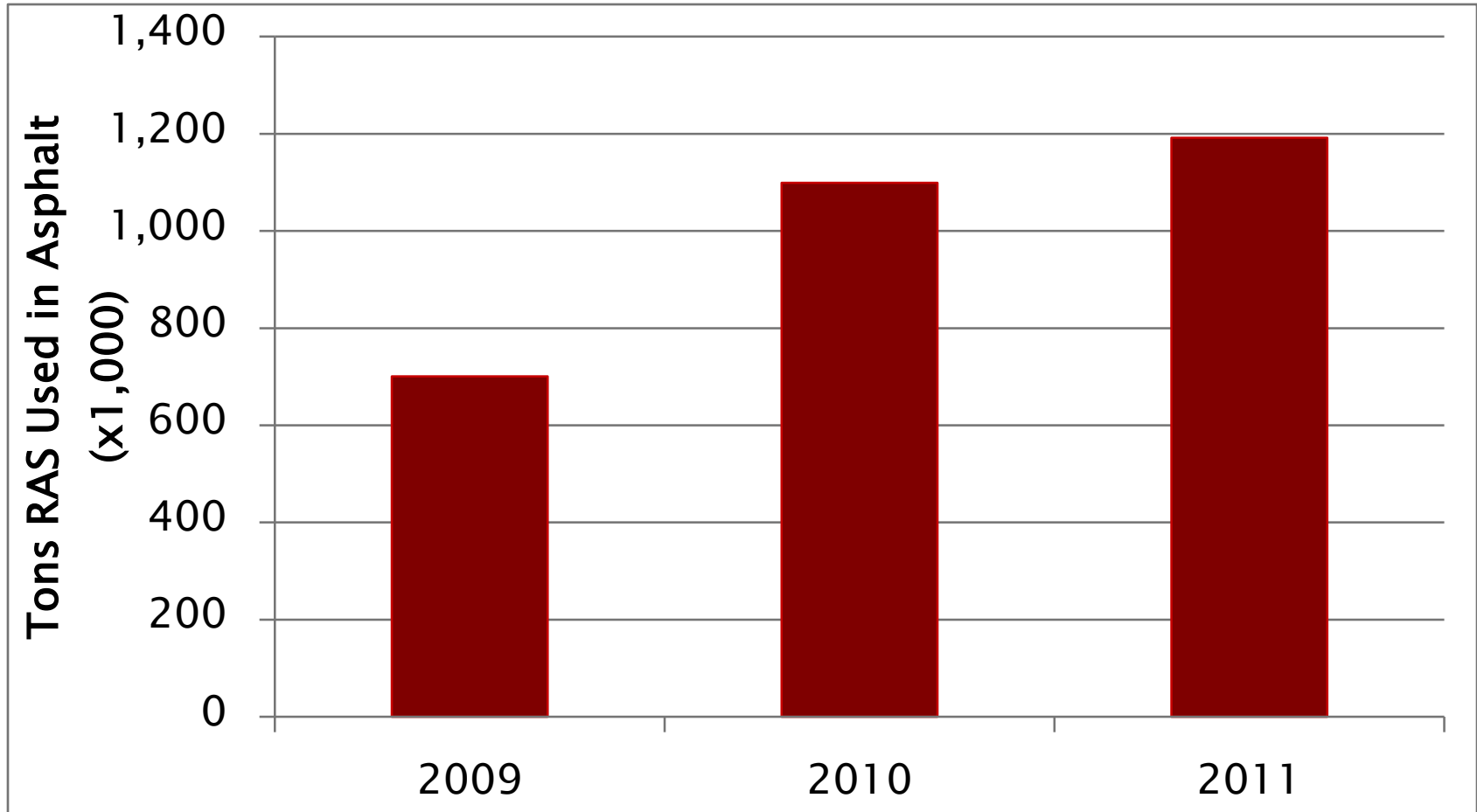
# HOW MUCH RAP IS IN AN AVERAGE MIX?



# 2011 AVERAGE RAP CONTENT BY STATE



# TONS RAS USED IN ASPHALT MIXES



Asphalt mix producers in 32 States use RAS

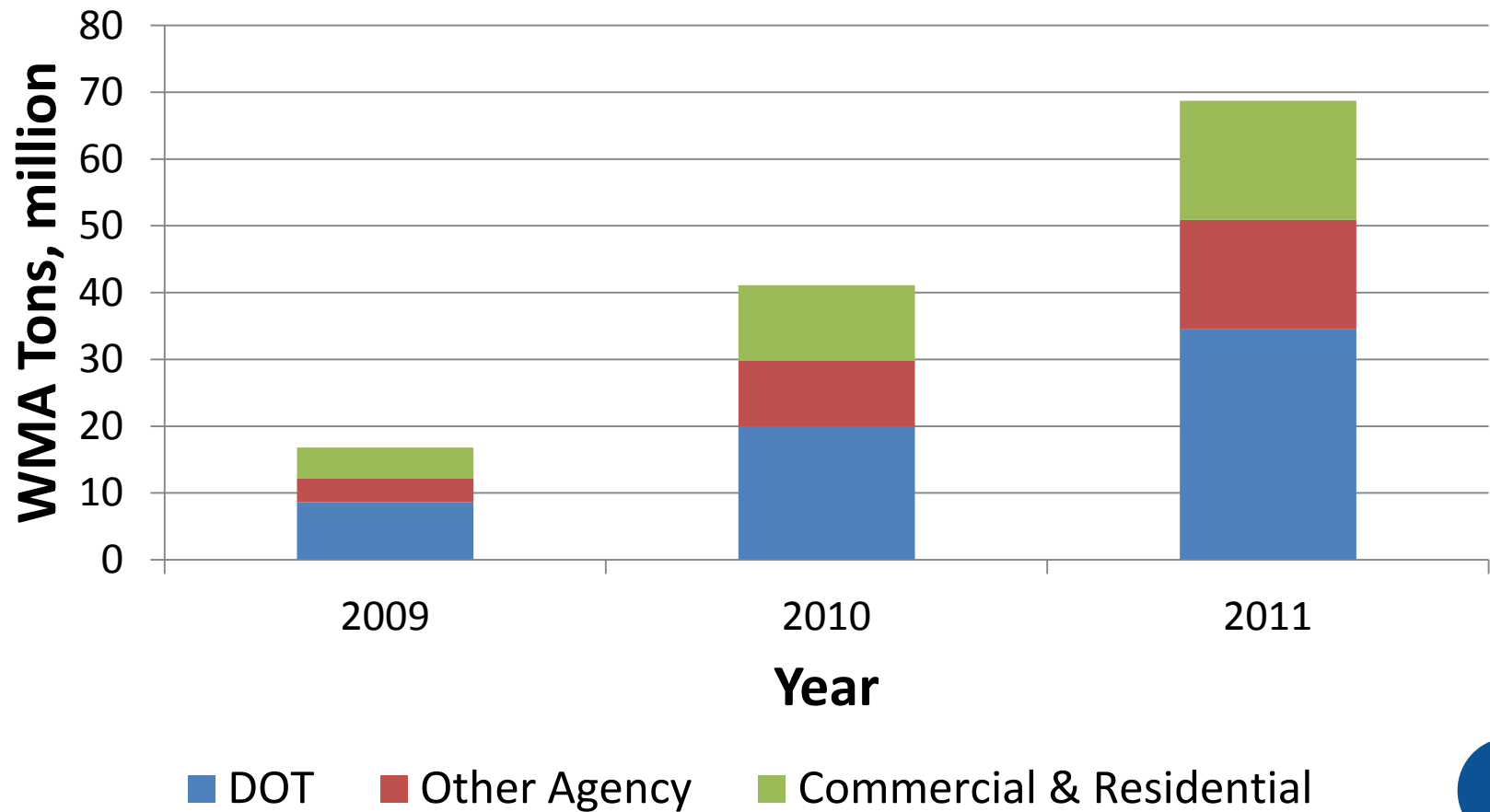


**69 MILLION.**

The total tons of WMA  
placed in 2011.

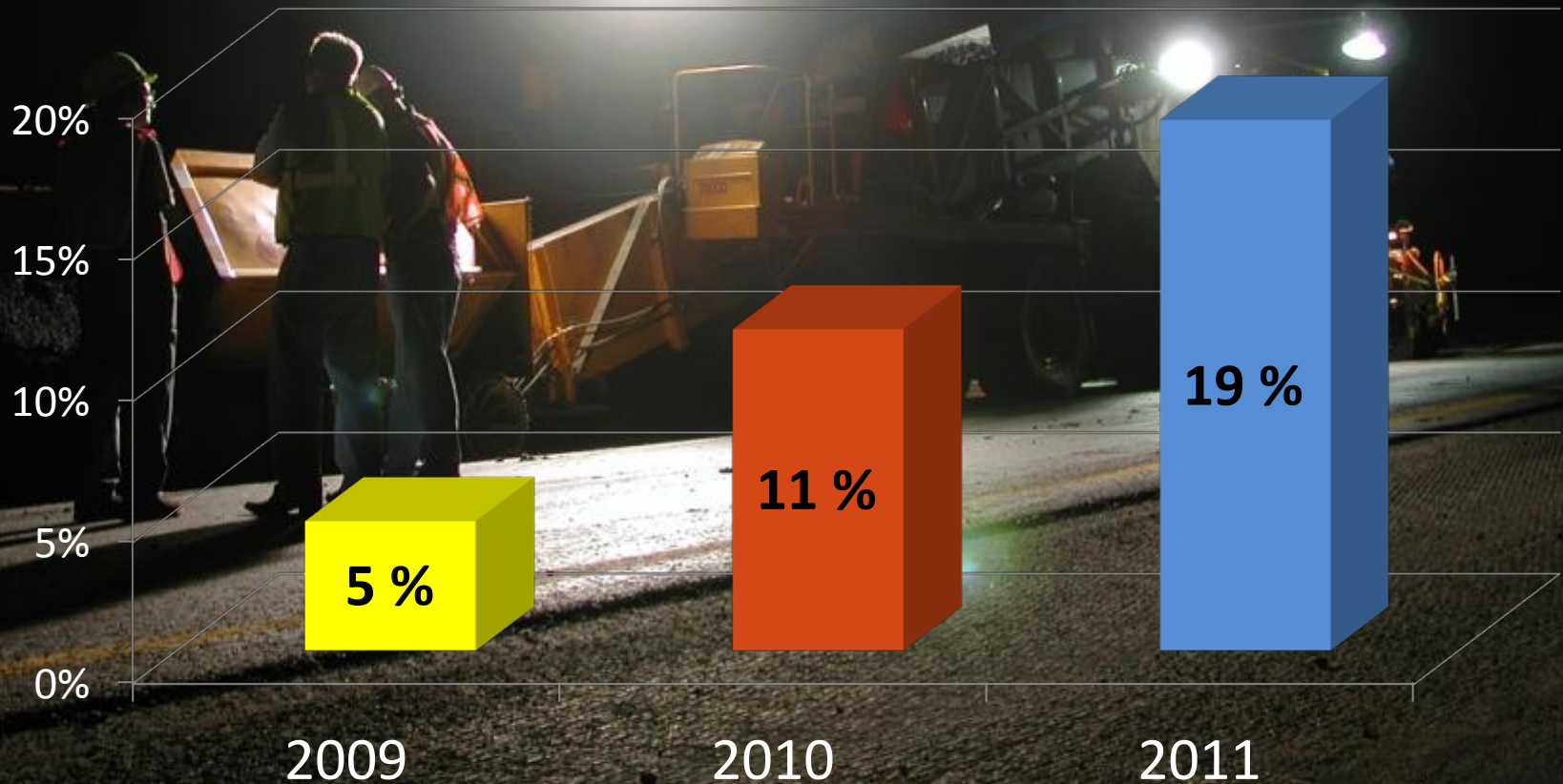
**THAT'S 67% MORE  
THAN THE LAST YEAR. OH,  
AND OVER 300% MORE THAN 2009**

# ESTIMATED WMA TONS



# WMA Usage

## *Percentage of Total Asphalt Production in US*





# MAINSTREAM TECHNOLOGIES

- RAP, RAS ETG and WMA TWG disbanded
- Rolled into existing Asphalt Mix ETG
  - Certain issues may go to Binder ETG
- Sign that these technologies are becoming mainstream

# LTPP

- Long Term Pavement Performance Program
- Adding WMA field study
- Different WMA technologies
- RAP included
  - RAS could be in supplemental sections
- Adding WMA to national database
- Will gather uniform data on performance

# CHANGES IN US PRACTICE

- Higher RAP contents in more mixtures.
- More contractors are fractionating.
- More interest in recycling asphalt shingles.
- More states are using binder replacement (or equivalent).
- WMA growing tremendously.

# AASHTO RAP SPECS CONSERVATIVE?

- INDOT study showed they could use higher recycled contents before changing grade.
  - Up to 25% before changing binder grade
  - Up to 40% by using one grade softer
  - Using binder replacement
- INDOT evaluated over 30 RAP stockpiles around the state – *they know what their RAP is like.*



# KNOW YOUR MATERIALS

- Here is what Indiana DOT did to evaluate their typical materials and revise their specifications for RAP mixes.
- Slides, data from Matt Beeson, INDOT Asphalt Engineer

# BACKGROUND

- Indiana is a non-PG Plus state
- Base grade PG 64-22 statewide
- PG 70-22 and PG 76-22 based on traffic
- PG 58-28, 64-28, and 70-28 for higher RAP contents
- Permissive WMA spec – foamed only
- Prior to 2010
  - Up to 15% RAP with no grade bump
  - Up to 25% RAP with one grade bump
- Are these the right limits?

# APPROACH

- Characterized RAP and virgin binders statewide
- RAP samples from 33 HMA plants in 2007
  - Indiana has about 100 Certified HMA Plants
  - Producers are not required to separate RAP by source



# AVERAGE RAP BINDER PROPERTIES

	High Temperature	Low Temperature
Mean	90.2	-11.1
Std. Deviation	5.02	3.11
Minimum	83.0	-21.3
Maximum	104.0	-0.8

- PG 90–11 average
- No statistical difference found between different regions of Indiana



# AVERAGE VIRGIN PG GRADES

PG -28 Grades			PG -22 Grades		
Specified Binder Grade	High Temp	Low Temp	Specified Binder Grade	High Temp	Low Temp
PG 58-28	63.6	-28.8	PG 64-22	67.6	-24.6
PG 64-28	68.9	-29.6	PG 70-22	72.5	-25.1
PG 70-28	70.4	-29.3	PG 76-22	77.8	-25.8
Average	n/a	-28.7	Average	n/a	-25.1

From acceptance samples in 2008

# ALLOWABLE BLEND PERCENTAGE

- AASHTO M 323 appendix

$$\% \text{RAP} = \frac{T_{\text{blend}} - T_{\text{virgin}}}{T_{\text{RAP}} - T_{\text{virgin}}}$$

- %RAP – Percent binder replacement
- $T_{\text{RAP}}$  – binder grade of RAP asphalt binder
- $T_{\text{virgin}}$  – binder grade of virgin asphalt binder
- $T_{\text{blend}}$  – binder grade of blended asphalt binder

# ALLOWABLE BLEND PERCENTAGE

## ○ High Temperature Grade

- High temperature PG grade of the RAP
  - Greater than target
- High temperature PG grade of virgin binder
  - Greater than target
- Blend is always going to be greater than specified PG grade

# ALLOWABLE BLEND PERCENTAGE

- Low Temperature Grade
  - All blends targeting  $-22^{\circ}\text{C}$
- Using  $-22^{\circ}\text{C}$  virgin binder

$$\% \text{RAP} = \frac{T_{\text{blend}} - T_{\text{virgin}}}{T_{\text{RAP}} - T_{\text{virgin}}} = \frac{-22.0 - (-25.1)}{-11.1 - (-25.1)} = 22.7\%$$

- Using  $-28^{\circ}\text{C}$  virgin binder

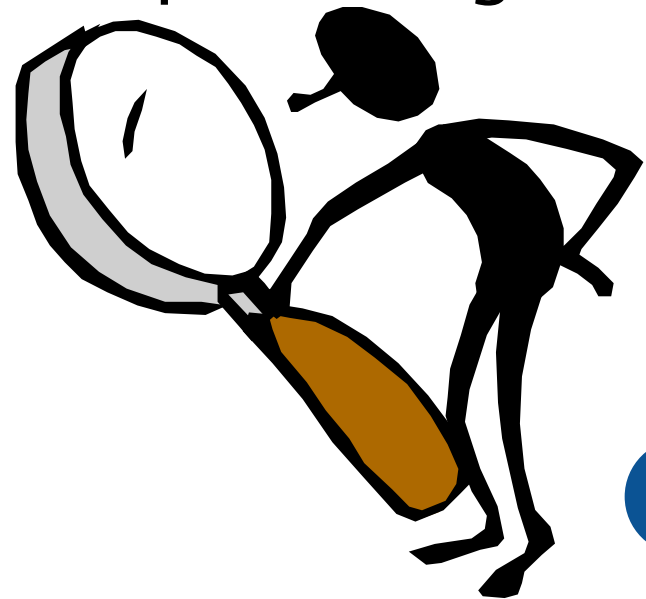
$$\% \text{RAP} = \frac{T_{\text{blend}} - T_{\text{virgin}}}{T_{\text{RAP}} - T_{\text{virgin}}} = \frac{-22.0 - (-28.7)}{-11.1 - (-28.7)} = 38.1\%$$

# SPECIFICATION CHANGE

- Based on INDOT findings and NCSC study
  - Up to 25% Binder Replacement allowed without a virgin PG grade change
  - 25% – 40% Binder Replacement with high and low temperature PG grades reduced by one grade
- Open Graded mixtures and high volume surface mixtures still limited to 25%

# TAKE AWAY

- Similar study can be completed in any state
  - Grade RAP samples
  - Grade virgin PG binder samples
  - Determine allowable blend percentage
- Florida DOT has done
- *Know your materials!*



# WHAT WE HAVE LEARNED

- High RAP contents can perform well – if properly designed, produced, constructed.
- Start with good mix design that accounts for the RAP.
- Shingles use increasing, appears promising.
- WMA increasing rapidly.
  - Longer haul distances
  - Cold weather paving
  - May allow for higher RAP and RAS contents.
- With caution and knowledge of materials



# THANK YOU!

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