Use of Recycled Shingles in HMA Pavements

HMA Construction – Moving Forward
Future of the Industry
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Background

- 10 million tons of asphalt Shingles enter waste stream each year
  - 1 million tons manufacturer waste
  - 9 million tons tear-offs or used Shingles
  - Third largest construction material waste
- ARMA analyzed a number of recycling options and identified HMA as the best use
  - Volume of waste used
  - Ease of recycling since Shingles composed of materials routinely used in HMA

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Background

- Why use Shingles?
  - Economic benefits
    - NAPA estimates cost savings per ton of HMA ranges from $2.15 to $3.30
    - Not all benefits accrue to all users
      - Tipping fees and handling costs vary
      - Actual savings more likely to be $1.25 to $1.85
  - RAP sources are declining
  - It’s the right thing to do
    - Process can be engineered to provide HMA with equivalent performance

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Background

- Potential benefits from the use of Shingles in HMA include:
  - Improved resistance to pavement cracking
    - Due to reinforcement from fibers
  - Improved resistance to rutting
    - Due to fibers and increased stiffness of binder
  - Reduced costs for the production of HMA
    - Conservation of natural resources
  - Conservation of landfill space
    - Reduced costs for Shingle waste disposal
- Studies ongoing at this time
  - At this time consider impact as neutral

Background

- Shingles typically contain:
  - Asphalt binder
    - Tear-offs contain 30 – 40% binder
    - Manufacturer waste 18 – 22% binder
  - 40 to 60% hard rock granules and fillers
  - 1 to 12 % fiber, felt, and miscellaneous materials

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Processing Shingles for Use in HMA

- The age old engineering question
  - How do you make a square peg fit into a round hole?

Square Peg

Square Peg In Round Hole

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Processing Shingles for Use in HMA

- Various equipment has been tried to grind the Shingles into a usable product
  - RAP Plant
  - Tree shredding approach
- Peterson Pacific
  - 40 – 60 TPH
  - Dust Control
  - Screen size

Processing Shingles for Use in HMA

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- Carrier aggregate used to keep Shingles from agglomerating and allow to flow through cold feed bin
  - RAP, 3/8” Stone, Washed stone screenings, Natural sand
- Blending by volume
- Blending methods
  - ASTEC dual bin blender
  - Ground blending with additional processing

Processing Shingles for Use in HMA

- Ground blended material is processed to minimize binder content variation
  - Trummel screen
  - RAP plant
- Ground blending problems
  - Expense
  - Binder content variability
    - Could be a result of tear-off Shingle binder contents

Sieve (mm)	12.5	9.5	4.75	2.36	1.18	0.600	0.300	0.150	0.075	A.C.%
RAP Extraction Results – 75 tests										
AVG YTD	98.9	90.4	65.9	50.7	39.6	29.6	18.6	11.1	6.4	3.98
STD YTD	0.8	1.9	3.5	3.1	2.6	1.7	1.4	1.1	0.9	0.27
RAP Shingle Blend Extraction Results – 19 tests										
AVG YTD	98.7	91.5	68.8	54.2	41.5	29.4	17.9	10.1	5.5	6.19
STD YTD	0.8	1.7	2.1	2.0	1.8	1.5	1.5	1.5	1.2	0.61

Processing Shingles for Use in HMA

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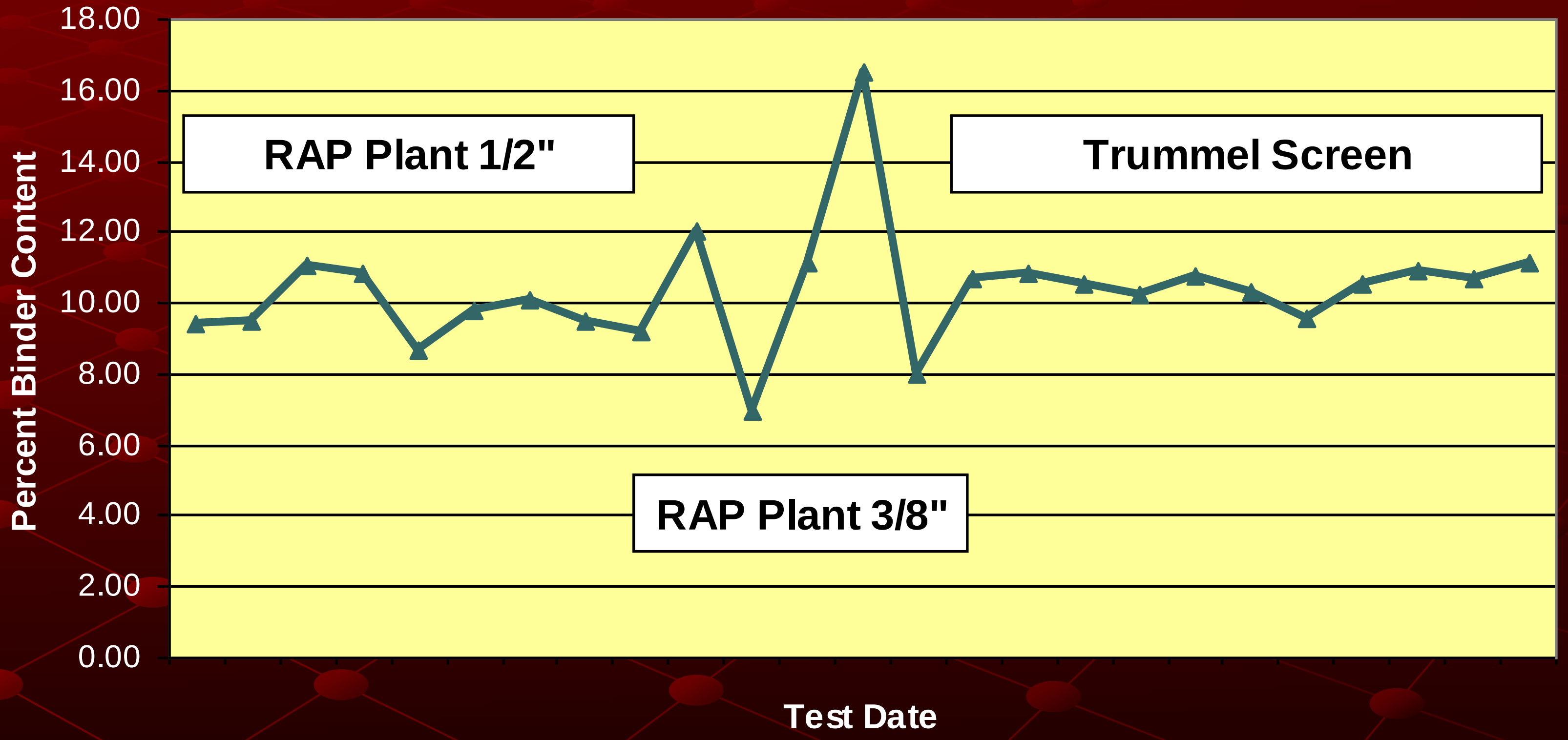

Processing Shingles for Use in HMA

- Most significant concern is proper sizing of the ground Shingle particle
  - Finer is better!
- Oversized Shingles particles impact:
  - Contribution to P_{be}
  - Mat texture
  - Consistency of blend with carrier aggregate

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Processing Shingles for Use in HMA

- Environmental concerns
  - Typical concerns for aggregate crushing and HMA production
  - HMA with Shingles is recyclable
  - Asbestos screening
    - MA – 25 ton lots
    - NJ – 5 ton lots
    - Must be Non-detect

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Typical Tear-off Shingle Composition

- Results shown below were obtained from processed tear-off Shingles
- Gradation and binder contents of Keating manufacturer waste are significantly different
  - Gradation is finer with lower binder content

Sample Number	Asphalt Content (%)	Percent Passing Sieve Size (mm)							
		9.5	4.75	2.36	1.18	0.600	0.300	0.150	0.075
1	29.1	100	98.6	93.7	70.7	41.4	31.4	22.8	13.8
2	29.3	100	97.7	91.3	68.5	42.1	33.8	26.4	17.8
3	31.1	99.4	93.3	86.4	62.9	39.8	29.9	21.1	12.4
Avg.	29.8	99.8	96.5	90.4	67.3	41.1	31.7	23.4	14.7

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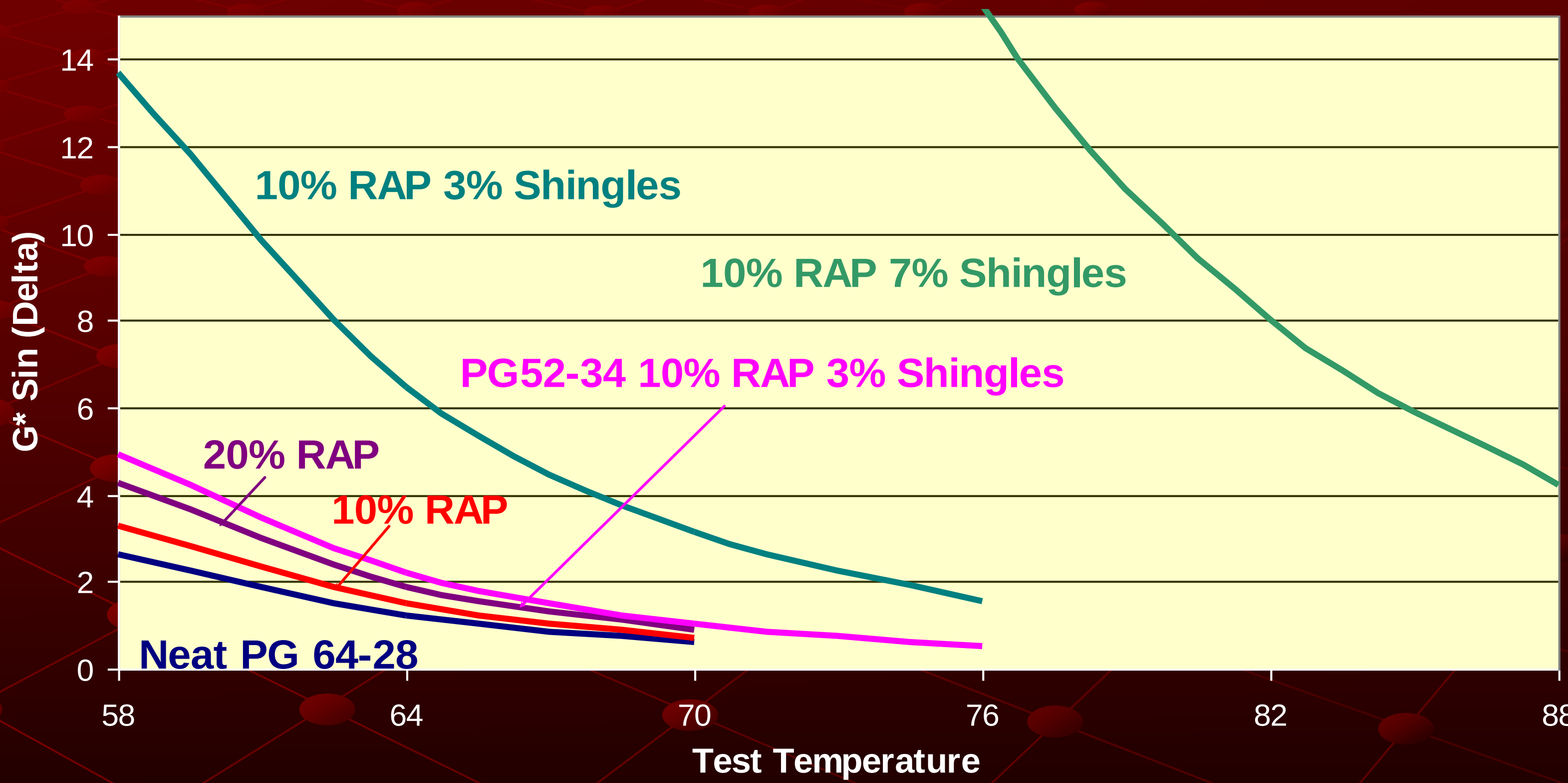
Shingle Impact on Binder Grade

- Blending of virgin and recycled binder
  - Black rock (paper) vs. homogenous blend?
- Keating binder experiment to determine impact on binders high temperature performance grade
  - Two virgin binders used
    - PG 64-28 and PG 52-34
  - RAP and Shingles recovered binder
    - AASHTO T164 and T170 procedures used
  - Materials blended to provide a uniform mixture
  - Test temperatures 52ºC - 86ºC
  - Results – Dynamic Shear G*/Sinδ

Shingle Impact on Binder Grade



Assumptions: Mix binder content of 5.2%, RAP binder content of 4.1%, Shingle binder content of 30%

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Shingle Impact on Binder Grade

Phase II

- Complete performance grading of PG 52-34 and PG 64-28 blended with 10% RAP and 3% Shingles
  - High temperature grading confirmed Keating results
  - Low temperature grade increased by one grade
- Pennsy Supply data on plant mix recovered binder indicates similar results obtained for PG 58-28 blended with 17% RAP and 3% Shingles
  - Delaware DOT results as high as PG 88-22

Test	Criteria	Sample	
		PG 52-34 10/3	PG 64-28 10/3
Original Binder			
Rotational Viscosity	3000 cP max	490 cP	1010 cP
Dynamic Shear	1.0 kPa min	1.83 kPa	1.39 kPa
Phase Angle	-	81.8°	80.3°
RTFO Binder Residue			
Mass Loss	1.0% max	0.312%	0.460%
Dynamic Shear	2.2 kPa min	4.69 kPa	4.78 kPa
PAV Binder Residue			
Dynamic Shear	5000 kPa max	2392 kPa	1549 kPa
Creep Stiffness	300 MPa max	162 MPa	93 MPa
Creep Stiffness Slope	0.300 min	0.311	0.320
Resulting Binder Grade			
		PG 64-28	PG 76-22

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Shingle Impact on Binder Grade
Phase III

- Complete performance grading of PG 64-28 blended with RAP and Shingles
  - Two mixes: Binder 5.1% AC, Top 5.5% AC
  - Tested various combinations of mix components

Test	Criteria	Sample			
		PG 64-28 VRS - B	PG 64-28 VR - T	PG 64-28 VRS - T	PG 64-28 VS - T
Original Binder					
Rotational Viscosity	**3.0 Pa-s**	**1.165 Pa-s**	**0.526 Pa-s**	**1.203 Pa-s**	**0.863 Pa-s**
Dynamic Shear	**1.0 kPa**	**1.954 kPa**	**2.021 kPa**	**1.717 kPa**	**1.141 kPa**
RTFO Binder Residue					
Mass Loss	**1.0%**	**0.89%**	**0.80%**	**0.97%**	**0.90%**
Dynamic Shear	**2.2 kPa**	**7.094 kPa**	**7.544 kPa**	**7.39 kPa**	**5.069 kPa**
PAV Binder Residue					
Dynamic Shear	**5000 kPa**	**4793 kPa**	**3356 kPa**	**4822 kPa**	**3867 kPa**
Creep Stiffness	**300 MPa**	**48 MPa**	**168 MPa**	**50 MPa**	**85 MPa**
Creep Stiffness Slope	**0.300**	**0.334**	**0.314**	**0.334**	**0.309**
Resulting Binder Grade					
		PG 76-16	PG 64-28	PG 76-16	PG 76-22

Shingle Impact on Binder Grade

Observations

- Addition of up to 20% recovered RAP binder has little impact on blended binder's high temperature grade
- Addition of recovered Shingle binder has significant impact on binder's high temperature grade
- Relatively low creep stiffness and high creep stiffness slope values for the PG 64-28 RAP Shingle binder suggests an incremental low temperature binder grade lower than -22ºC
- Fatigue performance of the PG 64-28 RAP Shingle binder should meet requirements for virgin PG 64-28 given the relatively low PAV DSR value

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Shingle Impact on Binder Grade
Observations

- Black rock (paper) vs. homogenous blend?
  - Some Shingle binder bound in discrete Shingle particles and does not contribute to the mixture's effective binder content
  - Test procedures used do not account for reduced binder contribution from Shingles
- Actual mixture binder grade:
  - High temperature grade higher
  - Low temperature grade higher

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Shingle Impact on HMA Volumetrics

- Laboratory experiment using Keating approved Mass Highway top and binder mixes
- Blends tested included:
  - Virgin, Virgin – RAP, Virgin – RAP – Shingles
- Recycled products added as a direct replacement for virgin aggregate resulting in slight variations in gradations
- Mixes compacted to 100 gyrations, data back calculated to 75 gyrations for analysis

	100% Virgin			75% - 25% Virgin - RAP			75% - 20% - 5% Virgin - RAP - Shingles		
Specimen Number	1	2	Avg	1	2	Avg	1	2	Avg
MHD 19.0 mm Dense Binder 5.2%									
Percent Air Voids	3.07	2.87	2.97	2.25	2.17	2.21	4.25	4.22	4.24
MHD 12.5 mm Top Course 5.6%									
Percent Air Voids	3.81	3.97	3.89	3.43	3.83	3.63	4.77	4.53	4.65

Shingle Impact on HMA Volumetrics
Observations

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- Mix air void rankings the same for both mixes evaluated
  - Virgin – RAP, Virgin, Virgin – RAP – Shingles
- Is all P200 created equally?
  - Is the P200 drying or extending the binder?
  - P200 in the Shingle mixtures is 15 to 25% higher than virgin or virgin - RAP mixes (binder – 4.0%, top – 4.5%)
- All mixes were compacted at the same temperature
  - Effects of recycled materials were not considered

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Shingle Impact on HMA Volumetrics
Observations

- Lower than expected effective binder content due to the presence of the discrete Shingle chips present in the mix
- Shingle contribution to P_{be} may be impacted by the mix production temperature and the size of the Shingle grind
- Recycled materials had significant impact on virgin binder used in these mixtures
  - 60% virgin binder, 40% recycled binder in both mixes

P.J. Keating Shingles Use

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- No significant production or placement problems
- Mix predominately supplied to private commercial work
  - Typical use is 5 - 7% of mix
  - Percentage use is based on mix type, surface vs. binder
  - Marshall and Superpave designs developed
- Shingles used in batch and drum facilities
- MassHighway allows the use of 5% manufacturer waste shingles in the production of subsurface mixes

P.J. Keating Observations

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- Issues and concerns noted:
  - Shingle sand and Shingle RAP blends tend to retain moisture
  - Mix working time reduced
  - Material handling
  - Shingle tabs can get through grinder
  - Lack of general acceptance of this recycling practice
    - Necessitates ability to use multiple recycled products at the same time

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P.J. Keating Observations

- Issues and concerns noted (continued):
  - Shingle contribution to the mixture's effective binder content
    - Tilcon NJ discounts by 60%
    - Keating discounts by 20%
  - Increased wear on equipment due to Shingle use
  - Consistency of Shingle supply
    - Tear-offs
    - Manufacturers – GAF, IKO, Elk 25k+ tons per year
  - Uniformity of Shingle grind supplied
    - Oversized particles may require screening after grinding
    - Binder content consistency

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Summary

- Shingles can be effectively used in HMA to produce a mix of equal or better quality
  - Binder savings in excess of those obtained from RAP use alone appear realistically achievable
- Practical issues need to be addressed
  - Use of multiple recycled products at the same facility at the same time
  - Material storage concerns
  - Consistency of Shingles and carrier aggregate blends
  - Required environmental testing

Summary

- Additional research required
  - Development of mix design protocol and standard specifications
    - Considering contribution of Shingles to the mixture's effective binder content
    - Must be volumetrically based
  - Determine amount of binder blending and the resulting binder's low temperature performance
    - Are different virgin binders necessary?
  - Develop database of Shingle mix performance
  - Identify hurdles to general acceptance of this type of recycled product