

# Best Practices for Using Reclaimed Asphalt Pavement (RAP) in Asphalt Mixtures

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# Outline

- What is RAP and its uses?
- Processing and Managing RAP
- RAP Sampling and Testing Best Practices
- Mix Design of Asphalt Mixtures Containing RAP
- "High" RAP in Asphalt Mixtures
- Research Studies on RAP
- Final Remarks



# **Reclaimed Asphalt Pavement (RAP)**

- □ RAP consist of:
  - □ Asphalt binder: often aged
  - □ Aggregate: quality aggregates
- Reclaiming process:







Milling Pavement Demolition Waste plant mix Source: Dykes paving, Preferred paving, Pavement recyclers



AAPA Study 2010

# **RAP Usage and It's Impacts**



### **Average Rap Use in Mixture by States**



Variation in RAP usage by different states from 2013 to 2017

5



# **Usage of RAP in the United States**



- Majority of states (38) limited
  usage of RAP to 30%
- Out of 38 states:
  - 16 states restricted to 20%
  - 12 states restricted to 25%
  - 10 states restricted to 30%
- Only 2 states identified in interval of 45% and 50%
- Southeast states (8 out of 13 states) observed to allow 30%
   RAP and above



### **RAP Quantification Basis in the United States**



- 20% allowable RAP content indicates incorporation of 200 kg of RAP material for every ton of asphalt mixture
- Qualifying Measures of RAP
  - o 19 states- use binder replacement
  - o 28 states- use mixture replacement
  - o 3 states-unknown divergence



# Impact of RAP on Virgin Binder

### □ Guidelines

- □ Up to 15% RAP: no change in binder grade;
- □ 20 to 25% RAP: use 1 temp. grade lower;
- □ Above 25%: Test RAP binder.
- Alternative: Conduct regional studies to determine
  RAP binder properties.



# Impact on Viscosity

Authors PMA binder grade RAP binder grade		Singh and Sawant (2016) PG 76-xx PG 88-xx	Kim et al. (2009) PG 76-22 PG 82-16	Roque et al. (2015) PG 76-22	
				Viscosity at 135°C (Pa·s)	RAP %
<b>0%</b> <sup>(1)</sup>	1.25	1.73	1.46		
15%	1.34	1.81	-21		12
20%	-	-	1.78		1.64
25%	1.36	1.79	-		-
30%	-	-	1.98		1.70
35%	171	1.82	-		
40%	1.38	-	2.24		1.90
100%	1.54	2.24	.=3		

- Increase in influence: 1.1 to 1.2 times for 15 to 35% RAP
- Sudden surge: 1.4 times usage raised to 40% RAP
- Reduction in viscosity leads to reduction in workability of mix and lower density



# **Challenges of RAP**

- Unknown aggregate and binder source
- Age of the RAP
- Variability due to poor material management
- Non fractionation of the RAP
- Less Knowledge in designing the mix

Material Management

Real Challenge: How to manage and process RAP?



## **Processing and Managing RAP**





# **Purpose of Processing RAP**

- □ Main goal of processing RAP:
  - □ Create uniform stockpile of RAP;
  - Separate or break large agglomerations of RAP;
  - Reduce maximum aggregate particle size to use for surface mix;
  - $\square$  Minimize the additional  $P_{200}$ .



Source: FHWA -HRT-11-021



### **Processing RAP (Same Source)**



13



### **Processing RAP (Multiple Source)**



Source: NAPA quality improvement series 129



# **RAP Sampling**

- Take representative <u>random</u> samples (AASHTO T2)
  - □ Minimum 5, preferably  $\geq$ 10 samples
  - Test portion of each random sample (for <u>binder content</u> and <u>gradation</u>)
  - Combine remainder samples to have one representative sample (for <u>mix</u> <u>design</u> purpose)



Source: FHWA -HRT-11-021



### **RAP Testing**





# **RAP Specific Gravity?**

- □ Method 1
  - Extract aggregate from solvent, divide into coarse and fine, calculate  $G_{sb}$  of aggregate
- Method 2
  - $\Box \quad \text{Calculate } G_{mm(RAP)} \text{ from } P_{b(RAP)} \text{ and } G_{b(RAP)}$

# **Mix Design of RAP Mixtures**



# **Factors Governing Usage of RAP**



- Fractionation
- Blending charts
- Performance tests
- Virgin binder grade selection
- Volumetric criteria

The plot represents the number of states that use each factor as a governing criterion in using



### **Volumetric Criteria**





### Laboratory Mix Design for RAP Mixtures?





### **Plant Production and Verification?**





### **Performance Tests**

Number	State	Performance Test
1	New Jersey	HWT, OT
2	South Dakota	TSR, APA
3	Vermont	TSR
4	Illinois	TSR. HWT, IFIT
5	North Carolina	Rut test
6	Washington	HWT

✤ Rutting resistance:

• Hamburg Wheel Tracking (HWT), Asphalt Pavement Analyzer (APA), and Rut tests

Tensile Strength Ratio (TSR) part of Superpave specification by states:

o South Dakota, Vermont, Illinois, Georgia, Arkansas, California, and Connecticut

✤ New Jersey: Overlay test

Illinois: Illinois Flexibility Index test

♦ Georgia: Permeability test

14	Texas	HWT	
15	Connecticut	TSR	
16	Louisiana	LWT, SCB	

HWT = Hamburg Wheel Tracking; OT = Overlay Test; TSR = Tensile Strength Ratio; APA = Asphalt Pavement Analyzer; IFIT = Illinois Flexibility Index Test; LWT = Hamburg Loaded Wheel Tester; SCB = Semi-Circular Bend test.



### **Performance Testing**







SCB



OT





# What is High RAP?

### □ High RAP

- Mix contain RAP >25%
- Require softer virgin binder to balance stiffness
- Require determination of binder grade
  - High PG DSR for Original and RTFO aged binder
  - □ Intermediate PG□DSR for RTFO aged binder
  - □ Low PG□ BBR test for RTFO aged binder







BBR



# **Blending of High RAP?**

- □ Two option are followed:
  - Blending at known RAP %age
  - □ Blending with a known virgin binder grade



# **Blending of High RAP?**

### Blending at known RAP %age

$$T_{virgin} = \frac{T_{blend} - (\% RAP \times T_{RAP})}{(1 - \% RAP)}$$

Where:

- $T_{virgin}$  = Critical temperature of virgin asphalt binder (high, intermediate, or low).
- $T_{Blend}$  = Critical temperature of blended asphalt binder (final desired) (high, intermediate, or low).
- %RAP = Percentage of RAP expressed as a decimal.
- $T_{RAP}$  = Critical temperature of recovered RAP binder (high, intermediate, or low).



# **Blending of High RAP?**

### □ Blending with known virgin binder grade

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

- Need to be determined at high, low and intermediate temperature
- Select range of content meeting all temperature requirements



### **Research Studies on RAP**



# **Two Studies: <u>Key</u> findings**

### □ FHWA-HRT-11-021

- Reclaimed asphalt pavement in Asphalt Mixtures: State of the practice
- NAPA: Quality Improvement Series 129
  - Best practices for RAP and RAS Management
- □ TxDOT Project 0-6947 (2020)
  - Revised Allowable Maximum Recycled Binder Ratio (RBR)
    Specification
- Laboratory and field evaluation of HMA with High RAP



# FHWA-HRT-11-021

- Widespread use of high RAP require support from State
  DOTs and contractors;
- Estimated use of RAP was 12% across US, according to
  State DOTs it can go up to 30%;
- RAP mixtures need to follow volumetric based mix design criteria; and
- Main challenge to increase use of RAP is the processing of RAP.



### **NAPA: Quality Improvement Series 129**

- Good management start with uncontaminated RAP;
- Milling from single project produce RAP with consistent properties;
- RAP from multiple sources can be processed to produce uniform and fractionated RAP stockpiles; and
- Frequent sampling, testing and analysis of RAP is vital to good management of RAP.



### **TxDOT Project 0-6947 (2020)**

- Addition of RAP compensate for virgin soft binder high PG grade but not the elastic recovery;
- □ Virgin binder low grade does not effect RAP low PG grade;
- Rutting performance enhanced with addition of RAP;
- With addition of RAP: G\*/Sinδ increases; S and m-value decrease; and
- □ Not all recycling agents produce the same results.



### Laboratory and Field Evaluation

- □ 30%, 35% and 40% RAP was included into the HMA;
- RAP was fractionated with size >8mm, effective in improving volumetric properties;
- Three test section constructed on Highway 6, Iowa with densities >94%.
- High and low PG grades increased with addition of RAP;
- HWTT test on field cores showed that with increase in RAP
  %age, rutting performance enhanced.



### **Laboratory and Field Evaluation**

- SCB test results indicate drop in fracture properties with the addition of RAP;
- 8 months condition survey results demonstrate that 40%
  RAP section performed well compared to 35% and 30%
  RAP sections.
- 27 months condition survey results showed similar performance results for all section.



# **Final Remarks**



# **Final Remarks**

- Proper *stockpiling* will help to ensure better management of RAP materials,
- □ RAP processing depends on the *sources* available;
- Fractionating RAP is the key *parameter* for consistent material properties and volumetric based mix design.
- Binder properties and performance grade need to be *determined* as per procedure mentioned;
- High RAP *binder grade* is the key parameter for selection of RAP %age,
- Literature focused on the better management of RAP materials by processing the RAP.



### **Final Remarks**

- Rutting and cracking tests were used as performance based criteria for RAP mixtures.
- Widespread application require support from State DOT's and contractors.



# **Thank You!**

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