Reclaiming Asphalt Pavement Usage

Alaska Asphalt Summit

Anchorage, AK November 10, 2015

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Granite Construction Incorporated

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Outline

- State of the Practice – National Trends
  - Specifications
  - Quantities
  - Performance
- Trends and Best Practices on How Much?
  - Design
  - Crushing/Stockpiling/Storage
  - Materials Designs
  - Production-Feeding/Plant Type/Plant Ops
  - Use with Others Technologies
  - Generating/Receiving

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Recycling Benefits
(In-place or Other)

- Conservation
  - Materials (aggregate, asphalt and cement binders)
  - Energy (raw materials, finished materials, trucking, etc.)
- Preservation of Environment
  - Landfill
  - Greenhouse Gases (GHGs)
  - Sustainability
- Economics
  - Reduce first and life cycle cost
  - Life cycle assessment based selection coming
  - Owner ultimately benefits from cost savings

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Green C, R & M Alternatives

- Processes
  - In-place PCC Recycling
  - Cold In-place Recycling HMA
  - Hot In-place Recycling HMA
  - Hot Central Plant Recycling HMA
- Materials
  - Reclaimed Asphalt Pavement (RAP)
  - Reclaimed Asphalt Shingles (RAS)
  - Crumb Rubber Modified Asphalt (CRM)
  - Recycled Concrete Aggregate (RCA)
  - Warm Mix Asphalt (WMA)
  - Porous HMA and PCC *
  - Two Lift PCC *
  - Existing HMA, PCC, and Aggregate Base as Base

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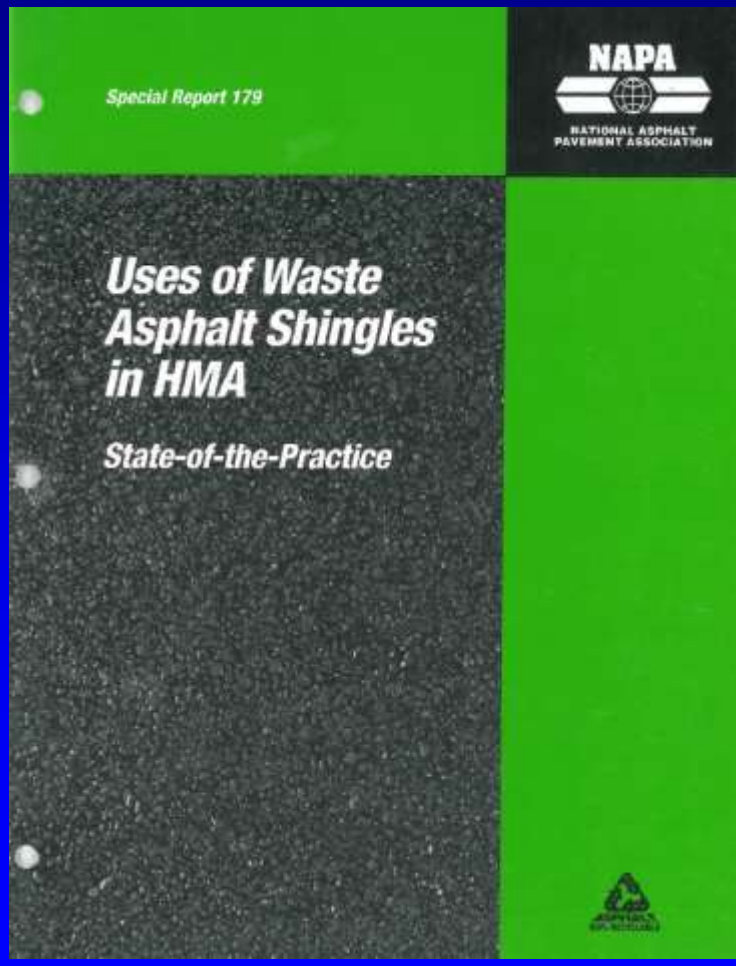
Recycling Quantities and Rates

- Domestic Waste[1]
  - 18M tons Paper and Paperboard (25%)
  - 4.2M tons Yard Waste (12%)
  - 0.3M tons Plastic (2%)
  - 2.6M tons Glass (20%)
  - Total - 25.5M tons
- Steel Recycling[2]
  - 76M tons Steel (76%) – US and abroad
- Reclaimed Asphalt Pavement[1]
  - 80M tons Asphalt Pavement (80%)
- Reclaimed Concrete Pavement[1]
  - 3M tons Asphalt Pavement (80%)
- [1]Ref: FHWA and EPA 1993
- [2]Ref: Steel Recycling Institute



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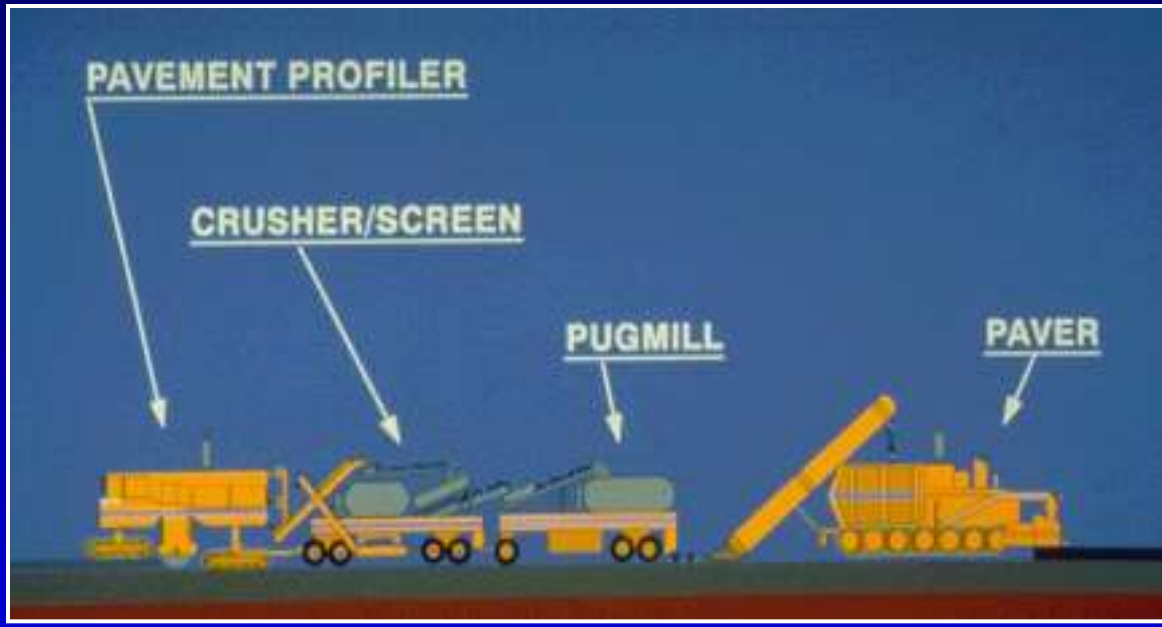
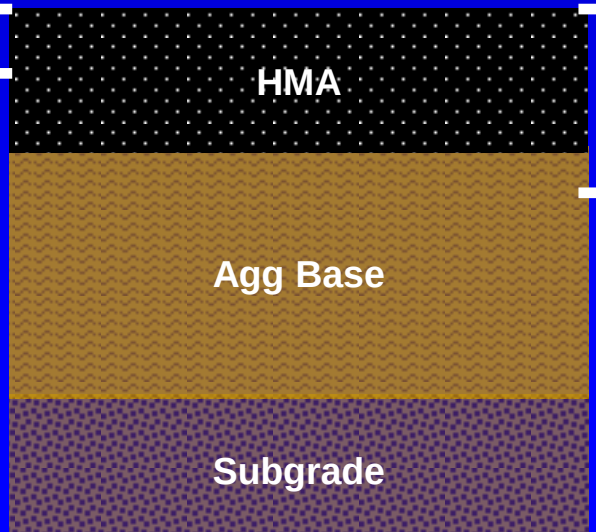
In-Place PCC Recycling

- Pro
  - *Excellent Base Course*
  - *Overlay with HMA*
    - WMA, RAP, RAS
  - Less Energy
  - Minimize Material Hauls
- Con
  - *Geometric Constraints*
  - Drainage Structures

Cold In-Place Recycling (CIPR)

- **Pros**
  - Stretch Dollars Further
  - Less Energy Required
  - Material Hauling Minimized
  - *Most Pavement Distress Treated*
  - *Significant Structural Improvements*
  - Ride Quality Improved
- **Cons**
  - Low to Mod Traffic
  - *Requires Wearing Surface*
  - *Rural/Larger Projects (Train)*
  - *Geometry/Profile*





Hot In-Place Recycling (HIPR)

- **Pros**
  - **Stretch Dollars Further**
  - **Less Energy Required**
  - **Material Hauling Minimized**
  - ***Near Surface Pavement Distress Treated***
  - **Ride Quality Improved**
  - ***Pavement Geometrics Preserved***
- **Cons**
  - **Low to Mod Traffic**
  - ***Minor Structural Improvement***
  - ***Rural/Larger Projects (Train)***

Recycling Train

Infrared Heater

Scarified Surface

Finished Surface

Hot Central Plant Recycling

- **Pros**
  - *Cost Savings*
  - *Materials Savings*
  - Energy Savings
- **Cons**
  - *Production Rate*
  - Additional
    - Feeder Bins
    - Separate Silos

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Reclaimed Asphalt Pavement (RAP)

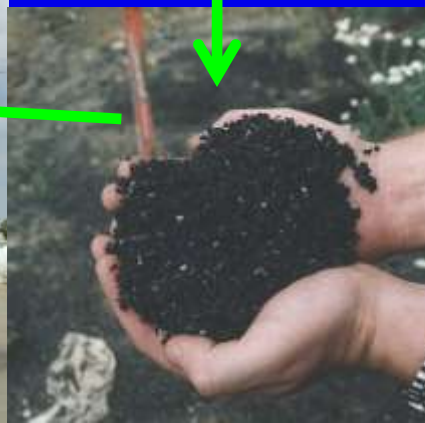
- Source: Millings, Plant Waste, R&R (chunks)
- Processing: Direct to Crushing, Screening, and Stockpiling

Reclaimed Asphalt Shingles (RAS)

- Source: Tear-Offs, Manufacture Waste
- Processing: Shredding, Screening, and Stockpiling
- 1% RAS ≈ 6% RAP
- 20-30% AC vs. 5% AC

Crumb Rubber Modified (CRM) Asphalt

- Source: Recycled Tires & Manufacture Waste
- Ground and Blended with Asphalt
- Crack Resistant and Quite
- *1500-2000 Tires/Lane Mile*



Recycled Concrete Aggregates (RCA)

- Source: Pavement & Structures Demolition, Plant Waste/CleanOuts
- Crush, Screen, Stockpile
- *Excellent Base w/ or w/o Other Materials*
- PCC Aggregates

RAP is Green

Politicians Love Green!

	Annual Consumption/ Production	Estimated Annual Savings		
		15% RAP	25% RAP	50% RAP
Asphalt Binder, tons	29M	3.5M	5.5M	11.3M
Aggregate, tons	521M	31.2M	52.1M	114.6M
HMA Price, $	44B	1.3B	2.2B	4.8B
Energy, 10^{12} Btu*	300	15	24	48
CO_2, tons	55.5M	3.9M	6.7M	13.9M

*Annual Energy Consumption is 100×10^{15}-Btu

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RAP Economics

- Assuming Optimum %AC = 5.0%
  - AC cost = $600/ton or $800/ton ($30-40/mix ton)
  - Aggregate cost = $20/ton ($19/mix ton)
  - Plus production, trucking, laydown…

- Examples:
  - If 20% ABR = $6-8/mix ton
  - If 25% ABR = $7.5-10/mix ton

  - RAP cost = milling, trucking, crushing, …

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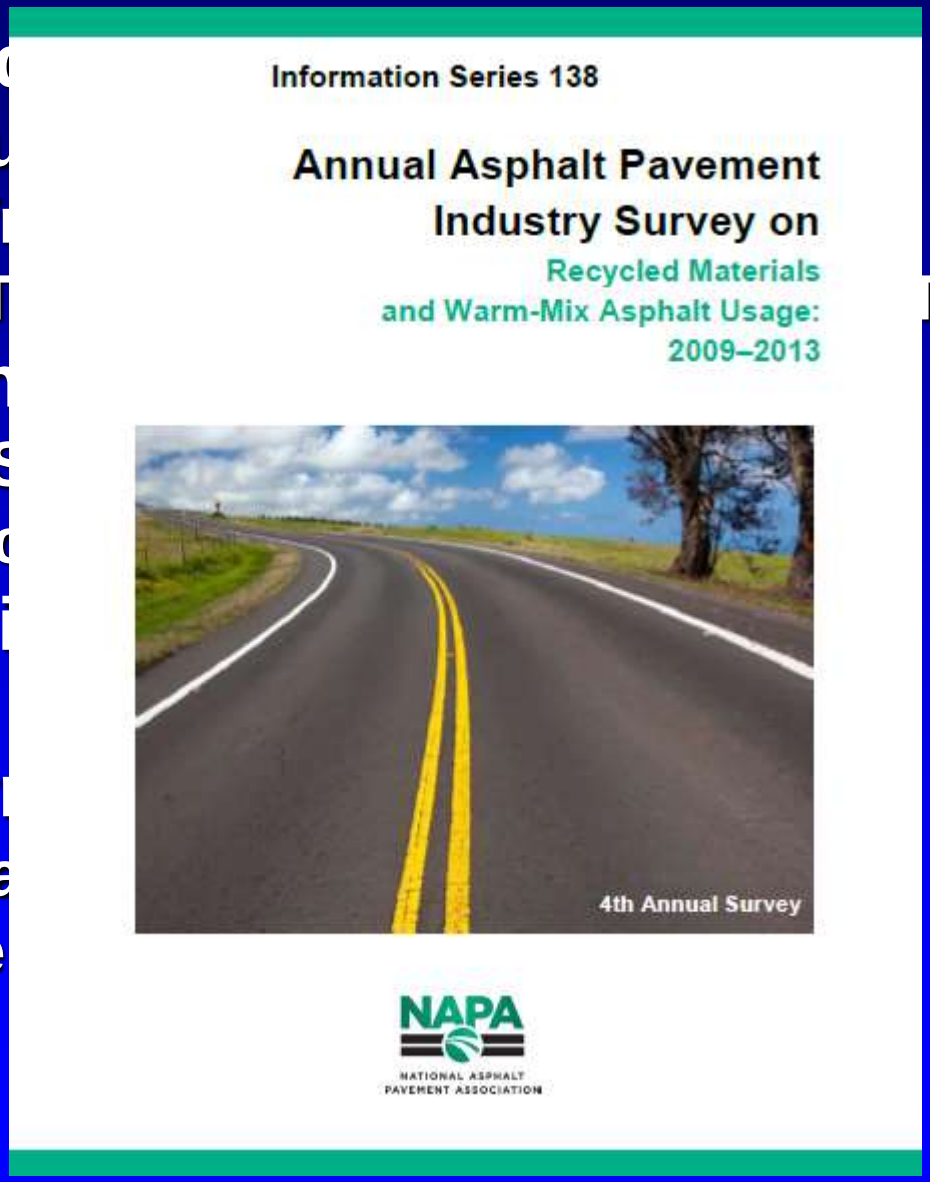
Specification Trends

- Recycled
  - Plateau
  - Move f
  - AASHT
- Location
  - Some S
  - Signific
- Virgin Bi
  - %ABR
- Near-terr
  - Thin La
  - Rejuve

– Good Logic

Ts


Information Series 138

Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009–2013

4th Annual Survey

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

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RAP Trends

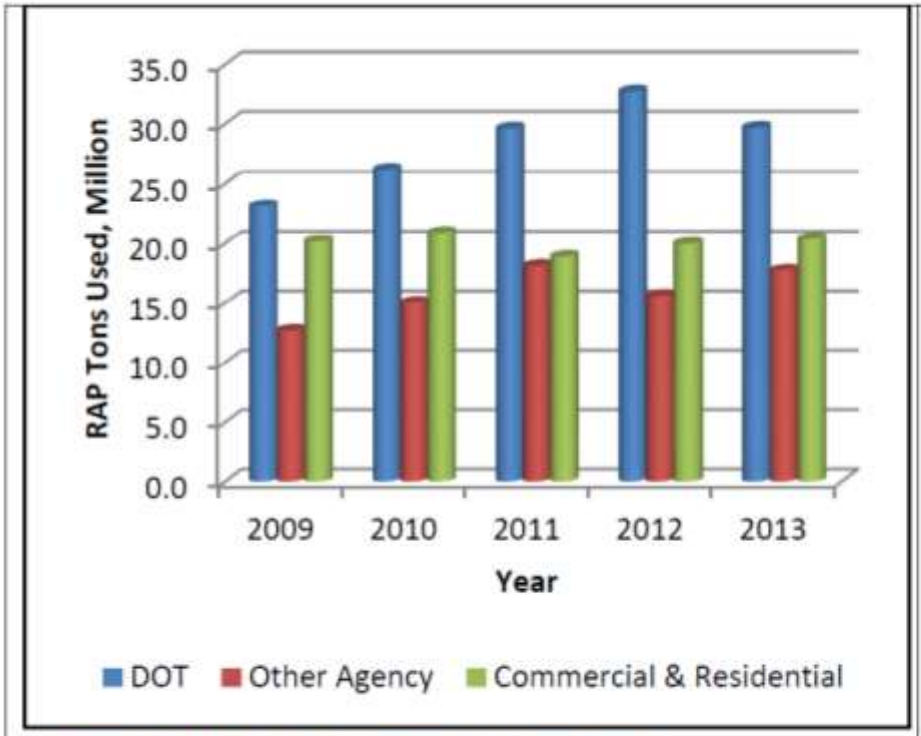

Figure 5: RAP Use by Sector (Million Tons)

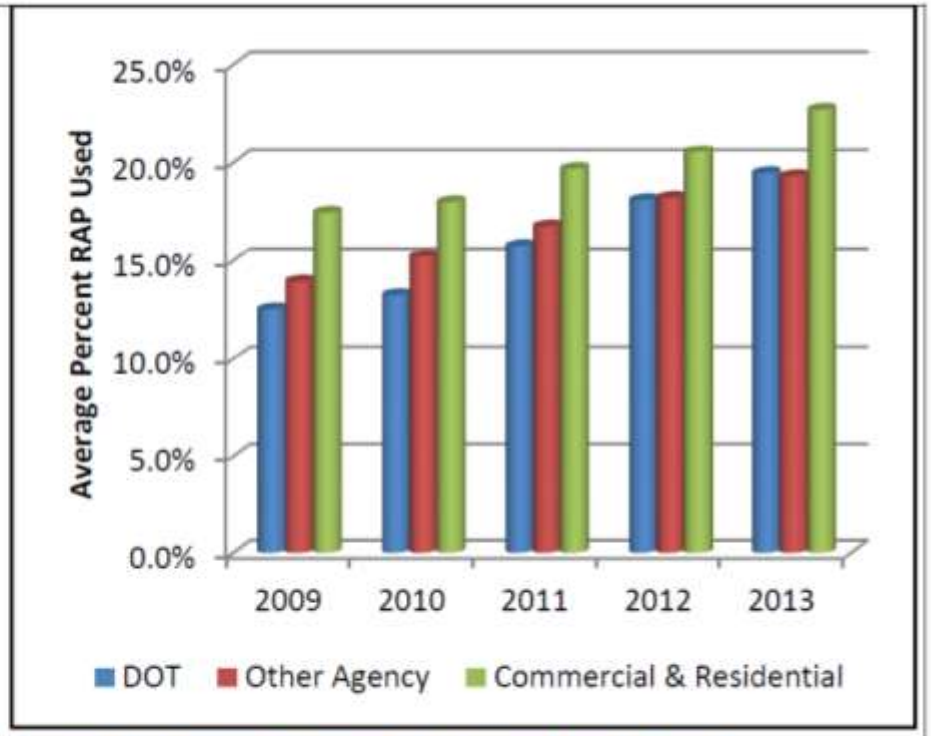

Figure 6: Average Percent RAP Used by Sector

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RAS Trends

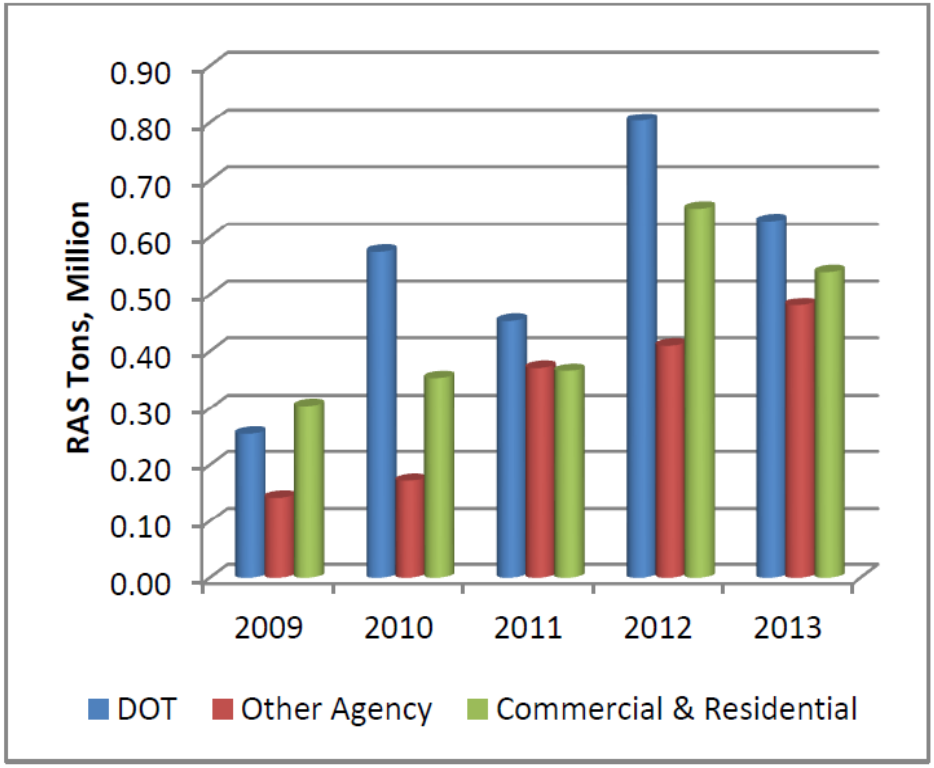

Figure 10: Estimated RAS Use by Sector (Million Tons)

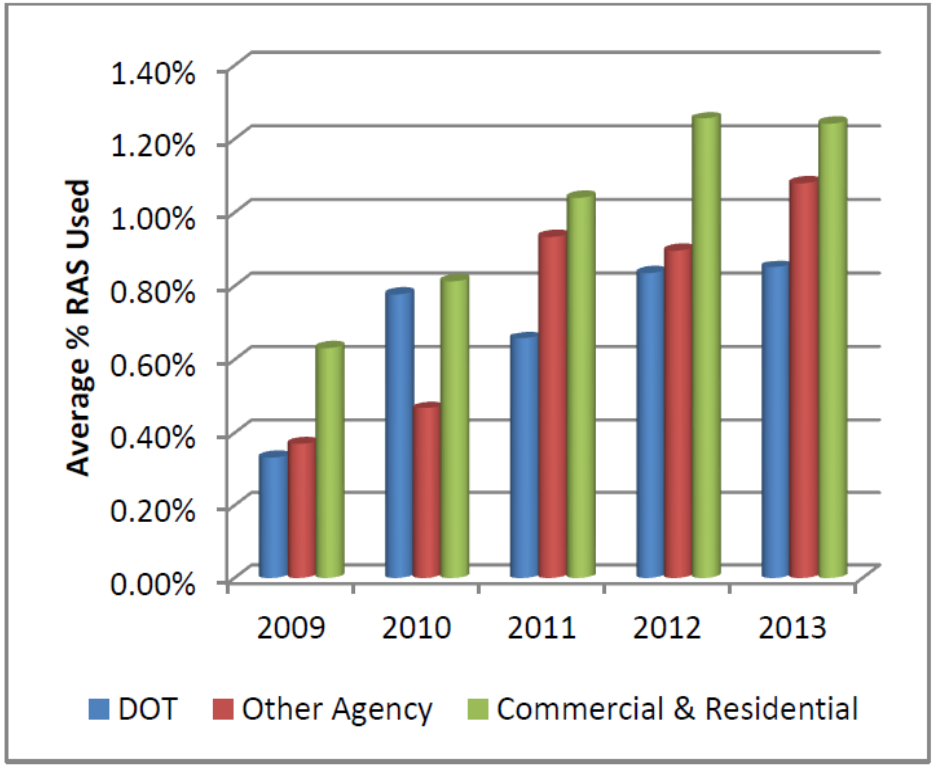

Figure 11: Average Percent RAS Used by Sector

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Performance Comparison of Virgin and RAP HMA Mixes (National Studies)

- NCHRP Report 752

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Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content

TRB's National Cooperative Highway Research Program (NCHRP) Report 752: Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content describes proposed revisions to the American Association of State Highway and Transportation Officials (AASHTO) R 35, Superpave Volumetric Design for Hot Mix Asphalt, and AASHTO M 323, Superpave Volumetric Mix Design, to accommodate the design of asphalt mixtures with high reclaimed asphalt pavement contents.

Project: Project Information
Project Number: 09-46

E-Newsletter Type: Recently Released TRB Publications
TRB Publication Type: NCHRP Report

This Summary Last Modified On: 6/25/2013

Performance Comparison of Virgin and RAP HMA Mixes (National Studies)

- NCAT Test Track (Auburn University)
  - 2009 Test Sections
    - 0 and 50% RAP Sections
    - 7” HMA Section (3 lifts)
    - Spring 2012 - 10 Million ESALs
    - No Observed Distress in 0% and 50% RAP Sections
  - Mississippi DOT Test Sections
  - 15% and 45% RAP Sections
    - 4” mill/fill (2 – 2” lifts)
    - 10 Million ESALs
    - 45% RAP Mix Performed Very Well
      - <3mm Rutting
      - Similar Cracking as Compared to 15% RAP Mix
        - 80 linear feet for 15% RAP
        - 61 linear feet for 45% RAP

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Performance Comparison of Virgin and RAP HMA Mixes (National Studies)

- LTPP - SPS-5 Project (West et al.)
  - 18 test projects across North America, constructed between 1989-1998
  - Performance comparison of virgin (0%) and 30% RAP mixes
    - IRI (smoothness)
    - Rutting
    - Fatigue cracking
    - Longitudinal cracking
    - Transverse cracking
    - Block cracking
    - Raveling
  - Pavements using 30% RAP performed equal or better than virgin pavements in most cases
    - Transverse and fatigue cracking were observed more often in some pavements with RAP than pavements with all virgin materials
    - Difference in cracking performance may be due to lower AC contents and/or high #200 contents (i.e. film thickness) of RAP Mix

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Current Focus – "High" ABR Mixes

- What is High Asphalt Binder Replacement?
  - >25% Virgin Asphalt Binder Replacement with RAP, RAS, or RAP&RAS
- %ABR = %Asphalt Binder Replacement
  - Specs Changing to %ABR from %RAP or %RAS
  - Why?
    - %AC in 25% Coarse RAP ≠ %AC in 25% Fine RAP
    - RAP with 4% vs. 5.5%AC
    - Tear-off RAS vs. Manufacture Waste RAS
    - …
- Why Does It Matter?
  - ↑ %ABR, the ↑ Binder and Mix Stiffness
  - ABR More Accurate then %RAP

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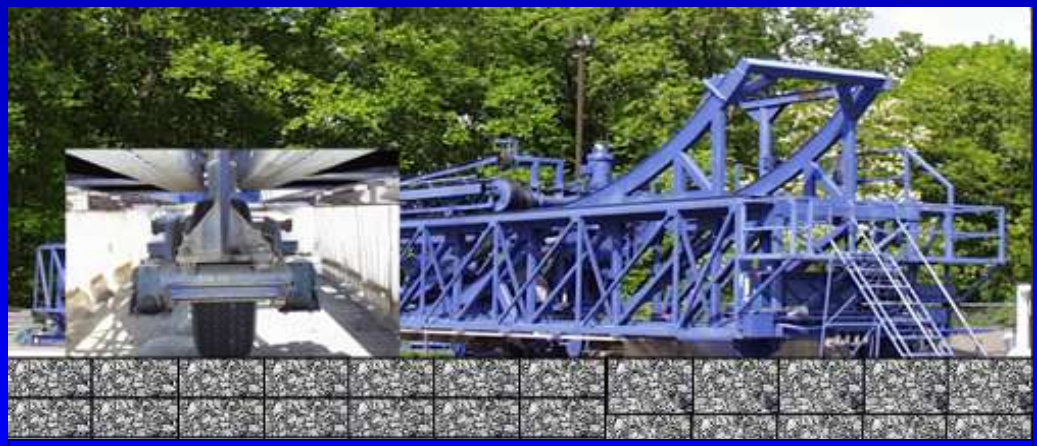
FHWA ALF High Binder Replacement Mixtures

- NAPA Annual Meeting - Technical Committee Meetings
- FHWA Memo – RAS and REOB Warning to DOTs
- FHWA ALF Test Sections TFHRC Phase
- Illinois DOT
  - http://www.youtube.com/watch?v=zJv2oZG2Mys
  - Reduced
    - 40% to 25%
    - 40% to 15%
    - 40% to 10% PMB



RAP, High RAP, RAS, RAP+RAS Sections with and without PG Grade Drops

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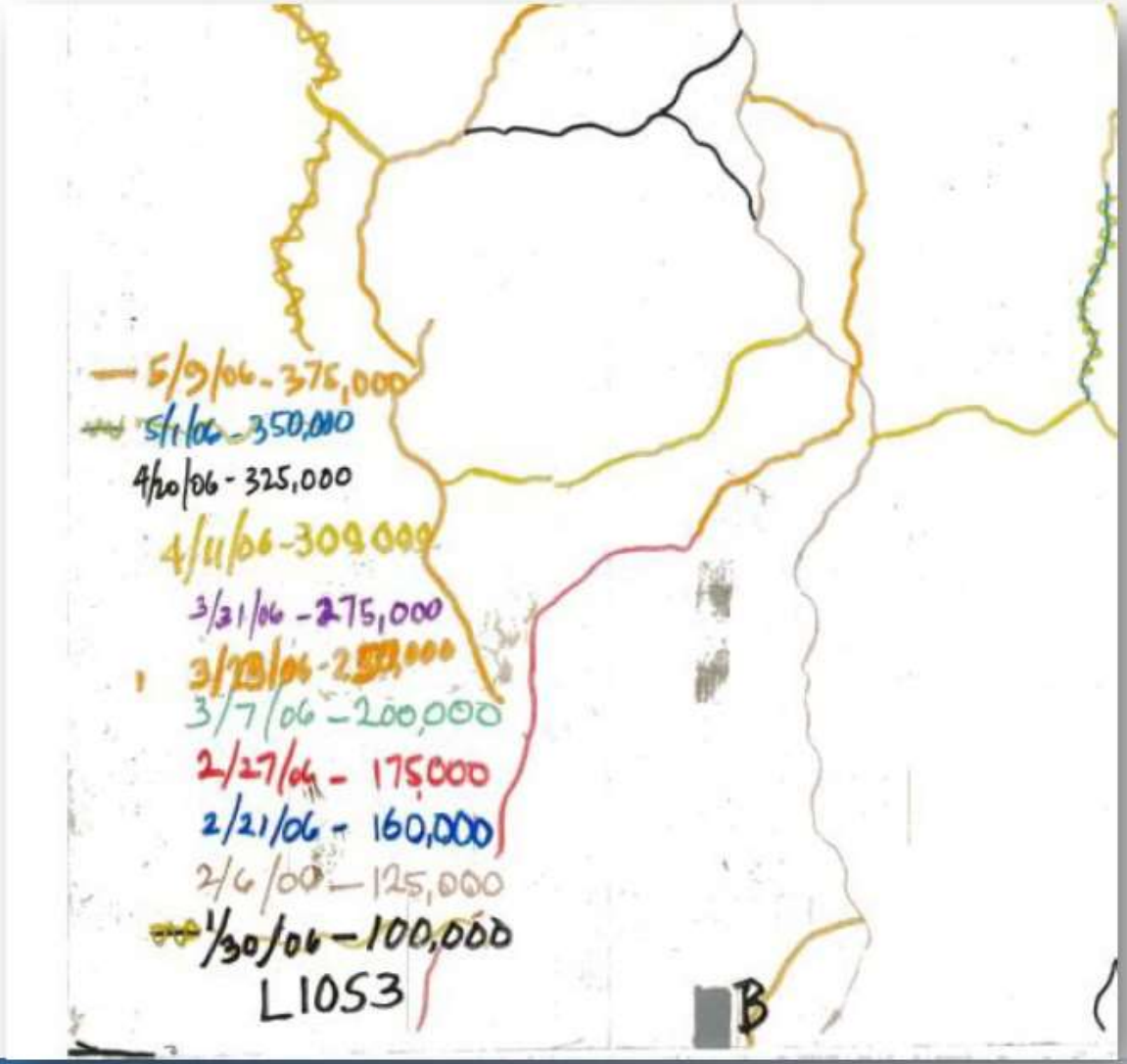
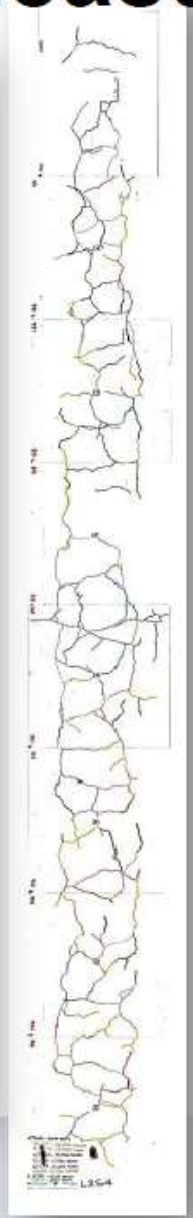
Cracking Performance Measured…



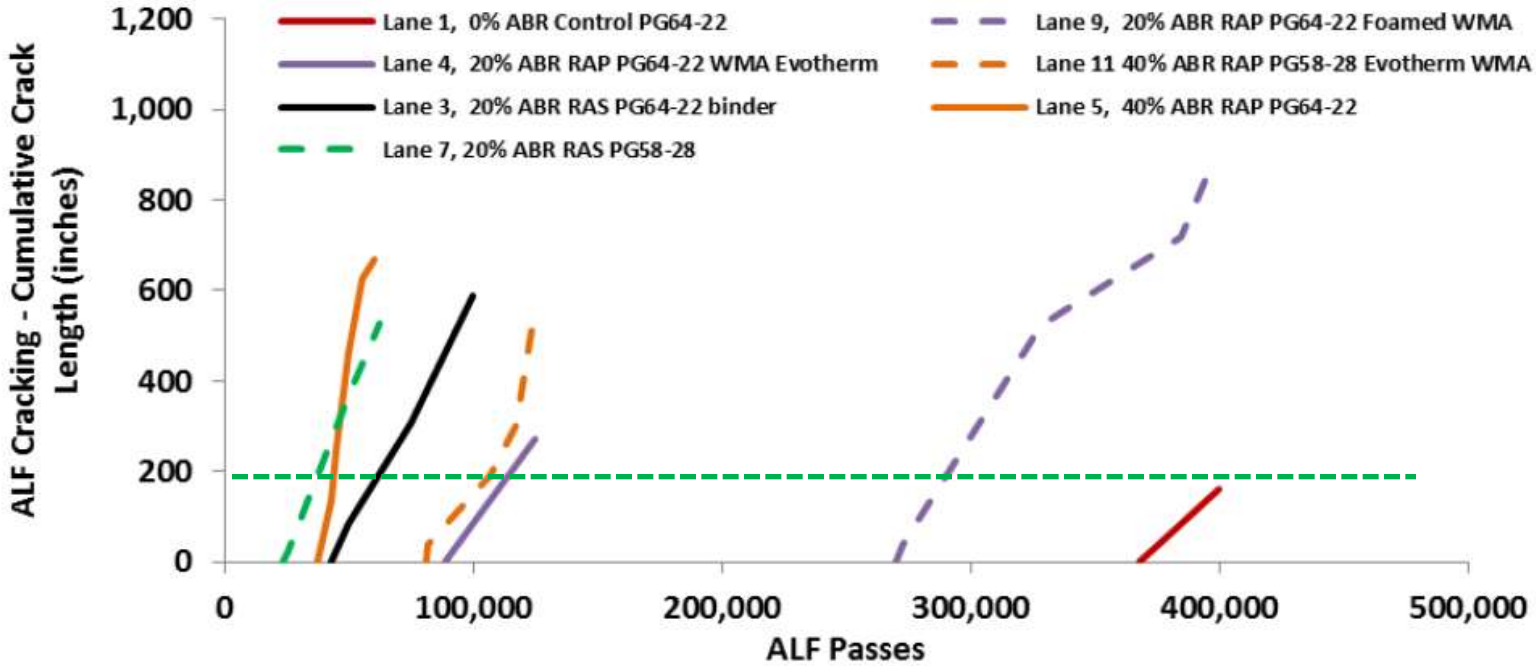


Crack lengths are individually traced with "map-measure"

Why?

TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

Cracking Performance Measured…



50,000 (12.5%), 100,000 (25%), 300,000 (75%)

How much virgin %AC above design optimum for equal performance?

U.S. Department of Transportation
Federal Highway Administration

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Current NCHRP Projects

- Many Related to High ABR Performance

http://www.trb.org/NCHRP/NCHRPProjects.aspx

Bituminous Materials

NCHRP 09-45	Test Methods and Specification Criteria for Mineral Filler Used in HMA
NCHRP 09-46	Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content
NCHRP 09-47	Engineering Properties, Emissions, and Field Performance of Warm Mix Asphalt Technologies
NCHRP 09-47A	Properties and Performance of Warm Mix Asphalt Technologies
NCHRP 09-48	Field versus Laboratory Volumetrics and Mechanical Properties
NCHRP 09-49	Performance of WMA Technologies: Stage I--Moisture Susceptibility
NCHRP 09-49A	Performance of WMA Technologies: Stage II--Long-Term Field Performance
NCHRP 09-50	Performance-Related Specifications for Asphaltic Binders Used in Preservation Surface Treatments
NCHRP 09-51	Material Properties of Cold In-Place Recycled and Full-Depth Reclamation Asphalt Concrete for Pavement Design
NCHRP 09-52	Short-Term Laboratory Conditioning of Asphalt Mixtures
NCHRP 09-53	Properties of Foamed Asphalt for Warm Mix Asphalt Applications
NCHRP 09-54	Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
NCHRP 09-55	Recycled Asphalt Shingles in Asphalt Mixtures with Warm Mix Asphalt Technologies
NCHRP 09-56	Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors
NCHRP 09-57	Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures
NCHRP 09-58	The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

What ABR from RAP is Sustainable?

- In Your Market?
- How Much is Generated?

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What Defines How Much?

- Specifications
- Availability
- Consistency/Variability for Design and Production
- Moisture Content
- Plant Processing/Production Capabilities
- Environmental Drivers and Other Materials

- How Do We Responsibly Maximize the Amount? – *That is a Best Practice!*

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Specifications

- % Limits: RAP, RAS, or Binder Replacement
- Rational Specs Key

- If No % Limit
  - RAP Binder Stiffness
  - RAP Gradation
  - RAP Aggregate Source Properties
  - Variability
  - Quality Product
    - We are the Stewards

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Availability of RAP

- In the Market
  - Amount
  - Recycling Volume (% & Total)
- Competing Use
  - Shoulder Backing
  - Base Course
  - CIPR, HIPR
  - Haul
- Agency Asset
- Cost if Not a Generator

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Consistency/Variability

- Gradation and Aggregate Source Properties
  - Acceptance – In or Out
  - Volumetric Specs – Any Bailey Method Users?
  - Pay Factors - What RAP Amount Maximizes PF?
    - Optimum vs. Change Cost
  - RAP & HMA Production QC Critical

- Feeding
  - Type & Number of Feeders
  - Fractionation of RAP

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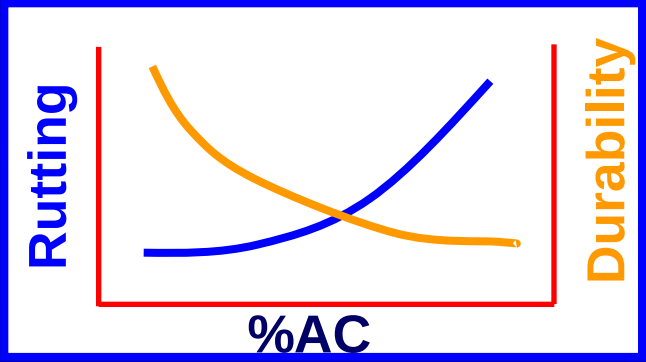
Design and Consistency/Variability



- Mix Design
  - Asphalt Binder Properties
    - Blending and Additives
  - Gradation, Volumetrics, Agg Props
  - Use Performance Tests!
    - WHY???

- Determine Optimum %RAP – Not All the Same!
  - QC - Material Properties, Design, Pay Factors
  - Plant Ops – Generating, Production, CapEx Options, Washing Fines, Fractionating to ↑ %RAP

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What Performance Tests

- Binder
  - Blending Charts?
  - Blended Materials?
  - True Grades?
- HMA
  - Hamburg?
  - Overlay Tester?
  - TSR?
  - DCT?
  - SCB?

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Our Future

- State DOTs
  - Hamburg for Durability
  - Cracking Test
    - NCHRP 9-57 - $60k
    - SCB or DCT?

- Balanced Mix Design Concept
  - Volumetrics Plus Durability and Cracking Requirements

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Our Future

- My Guess
  - Allowable %RAP↓ likely
  - 15-20%
  - Allowable %RAS ↓ or Disallowed
  - Location in Structure will matter
  - Rejuvenators?

- Balanced Mix Design with Optimum+ Concept for High ABR
  - +0.1%AC per 10% ABR
    - Virgin, FHWA, Washington?

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Consistency/Variability

- Stockpile and Crush for Consistency
  - Stockpile Uncrushed RAP Horizontally & Mine Vertically w/ Dozer
  - Horiz Impact or Jaw/Roll Crusher with Uniform Feed
  - Cool Weather

More Cost Effective to Feed Lower % Millings w/o Processing?

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Processing RAP

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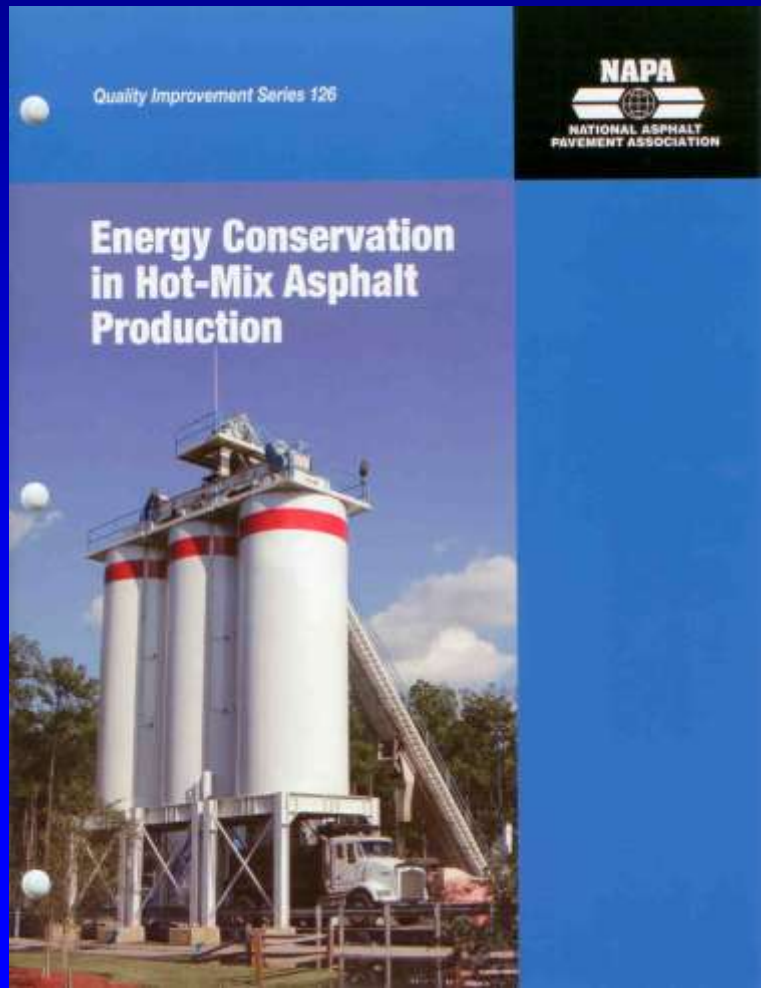
RAP Moisture

- Impacts:
  - % RAP Usable
  - Production Rate
  - Drying Cost
  - Mix Quality

- Reduce Moisture By:
  - Tall Stockpiles
  - Paving Under Stockpiles
  - Covering Stockpiles

RAP Moisture

- Rule of Thumb:
  - Every ↕ 1% MC, ↕ 10% Energy or Fuel Demand
  - RAP p200, Washed Fines
  - RAP MC + Washed Fines MC
  - See Examples in IS-126



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Fractionation and Feeding?

- Is Fractionation Necessary?
- Up to 30% RAP without Fractionation
  - Multiple Plants, with Volumetric Specs
- Fractionate Typically on ±3/8”
- RAP Feed Bins, Scalping Screens, RAP Gator
- Benefits
  - Increase Binder Replacement with Binder Rich Fraction (-3/8” Fraction)
  - Control of Properties (Grad, Volumetrics, …)
  - Reduced Variability
  - Is it Cost Effective?

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Fractionated Stockpiles

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Fractionation and Feeding

Production Capacity – Plant Type

- Batch Plants
  - Steam
  - Practicality of Delta Virgin Agg Temps for Mix Types
  - 50% RAP at 280ºF discharge
    - 3%MC = 700^{+}ºF Aggs, 400^{+}ºF Exhaust (BH)-Not Real
    - Typically up to ≈ 20-25%
- Parallel Flow Drums
  - Blue Smoke Limitations
  - Collar Location
  - External Mixers
  - Typically ≤ 25%
- Have Realistic Expectations

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Production Capacity – Plant Type

- Counterflow Drum with Volumetric Specs
  - 25% w/ Single Feeder
  - 35% w/ Twin Feeders
  - 30% RAP WMA
    - Flighting

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Production Capacity – Plant Type

- Double Barrel Drum with Volumetric Specs
  - 45% w/ Twin Feeders
  - 45% RAP WMA

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A Valuable Lesson Learned

- Marketing to Public Agency
- RAP BP Outcome
- Three RAP Types
  - A - Hot Plant Transfer RAP
  - B - HMA RAP
  - C - Agg Base RAP
- Keep A & B Separate or Blend
- C is Always Separate

GRANITE CONSTRUCTION COMPANY SINCE 1922

GRANITE Engineering Services

AAP

RECYCLED ASPHALT PRODUCT MANAGEMENT PLAN

The following procedures are established as a means to maintain consistency and quality of HMA products produced by Granite Construction Company. This document outlines procedures used during handling and processing of Recycled Asphalt Product (RAP) at our Crushing facilities and incorporating RAP into Hot Mix Asphalt (HMA) in our Hot Plants.

The plan includes methods for handling internally generated unprocessed RAP product, initial inspection of imported unprocessed RAP products, grading and sorting unprocessed RAP by quality level, stockpiling unprocessed RAP, blending and processing RAP (crushing, screening), quality control testing performed during processed RAP production, stockpiling of processed RAP, RAP mix design procedures, and introduction of RAP products into HMA products.

We have established three categories of unprocessed RAP

1. "A" HOT PLANT TRANSFER RAP
2. "B" HMA RAP
3. "C" AGGREGATE BASE RAP

Only "A" and "B" category unprocessed RAP will be used to produce HMA quality RAP. "C" category RAP will be used to produce aggregate base.

Inspection Procedure for imported RAP

1. The Crushing facility will accept RAP Monday – Friday, 7:00 am to 3:00pm
2. Upon entry into the plant facility, trucks importing unprocessed RAP stop at an inspection platform and contact the QC laboratory by CB radio or other means to request inspection. Laboratory supervisor will dispatch a technician to inspect load.
3. An inspection will be made to determine composition / quality and assign grade for each load of imported RAP. Technicians will be trained to determine the quality level of the inspected load. Empirical knowledge of local aggregate sources will be relied upon in the inspection process.
4. Loads containing excessive amounts of debris, steel, or other deleterious materials will not be accepted.

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A, B, C Piles

- A and B RAP Piles
  - Maximize %RAP
  - Low Binder Stiffness
  - Best Agg Qualities
  - Minimize Binder Grades
- C RAP Pile
  - EnviroBase

Process – Inspect, Crush, Pile, Design, Blend, Verify

- Every Load Inspected by QC
- Plant Transfer = A Pile Source
- Project and Import = B Pile Source
- Import (including PCC) = C Pile Source

RAP or CRAP – you be the judge!

- There is More Value in High Quality RAP Products

Performance Test

Stacking Green Technologies = Sustainability

- RAP + ?
- Some Local Public Works Examples…
- What Have You Seen?

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Local Green Pavement Examples

McCarran Blvd CIPR - 2002

- Plumb Ln to Lakeside Dr
- Milled (RAP) and CIPR w/ new HMA Surface

Taylor St Reconstruction 2010

- In-Place Recycle Existing HMA+Base
- WMA w/ 15% RAP Surface Course

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Bravo Ave Reconstruction 2010

- In-Place Recycle Existing HMA+Base
- WMA w/ 15% RAP Surface Course (7k tons)

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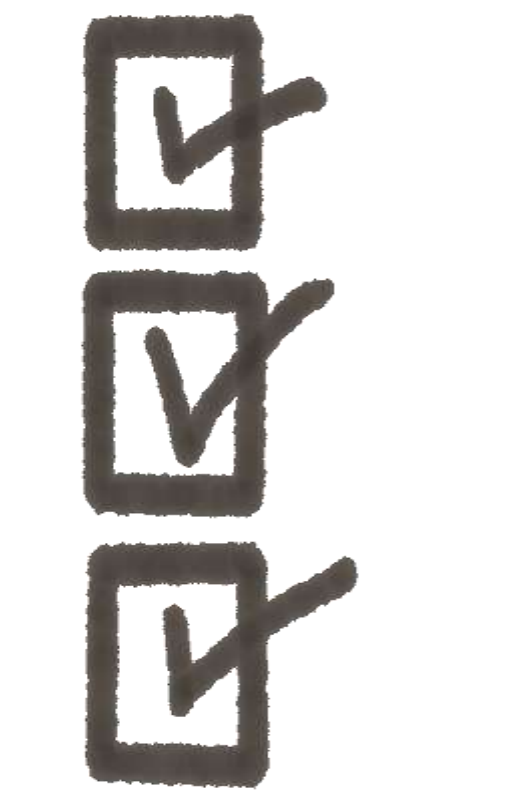
BP's - What Matters

- Plant Capabilities
  - Right Equipment, Set up Right
  - Manufacturers Help
- RAP Management Plan
  - Piles A, B, C, …
- Variability
  - Understand, Control & Leverage It
- Moisture Content
  - Manage It
- Fractionation
  - To or Not To…
- Knowledge Transfer – Barrier Removal
  - Be Green



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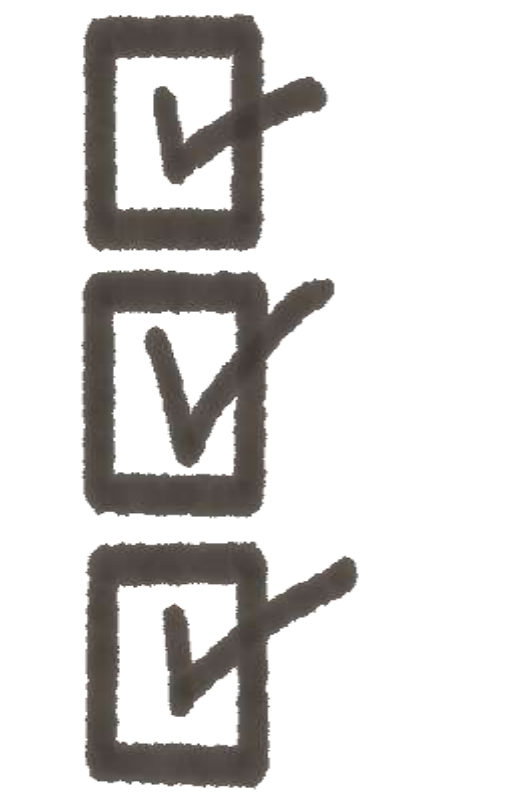
BP's - What Matters

- HMA Design
  - Use What?
- Product Quality
- Do It Right for
  - The Taxpayers
  - Our Companies
  - Our Industry
- Our Future Depends on It!



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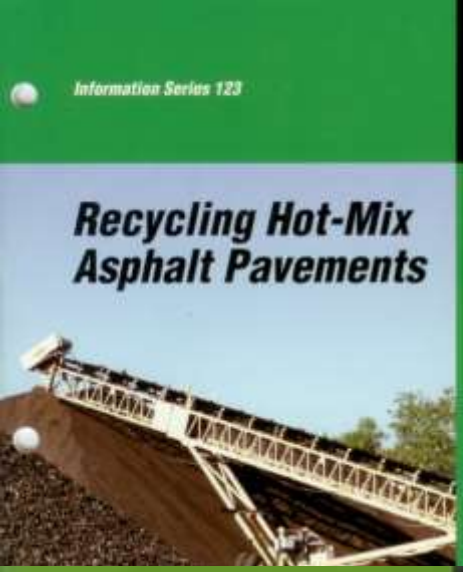
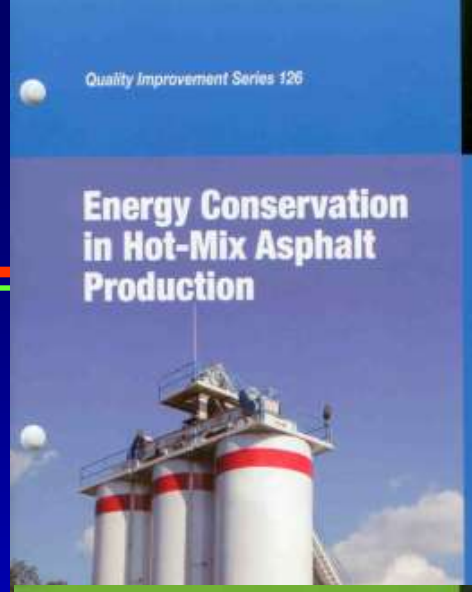
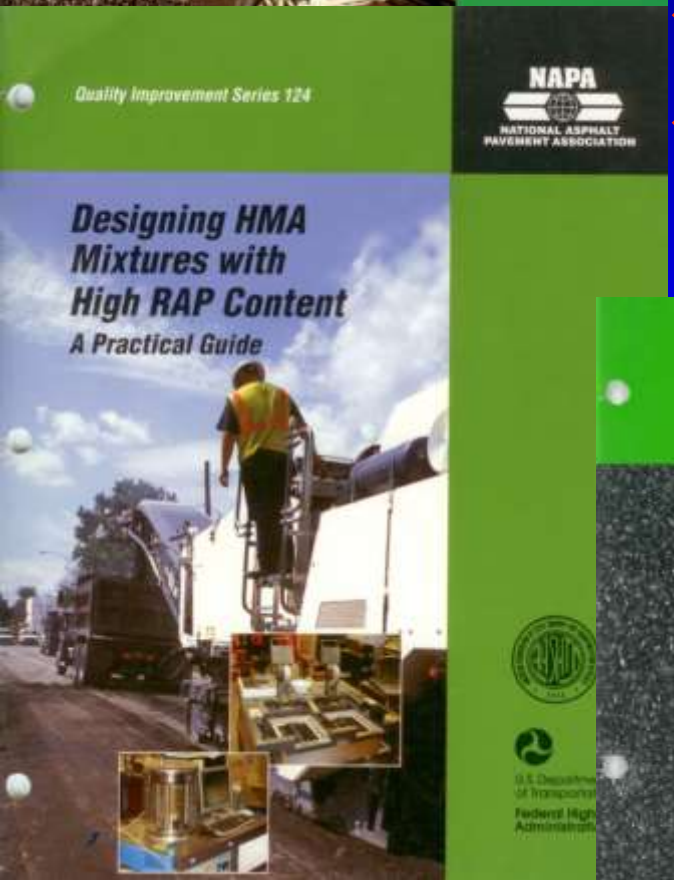
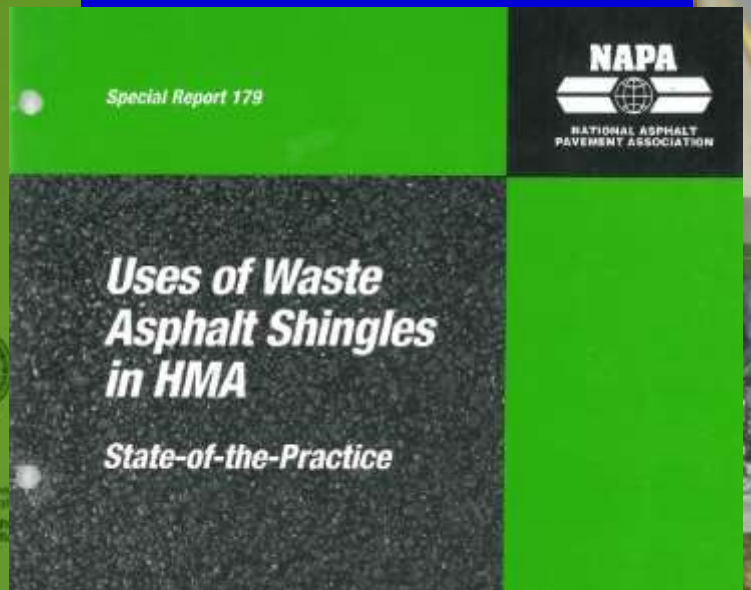
Resources

- NAPA
- www.hotmix.org
- State APA
- Equipment Manufacturers









Questions / Feedback

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