TEST & EVALUATION REPORT

Shingle Rejuvenator Benchmark Life-Cycle Study

May 18, 2023

Report For: Greener Shingles Rejuvenator
Saskatchewan, Canada

Email: info@greenershinglesrejuvenator.com

Sample Data/Information:

SAMPLE ID	GRADE/TYPE	DATE SAMPLED	DATE RECEIVED	SOURCE
Aged Asphalt Shingles	Architectural – Post Consumer	*Note 1	9/15/22	Roofing Contractor
Shingle Rejuvenator	Greener Shingles	9/2022		
Shingle Rejuvenator	Competition	9/2022		

***Shingles removed from a home in Crystal River, FL approximately 14 years after installation**

OBJECTIVES:

Conduct a Benchmark Life-Cycle Study of two rejuvenators utilizing aged asphalt shingles that were removed from a home after approximately 14 years of exposure in Crystal River, Florida. Determine the estimated contribution to the shingles life-cycle made by both rejuvenators and quantify the differences.

The study used a miniature steep sloped roof, constructed at PRI made with commonly used stock material (2X4's, plywood, peel-n-stick underlayment, and stainless-steel roofing nails). Both slopes were roofed with the aged shingles, with one side being treated with Greener Shingles rejuvenator and the other side being treated with a competitive rejuvenator. Both were applied according their manufacturer's recommendations. See appendix for photos and details of construction

The miniature roof was weathered according to ASTM D4798 – "Standard Practice for Accelerated Weathering Test Conditions and Procedures for Bituminous Materials" using a modified exposure cycle consisting of, 51 minutes of light only and 9 minutes of light with rain. Studies have shown that 3000 Hours of APWS aging can be correlated to 10 years of normal outdoor exposure.

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CONCLUSIONS: Primary Property Assessment

- **Mass Loss**: Mass loss in asphalt shingles is due to both the oxidative aging of the binder and granular loss during the accelerated weathering process.
  - After 1,500 hours of exposure the mass loss of the competitive rejuvenator was 2.8% compared to 0.5% for the Greener Shingles' rejuvenator.
    - ***Greener Shingles Rejuvenator performs 5.6 times better than the competition.***
  - After 3,000 hours of exposure the competitive rejuvenator was 3.8% compared to 1.0% for the Greener Shingles' rejuvenator.
    - ***Greener Shingles Rejuvenator performs 3.8 times better than the competition.***

- **Wash off Material**: The exposure cycles consistently contained particulate material and shingle granules that were washed off by the accelerated weathering process.
  - After 1,500 hours of exposure the mass of the collected particulate from the competitive rejuvenator was 1.78g compared to 0.70g for the Greener Shingles' rejuvenator.
    - ***Greener Shingles Rejuvenator performs 2.5 times better than the competition.***
  - After 3,000 hours of exposure the mass of the collected particulate from the competitive rejuvenator was 9.86g compared to 3.94g for the Greener Shingles' rejuvenator.
    - ***Greener Shingles Rejuvenator performs 2.5 times better than the competition.***

- **Oxidative Aging** **(Measured by Carbonyl Indices)**: Oxidative aging in asphalt-based products can be quantified by a peak in a specific position on an FT-IR spectrum (See Appendix B-1 through B-7).
  - After 1,500 hours of exposure the competitive rejuvenator exhibited a 22.8% increase in carbonyl index, compared to Greener Shingle's 7.8% increase.
    - ***Greener Shingles Rejuvenator performs 2.9 times better than the competition.***
  - After 3,000 hours of exposure the competitive rejuvenator exhibited a 49.5% increase in carbonyl index, compared to Greener Shingle's 9.6% increase.
    - ***Greener Shingles Rejuvenator performs 5.2 times better than the competition.***

- **Shingle Flexibility**: After 1,500 and 3,000 hours of exposure, both rejuvenators improved low temperature flexibility from -22°F (pre-treatment) to -31°F post rejuvenator applications

- **Shingle Color and Appearance:** After 3,000 hours of exposure, both rejuvenators resulted in shingles that have similar appearances and colors.

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DATA / RESULTS:

PROPERTIES	TEST METHODS	RESULTS, EXPOSURE HOURS			
		Untreated, 0 Hours	Treated, 0 Hours	Treated, 1,500	Treated, 3,000
Properties of Shingles Treated with Competitive Rejuvenator					
Visual Inspection of shingles (Photos)	PRI	See Appendix			
Weight of 5"x10" Sample, g	D751	147.8	137.7	133.8	132.41
Mass Change, % (Note 2)		---	---	-2.8	-3.8
Low Temperature Flexibility, °F (Note 3)	D5147-12	-22	-31	-31	-31
Carbonyl Index	E7214	0.95	1.01	1.24	1.51
Increase in Carbonyl Index from 0 Hours, %	Calculation	N/A	N/A	22.77	49.50
Material Lost during Exposure Cycles, g (Note 4)	PRI	N/A	N/A	1.78	9.86
Properties of Shingles Treated with Greener Shingles Rejuvenator					
Visual Inspection of shingles (Photos)	PRI	See Appendix			
Weight of 5"x10" Sample, g	D751	147.8	146.4	145.7	145.0
Mass Change, % (Note 2)		---	---	-0.5	-1.0
Low Temperature Flexibility, °F (Note 3)	D5147-12	-22	-31	-31	-31
Carbonyl Index	E7214	0.95	1.67	1.80	1.83
Increase in Carbonyl Index from 0 Hours, %	Calculation	N/A	N/A	7.78	9.58
Material Lost during Exposure Cycles, g (Note 4)	PRI	N/A	N/A	0.70	3.94

Note 2 – Mass Change is calculated from the mass loss of a representative 5"x10" representative sample of shingle taken at each inspection interval, mass loss is expected with aging, lower mass loss is desirable.

Note 3 – Low temperature flexibility is the lowest temperature at which the shingle remains flexible – lower temperatures are more desirable.

Note 4 – Loss during exposure was measured by collecting granules and particulate matter from the collection system attached to the APWS weatherometer (See Appendix X-1 for collection apparatus & sample photos).

Note 5 – Untreated samples were not exposed to additional aging in the APWS.

DISCUSSION:

Although both rejuvenators exhibited efficacy via improving granule adhesion and shingle flexibility, Greener Shingles rejuvenator exhibited better overall comparative life-cycle properties. Based on the primary data Greener Shingle's reduced oxidative aging (Carbonyl Index), and mass loss suggest the life-cycle of Greener Shingle's rejuvenation would be greater than the competitors.

- *Carbonyl Index Note: when initially treated an increase in Carbonyl Index results this is due to the addition of bio-based oils (rejuvenators) that give an FT-IR response in the same peak area as the oxidative aging.*

Tested by: _____ Date: May 18, 2023
Greg Lavin, Laboratory Technician

Reported by: _____ Date: May 18, 2023
Steven Loeffler, Client Services Manager

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APPENDIX

APPENDIX A-5 (Roof Deck Construction):

Step 4 – Ridge Cap Installation:

Completed Roof Deck Before Rejuvenator Application

DISCUSSION:

A type of common, commercially used ridge-cap shingles were then cut and applies to the cap of the roof deck. The cap was selected for the closest visual match to the shingles used.

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APPENDIX A-6 (Roof Deck Construction):

Step 5 – Application of Rejuvenators:

REJUVENATOR APPLICATION DATA:

PROPERTY	TEST METHODS	RESULTS, SAMPLE ID	
		Competitive	Greener Shingles
Rejuvenator Application Data			
Dilution Rate, (%Water : %Product)	PRI Measurements	50:50	70:30
Volume Applied, mL		266	266
Weight Applied, g		263.6	257.1
Specific Gravity of Diluted Product	ASTM D70	0.9920	0.9674
Calculated Application Rate, gal/ft^2	Calculation	0.0099	0.0099

DISCUSSION:

Both rejuvenators were prepared and applied according to manufacturer guidelines using common garden spray bottles and allowed to cure for 24 hours:

- Competitive rejuvenator – A mixture of 50% water and 50% Rejuvenator concentrate stirred by hand to homogeneity
- Greener Shingles rejuvenator – A mixture of 70% water and 30% Rejuvenator concentrate stirred by hand to homogeneity
- Both diluted products were applied to their respective side of the roof deck at a target rate of 1 gallon per 100ft^2 using simple spray bottles.

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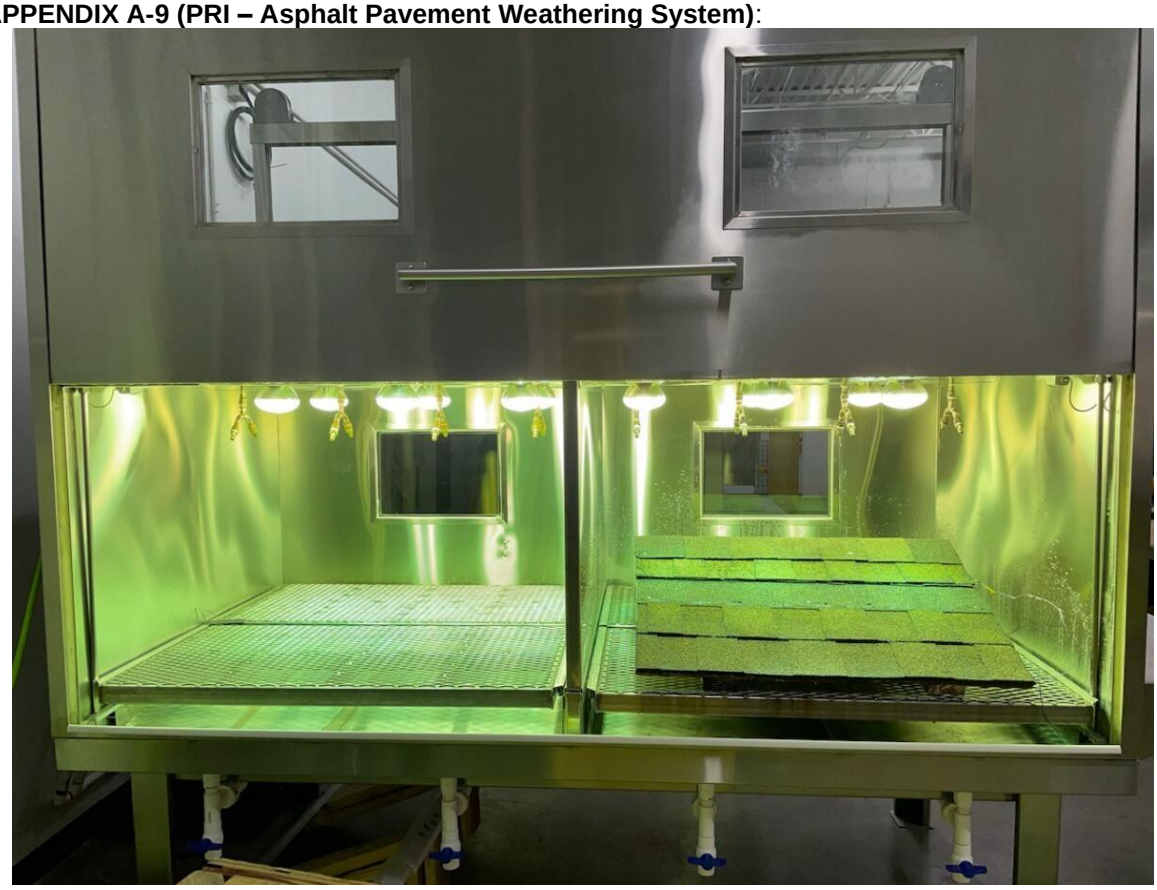
APPENDIX A-9 (PRI – Asphalt Pavement Weathering System):



DISCUSSION:

An open view of PRI's Asphalt Pavement Weathering System with the roof deck positioned in the front chamber (right).

PRI's APWS was used for accelerated weathering of the roof deck after the application and curing of the rejuvenators. The weatherometer is monitored daily for even light distribution and water spray coverage, while temperature of the chamber, roof surface, water, ambient temperature and relative humidity are all tracked continuously.

ACCELERATED AGING PARAMETERS:

PARAMETER	SETTING
APWS Cycle and Climate Information	
Cycle Reference Method	ASTM D4798, Cycle A
Time of UV Light Exposure, mins	51
Time of UV Exposure with Rain Cycle, mins	9
Average Maximum Shingle Temperature, °F (Note 1)	149.5
Average "Rain Rate", gal/hr	12.6

Note 1 – Average Maximum Shingle Temperature is measured by taking the average of the temperature readings immediately before the beginning of the "rain cycle" when the temperature is at its highest level.

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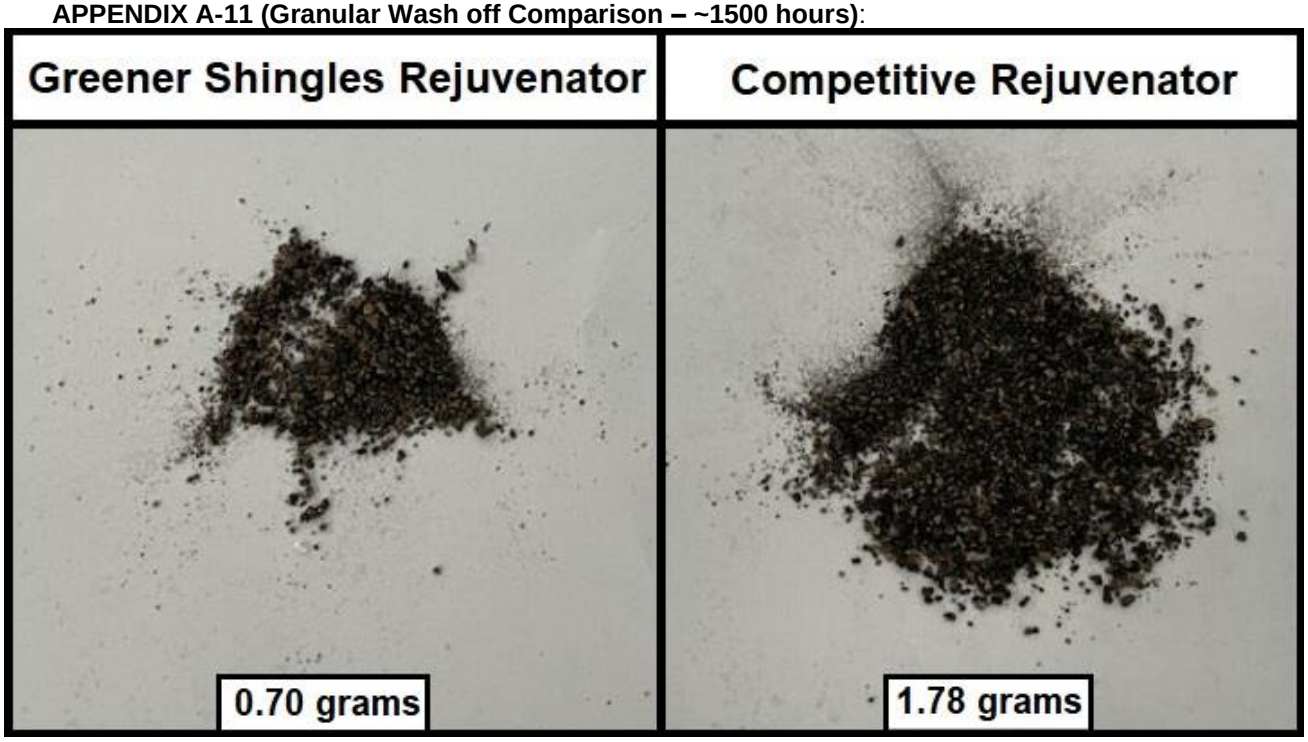
APPENDIX A-11 (Granular Wash off Comparison – ~1500 hours):



DISCUSSION:

Granules and particulate washed from the roof decks after 1500 hours of exposure. Particles have been filtered from the accompanying runoff water and dried for quantification.

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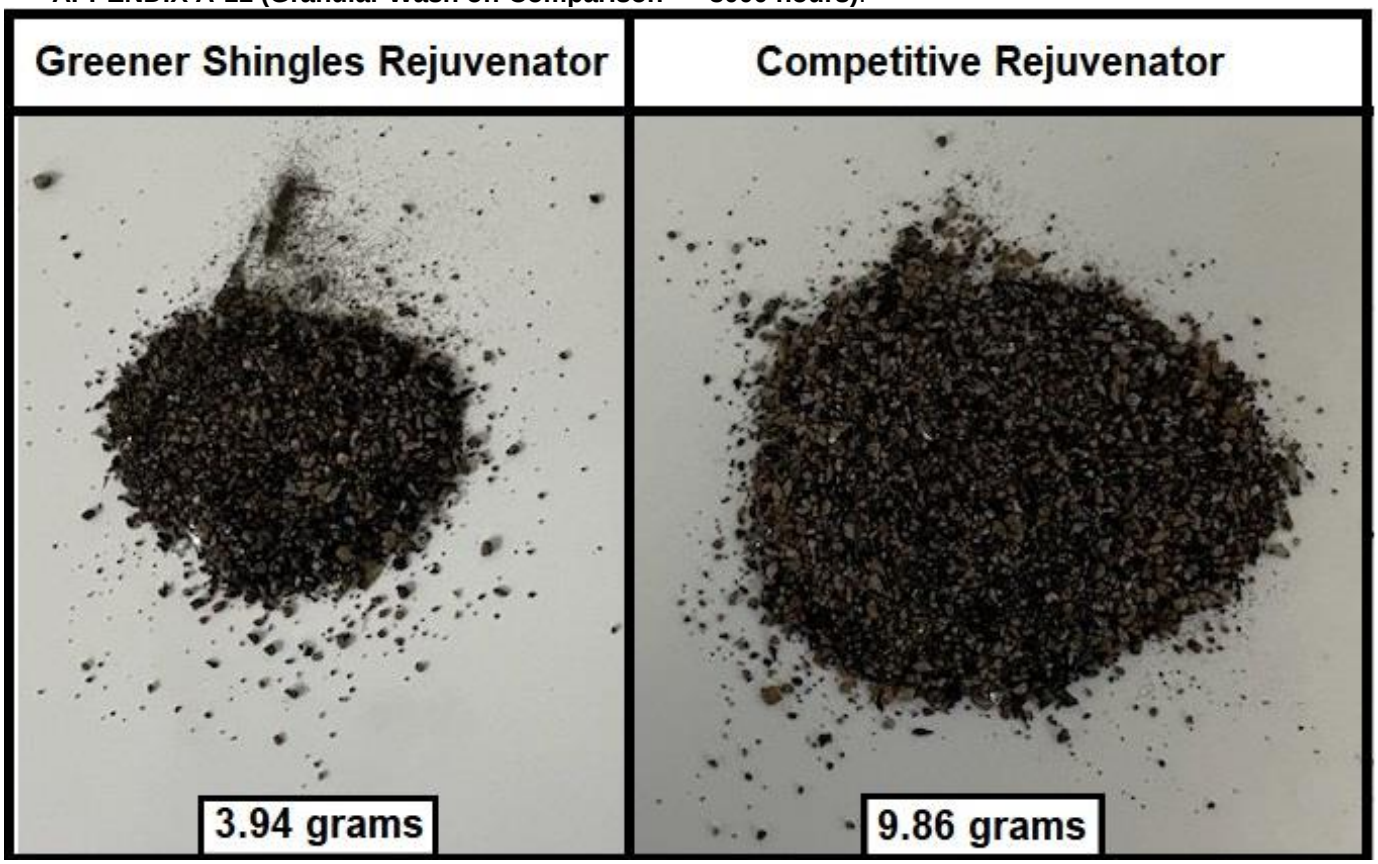
APPENDIX

APPENDIX A-11 (Granular Wash off Comparison – ~3000 hours):



DISCUSSION:

Granules and particulate washed from the roof decks after 3000 hours of exposure. Particles have been filtered from the accompanying runoff water and dried for quantification.

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