Multi-Disciplinary Approach to the Characterization of Recycled Asphalt Shingles (RAS) Materials in Asphalt Pavement Applications

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PRI Asphalt Technologies, Inc. 6408 Badger Drive Tampa, FL 33610 Tel: 813-621-5777 Fax: 813-621-5840 WebSite: http://www.priasphalt.com

Outline

- Objective
- Background
- Composition of Roofing Materials
- Characterization of Different Components
  - Physiochemical Analysis of RAS Asphalt
  - Impact of Aged Coating
- Use of RAS in HMA and SMA applications
  - Experimental Study
- Conclusions

Objective

- To characterize the various components of recycled asphalt roofing materials.
- Discuss the impact of recycled asphalt roofing materials on various pavement applications.

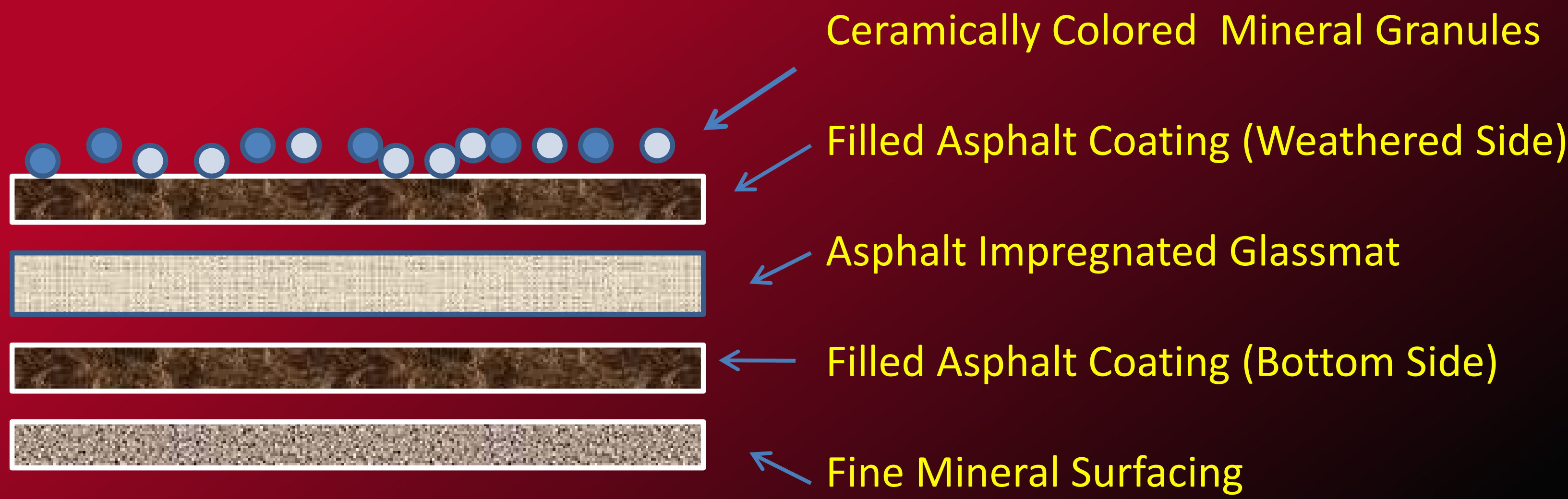
Background

- Estimated that over 11 MM tons of asphalt roofing waste is generated annually.
- Asphalt Roofing Shingles comprise ~60% of the available recycled roofing materials.
- Asphalt Roofing Shingles have gained widespread use in Hot-Mix Asphalt paving
  - Has been used since early 1960's
- Numerous states are allowing the use of RAS in HMA

Types of Asphalt Roofing Materials

- Asphalt Roofing Shingles
- Asphalt Saturated Felts/Glassmats
- Mineral Surface Roll Roofing
  - Peel-n-Stick products
- Modified Bitumen Membranes

Asphalt Roofing Shingle



Composition of Asphalt Roofing Shingles

- Shingles consist of the following general components:
  - 50-60% Inorganic fillers/granules
  - 20-25% asphalt (coating) for shingles
  - >25% asphalt for others
  - 1-12% inorganic/organic fibers

Asphalt Roofing Shingle Specifications

Property	Organic Felt Shingles (ASTM D 225)	Glass Mat Shingles (ASTM D 3462)
ASTM D 5 -Penetration, dmm@ 25°C	N/A	15 minimum
ASTM D 36 – Softening Point, °F	N/A	190-235
Minimum Average Mass/Unit, lb/ft^2	95.0	70.0
Minimum Mass/Unit Area of Mineral Matter passing No.6 and Retained on No. 70, lb/ft^2	18.5	25.0
Tear Strength	N/A	Requirement

Composition of Recycled Asphalt Shingle

Property			Description	Test Methods	Results; Wt %
Composition					
Asphalt			Shingle Coating	D 2172A Extraction D 5404 Recovery, D 2974, 8A &C Organics	21.1
Organic Materials			Contaminates, possible organic felt		3.7
Inorganic Materials	+ 200 mesh (0.075µ)		Granules, fiberglass mat		49.3
	- 200 mesh (0.075µ)		Filler, backsurfacing, fiberglass mats		25.8
Unaccounted for / loss			--		0.1
Recovered Material Properties					
Inorganics	Sieve Analysis, % passing	No. 4	Granules, fillers, backsurfacing and fiberglass mat fibers	ASTM C 117/ 136 / 546	99.7
		No. 8			99.2
		No. 30			63.6
		No. 50			53.7
		No. 100			44.8
		No. 200			34.6
Asphalt	Absolute Viscosity, P	60°C	Air blown Coating	AASHTO T 315	3,877,000

Asphalt Used Shingles

- The asphalt used in roofing shingles is much harder than paving asphalts
  - Penetration$_{25C}$ of Paving Asphalt 50 – 300 dmm
  - Penetration$_{25C}$ of Roofing Asphalts 15-70 dmm
- The asphalt used in roofing shingles is termed a "coating" and comes from the air-blowing of flux.
- Flux properties are typically soft streams in the range of a PG 46-34 to PG 52-28.

Asphalt Used in Shingles

- Flux is converted to a coating through the air-blowing process:
  - Asphalt is heated to typically 500°F
  - Air is bubbled through the asphalt
- Process is run to a target Softening Point in the range of 200-220°F
- Coating must meet certain Penetration(25°C) range
  - Typically 15-25 dmm

Chemical Analysis of Asphalt Coatings

- An experiment was performed where the compositional analysis of the conversion of flux to coating was evaluated.
- Flux – Mid-Continent Source
- The flux was converted to coating using a laboratory blowstill (500°F, 2 l/min (air flow), agitation) then subsequently weathered.
- The compositional analysis was performed using TLC-FID Detection to analyze the four generic fractions of asphalt.

Accelerated Weathering

- Accelerated Weathering was performed to determine impact of long term exposure on the asphalt coating
- ASTM D 4798 – Accelerated Test Conditions and Procedures for Bituminous Materials was used.
  - Cycle A (51 min light , 9 min light/spray), 60°C
  - Failure determine when more than 10% of the surface is cracked (spark testing)
  - Coating failed at 4000 hours of exposure

Asphalt Coating

- The aged asphalt coating has a high asphaltene content and very low naphthene aromatics content.
- The resulting rheological properties can greatly modify a paving binder's performance.

Property	Resid	Coating	Accelerated Weathering, hours		
			1,000	2,500	4,000 (failure)
Asphaltenes	18.5	33.2	43.9	48.7	53.3
Polar Aromatics	26.5	20.8	28.2	28.7	28.9
Naphthene Aromatics	42.0	32.9	16.2	12.0	6.0
Saturates	13.0	13.1	11.7	10.6	11.8

Impact of RAS on Performance Grading

- Blend of 24 wt% Recovered RAS[1] Binder and 76 wt% PG 64-22
- RAS Asphalt recovery and blended with virgin PG 64-22

PROPERTY			TEST METHOD	SPECIFICATIONS	RESULTS
Blend (24% Recovered Asphalt from Shingles + 76% PG 64-22)					
Viscosity, Pa•s		135°C	AASHTO T 316	3.0 max.	1.100
		165°C		Report	0.270
Dynamic Shear (G*/sinδ, 10 rad./sec.), kPa		70°C	AASHTO T 315	1.0 min.	4.160
		76°C			2.010
		82°C			***0.998***
After RTFOT					
Mass Change, % (Mass Loss is reported as Negative)			AASHTO T 240	1.0 max.	-0.168
Dynamic Shear (G*/sinδ, 10 rad./sec.), kPa		76°C	AASHTO T 315	2.2 min.	5.690
		82°C			2.710
		88°C			***1.350***
PRESSURE AGING RESIDUE (100°C,300 psi,20 hr.)			AASHTO R 28		
Dynamic Shear (G*•sinδ, 10 rad./sec.), kPa		31°C	AASHTO T 315	5,000 max.	3,480
		28°C			4,730
		25°C			***6,350***
Creep Stiffness	Stiffness,MPa (60 sec.)	-6°C	AASHTO T 313	300 max.	98
	m Value			0.300 min.	0.328
	Stiffness,MPa (60 sec.)	-12°C		300 max.	217
	m Value			0.300 min.	***0.291***
True Performance Grade					**81.9-20.5**
SUPERPAVE™ Performance Grade					**76-16**

[1]RAS Binder has PG 100+

Impact of RAS on Performance Grading

- HMA (PG 64-22) containing 3 wt% RAS
- Asphalt binder recovered after preparation of HMA

PROPERTY			TEST METHOD	SPECIFICATIONS	RESULTS
Sample As Received					
% Moisture			Oven Drying	Report	0.11
Extraction Data					
% Asphalt, twm			ASTM D 2172 (Method A) w/Toluene	Report	4.9
Recovered Binder from Bituminous Mixture with 3% Shingles					
Absolute Viscosity, P		60°C	ASTM D 2171	Report	34,603
Dynamic Shear (G*/sinδ, 10 rad./sec.), kPa		76°C	AASHTO T 315	2.2 min.	2.940
		82°C			***1.460***
PRESSURE AGING RESIDUE (100°C,300 psi,20 hr.)			AASHTO R 28		
Dynamic Shear (G*•sinδ, 10 rad./sec.), kPa		31°C	AASHTO T 315	5,000 max.	2,790
		28°C			4,050
		25°C			***5,480***
Creep Stiffness	Stiffness,MPa (60 sec.)	-12°C	AASHTO T 313	300 max.	203
	m Value			0.300 min.	0.302
	Stiffness,MPa (60 sec.)	-18°C		300 max.	***400***
	m Value			0.300 min.	***0.259***
True Performance Grade					**78.9-22.3**
SUPERPAVE™ Performance Grade					**76-22**

Inorganic Materials

Property			Description	Test Methods	Results; Wt %
Composition					
Asphalt			Shingle Coating	D 2172A Extraction D 5404 Recovery, D 2974, 8A &C Organics	21.1
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Granular Components of Shingles[1]

Component	Typical Quantity, wt% of shingle	Typical Size
Ceramic Granules	10-20 %	Passing no. 12 Retained No. 40
Headlap Granules	15-25%	Same as above
Backsurface Sand	5-10 %	Passing No. 40 Retained No. 140
Stabilizer	15-30 %	90% passing No. 100 70% passing No. 200

[1]Influence of Roofing Shingles on Asphalt Concrete Mixture Properties

Mineral Filler (Stabilizer)

- Mineral fillers are blended into the asphalt to stabilize the asphalt coating
- Typically use minus 0.150 mm (plus #100)
- Typically use various types of limestone, rock silica sand and boiler slag.
- Amount of filler in the coating can vary from from 55-70 wt% of the coating.

Recovered Fiber Properties

- The fiber from the predominantly non-woven fiberglass or cellulose fibers:
  - Encapsulated in asphalt
  - Form and properties have not changed much during aged
- The fibers contained in RAS can be potentially be used in various paving applications to increase resistance to permanent deformation and tensile strength

Impact of Components on Paving Applications

- In order to determine the impact of RAS on asphalt paving applications:
  - Two design were proposed:
    - Use of RAS in the Hot Mix Asphalt “Additive”-HMA
    - Use of RAS in the Asphalt Binder “Modifier” –SMA
- The RAS used was processed to have the following properties:
  - 100% passing 0.850 mm
  - 100% retained 0.212 mm
  - Composition:
    - 30.7 wt% Asphalt,6.8 wt% fiber, 62.5 wt% Filler

Phase I: Experimental Design (HMA)

- Mix Design – Florida S-1 dense graded mix*
  - Control (PG 64-22), 10 % RAS
  - Air Voids – 4.0 %
  - Asphalt Content – 7.0 %
  - Aggregates (Limestone (LS), Limestone Screenings (LSS) and Sand (SA)
  - Control: 55 wt % LS, 25 wt% LSS and 20 wt% SA
  - RAS Additive: 55 wt% LS, 20 wt% LLS, 10 wt% SA & 10% RAS

* Work based on Marshall Mix Design

Phase I: Mix Specimen Properties

Mix Properties	Control	w/10% RAS
Asphalt wt%	7.0	7.0
Specific Gravity	2.207	2.180
Maximum Gravity	2.300	2.287
% Air Voids	4.0	4.7
Stability, N	7,459	18,770
Flow, mm	2.24	3.23

Phase I: Indirect Tensile Strengths

- Testing performed according to ASTM D 4123 (25°C)

Sample ID	Total Binder	Neat PG 64-22	Average Tensile Strength (kg)	Standard Deviation (kg)
Control	6.5	6.5	935.2	901.7
RAS	7.0	3.5	1,792.9	1,755.9

RAS mixture produces much higher tensile strengths

Phase I: Georgia Loaded Wheel Testing

- Testing performed on Georgia DOT Loaded Wheel Tester
  - 689.5 kPa,38.9 – 40.9°C

ID	# Cycles	Rut Depth (mm)
Control	8,000	5.3
RAS	8,000	1.5

RAS mixture has less Permanent Deformation

Phase II: Experimental Design (SMA)

- Mix Design – Florida S-1 dense graded mix*
  - Modified gradation to typical SMA Design
  - Used same aggregates as listed in HMA Design
  - Incorporated other modifiers
    - SBS
    - Trinidad Lake Asphalt (TLA)
    - Cellulose Fibers (CL)
  - Targeted Drain-Down

* Work based on Marshall Mix Design

Phase II: Modified Binder Drain-Down

- 1 kg of each mix was prepared at 170-175°C
- 500 grams was conditioned at 170°C in glass beaker for one hour.
- The residual binder adhering to the glass beaker was weighed – wt% drain down

Modified Binder	Base Binder	Wt% of Binder	Wt% of Modifier	Drain-Down Wt%
Control	PG 67-22	100.0	0.0	5.64
RAS	PG 58-28	71.4	28.6	2.29
SBS*	PG 67-22	96.0	4.0	3.52
TLA	PG 67-22	75.0	25.0	7.95
CF	PG 67-22	96.0	4.0	0.75

*radial SBS

Conclusions

- Aged Roofing Asphalt has a high percent of Asphaltenes resulting increased stiffness
- Asphalt (with RAS incorporated) ~ 5 wt% in HMA
  - The RAS Modified binder is extremely stiff (Performance Grade PG 64-XX >> PG 76-XX).
    - Two grade increase
  - The RAS Modified binder reduces the low temperature performance (PG XX-22 >> PG XX-16)
    - One grade decrease

Conclusions (Conclusions)

- The incorporation of RAS in HMA:
  - Increased the Indirect Tensile Strength versus Control
  - Reduced Permanent Deformation based on testing with Georgia Loaded Wheel Tester

Conclusions (Continued)

- The fiber that is contained in the RAS can be beneficial for open grade mixes (SMA)
- Drain- down studies performed showed:
  - The RAS modified binder showed less drain-down than control, SBS modified and TLA mixes.
  - The fibers do assist in reducing the drain-down

Discussion!