




asphalt institute  
Laboratory services

## RAP Blending

SEAUPG  
December 2010




www.asphaltinstitute.org

asphalt institute  
Laboratory services

## National Binder Technician Certification Program

- Visit Asphalt Institute's booth
- Register to win iPad by signing up for free 30-minute NBTC webinar (January 5)
- iPad drawing noon tomorrow
- Must be present to win



www.asphaltinstitute.org

asphalt institute  
Laboratory services

## Current Research

- Completed report on AAPT 06-01, *Development of Testing Procedures for Predicting Non-Load Associated Cracking of HMA Airfield Pavements*
- Continued work on NCHRP Co-op
  - Mixture fatigue & fracture energy validation for newer MSCR binder test
  - WMA laboratory aging and with modulus & performance testing
- Low Temp Pooled Fund-testing of MN Road cores


www.asphaltinstitute.org

asphalt institute  
Laboratory services

## Why Use RAP ?

- Economics
  - Components of RAP still have value
    - Particularly true of asphalt binder
    - Can reduce the amount of new asphalt binder in a mixture

**20% RAP with 5% asphalt content**



**1% savings in new asphalt binder**

www.asphaltinstitute.org

asphalt institute  
Laboratory services

## Considerations in Using RAP

- RAP variability
  - Variability in the original pavement materials
    - Multiple layers
    - Different specifications
  - Storage of RAP
    - RAP from different projects stored in same stockpile
    - "Anything goes" pile

www.asphaltinstitute.org

asphalt institute  
Laboratory services

## Determining RAP Properties

- Mix design
  - Low RAP (usually  $\leq 19\%$  of total aggregates)
    - Asphalt Content of RAP
    - Aggregate Gradation of RAP
    - RAP Specific Gravity
    - Consensus Aggregate Properties
  - High RAP (usually  $>19\%$ )
    - All of the above
    - Asphalt binder physical properties

www.asphaltinstitute.org

## Extraction and Recovery Procedures

asphalt institute

- Extraction
  - Determine asphalt content of RAP
  - Determine RAP aggregate gradation
  - Necessary for mix design
- Recovery
  - Determine asphalt binder physical properties
  - Necessary for blending charts
    - Usually for high RAP mixtures
    - Need to offset stiffer RAP with softer binder

7

www.asphaltinstitute.org

## Extraction and Recovery of RAP

asphalt institute

- Solvent extraction
  - ASTM D2172
    - Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
    - Method A (Centrifuge) - most common
    - Method B (Reflux) - completely contained
    - Method E (Vacuum)
- Ignition oven



8

## Component Analysis of RAP

asphalt institute

- After extraction procedure...
  - Determine the final mass of the sample and the amount of asphalt binder extracted to measure asphalt content

Use extracted aggregate for further testing

- Check gradation
- Consensus properties



9

www.asphaltinstitute.org

## Determining Physical Properties of RAP Binder

asphalt institute

- Recovery procedures
  - Conducted after extraction procedure
  - ASTM 1856
    - Recovery of Asphalt from Solution by Abson Method
  - ASTM D5404
    - Recovery of Asphalt from Solution Using the Rotavapor Apparatus



10

www.asphaltinstitute.org

## Determining Physical Properties of RAP Binder

asphalt institute

- Recovery procedures
  - AASHTO T319
    - Quantitative Extraction and Recovery of Asphalt Binder from Hot Mix Asphalt (HMA)
    - Modified version of SHRP procedure
    - Tumbles mix and solvent together
    - Performs extraction and recovery



11

www.asphaltinstitute.org

## RAP Aggregate Properties

asphalt institute

- Gradation
  - ASTM D5444
    - Mechanical Size Analysis of Extracted Aggregate
    - May need an aerosol to keep fines from floating
  - More than one sample may be needed



12

www.asphaltinstitute.org

### RAP Aggregate Properties

asphalt institute

- Consensus properties
- RAP aggregate specific gravity
  - Method #1
    - Split extracted aggregate into coarse (+ 4.75-mm) and fine (- 4.75-mm) fractions
    - Determine the specific gravity of each size fraction
  - Advantages
    - Direct measure of specific gravity of RAP aggregate
  - Disadvantages
    - Extraction (or ignition oven) procedure can change aggregate properties
    - Sample may still contain asphalt or solvent, making it difficult to accurately determine specific gravity

13

### RAP Aggregate Properties

asphalt institute

- Method #2
  - Determine  $G_{mm}$  of RAP (ASTM D2041)
  - Determine asphalt content of RAP
  - Calculate  $G_{se}$  of RAP and use instead of  $G_{sb}$  in volumetric calculations
- Advantages
  - Gse easy to determine; more repeatable than  $G_{sb}$  measurements
- Disadvantages
  - Use of  $G_{se}$  instead of  $G_{sb}$  artificially raises VMA

14

### RAP Aggregate Properties

asphalt institute

RAP Aggregate Specific Gravity

$G_{mm}(RAP) = 2.545$   
 $G_b(RAP) = 1.020$   
 $P_b(RAP) = 4.5\%$

$$G_{se}(RAP) = \frac{100 - P_b(RAP)}{\frac{100}{G_{mm}(RAP)} - \frac{P_b(RAP)}{G_b(RAP)}}$$

$$G_{se}(RAP) = \frac{100 - 4.5}{\frac{100}{2.545} - \frac{4.5}{1.02}}$$

$G_{se}(RAP) = 2.738$

15

### RAP Aggregate Properties

asphalt institute

- RAP aggregate specific gravity
  - Method #2A
    - Determine  $G_{mm}$  of RAP (ASTM D2041)
    - Determine asphalt content of RAP
    - Calculate  $G_{se}$  of RAP
    - Assume asphalt absorption,  $P_{ba}$ , based on experience with materials
    - Calculate  $G_{sb}$  of RAP aggregate

16

### RAP Aggregate Properties

asphalt institute

- RAP aggregate specific gravity
  - Advantages - Method #2A
    - Gse easy to determine; more repeatable than  $G_{sb}$  measurements
    - Use of assumed  $P_{ba}$  allows for determination of  $G_{sb}$
  - Disadvantages - Method #2A
    - Assumption of  $P_{ba}$

17

### RAP Aggregate Properties

asphalt institute

RAP Aggregate Specific Gravity

$G_{mm}(RAP) = 2.545$   
 $G_b(RAP) = 1.020$   
 $P_b(RAP) = 4.5\%$   
 $P_{ba}(RAP) = 1.5\%$

$$G_{sb}(RAP) = \frac{G_{se}(RAP)}{\frac{P_{ba}(RAP) \times G_{se}(RAP)}{100 \times G_b(RAP)} + 1}$$

$$G_{sb}(RAP) = \frac{2.738}{\frac{1.5 \times 2.738}{100 \times 1.020} + 1}$$

$G_{sb}(RAP) = 2.632$

18



### RAP Binder Properties

asphalt institute

- Physical properties of RAP binder
  - Used to construct blending charts
  - Characterize at high, intermediate, and low temperatures

19

www.asphaltinstitute.org

### RAP Binder Properties

asphalt institute

- After recovery...
    - Ensure that there is sufficient material for testing (minimum 50 grams)
    - Perform binder classification testing in accordance with AASHTO MP1
      - Rotational Viscosity
      - Flash Point
      - Mass Loss
- Not Needed

20

www.asphaltinstitute.org

### RAP Binder Properties

asphalt institute

- Tests on recovered RAP binder
  - Dynamic shear rheometer (DSR) at high temperature
    - Determine critical temperature ( $T_c$ ) for original recovered binder
    - $T_c$  is determined where  $G^*/\sin \delta = 1.00$  kPa for recovered RAP binder

21

www.asphaltinstitute.org

### Binder Grade Selection for RAP Mixtures

asphalt institute

- Developing Blending Charts
  - Method A - Blending at a Known RAP Percentage (Virgin Binder Grade Unknown)
    - Binder Grade Required by the Project - **KNOWN**
    - Recovered RAP Binder Properties - **KNOWN**
    - Percentage of RAP in Mixture - **KNOWN**
    - Virgin Binder Properties/Grade - **UNKNOWN**

22

www.asphaltinstitute.org

### Binder Grade Selection for RAP Mixtures

asphalt institute

- Developing Blending Charts
  - Method B - Blending with a Known Virgin Binder Grade (RAP Percentage Unknown)
    - Binder Grade Required by the Project - **KNOWN**
    - Recovered RAP Binder Properties - **KNOWN**
    - Percentage of RAP in Mixture - **UNKNOWN**
    - Virgin Binder Properties/Grade - **KNOWN**

23

www.asphaltinstitute.org

### Binder Grade Selection for RAP Mixtures

asphalt institute

ACTION	RAP
No Change in Binder Grade	15% or less
One Grade Lower*	16 - 25%
Use Blending Charts*	>25%

\*Varies per agency. Example: Some agencies allow 30% RAP with no grade adjustment

24

www.asphaltinstitute.org



## Handling RAP During the Mix Design Process

asphalt institute

- Handling RAP in lab
  - Recommended RAP heating procedure
    - 110°C (230°F) for 2 hours (max)
    - Suitable for 1000 to 2000g batches
    - Higher temperature or longer time may affect properties of some RAP
  - Virgin aggregate
    - Heat to 10°C above mixing temperature

25

W a r e d r i v e n . www.asphaltinstitute.org



## NCHRP 9-12 Recommendations

asphalt institute

*Recommended use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method*

W a r e d r i v e n . www.asphaltinstitute.org



## NCHRP 9-12 Recommendations

asphalt institute

- Blending occurs at higher RAP contents. At low RAP contents, effects are not significant
- Results from all phases support concept of a tiered system.
  - Mix ETG recommendations were largely confirmed

27

W a r e d r i v e n . www.asphaltinstitute.org



## NCHRP 9-12 Recommendations

asphalt institute

- RAP mixtures should be able to perform at least as well as virgin mixes
- RAP aggregates need to be included in consensus properties and gradations. Watch changes in aggregates due to extraction
  - Exception: sand equivalent value

28

W a r e d r i v e n . www.asphaltinstitute.org



## NCHRP 9-12 Practical Considerations

asphalt institute

- Mixtures with 15 to 20% RAP may become more common
- At high RAP contents, gradation and properties of RAP aggregate may limit amount of RAP used
  - Processing or screening RAP

29

W a r e d r i v e n . www.asphaltinstitute.org



## NCHRP 9-12 Practical Considerations

asphalt institute

- RAP variability may need to be controlled to meet production tolerances
- Blending charts may limit use of high RAP contents unless there are strong economic incentives

30

W a r e d r i v e n . www.asphaltinstitute.org





### NCHRP 9-12 Products

asphalt institute

- Final Report
- Implementation Plan
- Guidelines for Agencies
- Manual for Technicians
  - NCHRP Report 452
- Proposed specification changes for review and balloting by AASHTO

31

www.asphaltinstitute.org

### Asphalt Mix Design Using Reclaimed Asphalt Pavement (RAP)

asphalt institute

Adjusting gradation and asphalt content to account for asphalt binder in the RAP

www.asphaltinstitute.org

### Asphalt Mix Design Using RAP

asphalt institute

- When using RAP in asphalt mix designs, the aggregate gradations and the total asphalt content are altered slightly from the original batch percentages due to the asphalt contained in the RAP
- A laboratory analysis of the RAP has to be performed

33

www.asphaltinstitute.org

### Asphalt Mix Design Using RAP

asphalt institute

- Taking the asphalt in the RAP into account, the actual aggregate blend percentages need to be adjusted and the gradation of the blend determined.
- An alternative procedure would be to determine the weight of RAP needed to result in a desired weight of aggregate. We will look at both procedures

34

www.asphaltinstitute.org

Is RAP Just  
"Black Rock"?

asphalt institute

www.asphaltinstitute.org

### The RAP, Black Rock Question

asphalt institute

- Does RAP Act Like a Black Rock in the Mixture?
  - When a chunk of RAP is added to the mix does the RAP asphalt binder actually interact (blend) with the virgin AC?
    - Answer to this question determines the need for blending charts

36

www.asphaltinstitute.org

asphalt institute

## Is RAP Black Rock?

Supplemental Information

www.asphaltinstitute.org

asphalt institute

## If RAP Is Black Rock...

- Blending chart premise is invalid
- Mix properties/ behavior depend on virgin binder only
- How can we evaluate?
  - Analyze mixture properties, not just the extracted binder

www.asphaltinstitute.org

asphalt institute

## Three Treatments

- **Case A** - virgin binder with virgin aggregate plus extracted RAP aggregate.
- **Case B** - virgin binder with RAP
- **Case C** - virgin binder physically blended with recovered RAP binder
  - Aggregate gradation and source constant
  - Total binder volume constant
  - Three RAP stiffness
  - Two virgin binders (PG 52-34, PG 64-22)

www.asphaltinstitute.org

asphalt institute

## Black Rock Analysis

- **Case A** represents “black rock”
- **Case B** represents standard practice
- **Case C** represents total blending


- If no blending occurs, Case A = Case B
- If partial blending occurs, Case A < Case B < Case C

www.asphaltinstitute.org

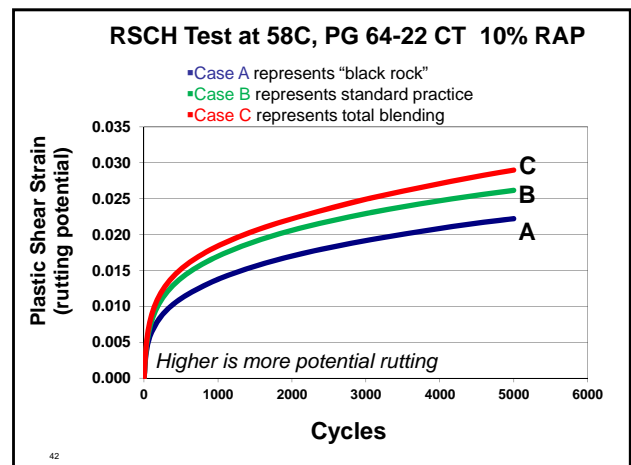
asphalt institute

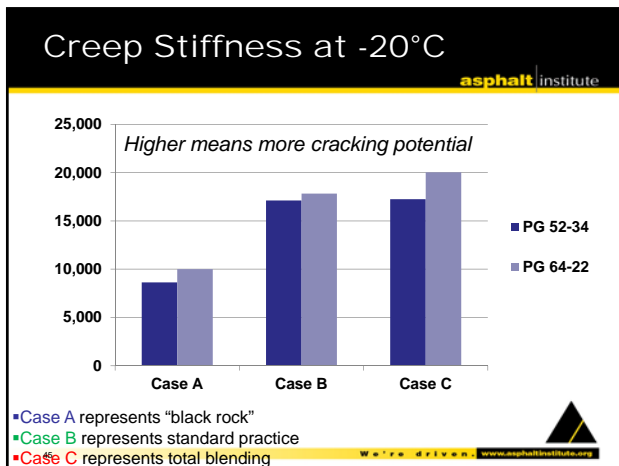
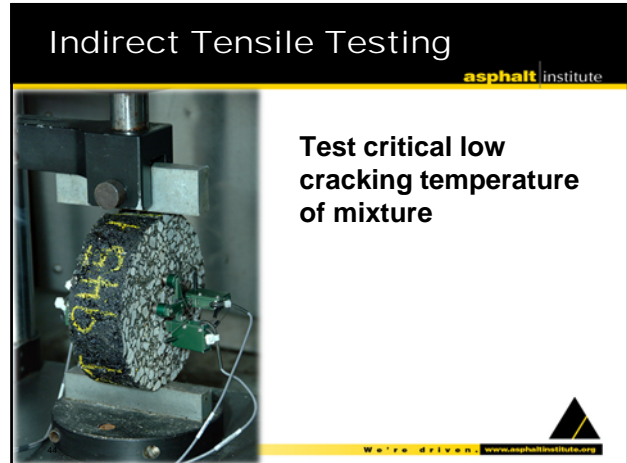
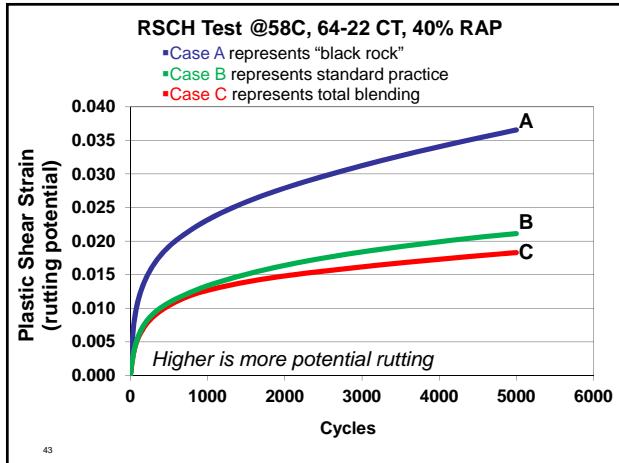
## Superpave Shear Test (SST)

Potential rutting



www.asphaltinstitute.org





- ### Primary Finding
- Blending does occur to an appreciable extent
  - Therefore
    - Concept of blending charts is reasonable
- 

- ### Conclusions
- RAP is good
  - Adjust for it
  - Need to work on what Gsb to use
  - If in doubt, check with a performance test or use blending chart

Thank You