March 11, 2020

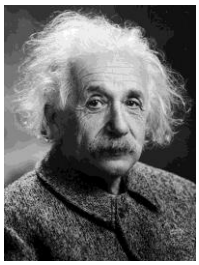
UNDERSTANDING THE USE OF REJUVENATORS

Presented by:
Grant Wollenhaupt

Benchmarking

Let's set some realistic expectations here

Less Like



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More Like

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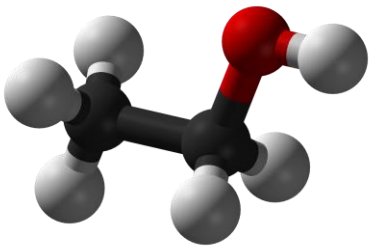
Objective

THE BASICS or ENOUGH TO ASK QUESTIONS

Oil

Back to Basics

Oil



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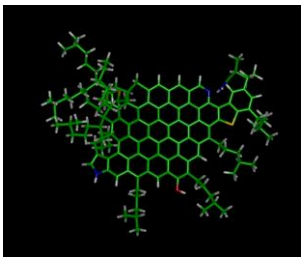
Oil



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Oil

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Dead Dinosaur Advice

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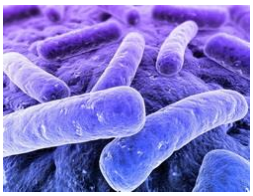

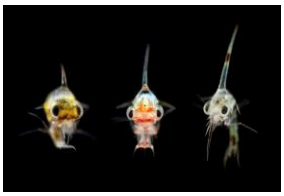

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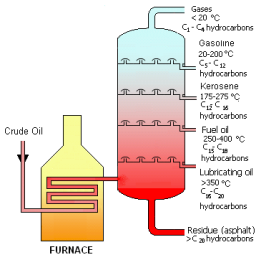
Oil



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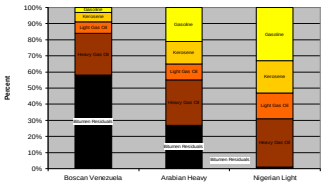
Asphalt Binder Yield From Crude Sources (Not All Binders are Same, Binder Aging Will Vary)

Percent Asphalt Binder Content (Residual) versus Crude Sources

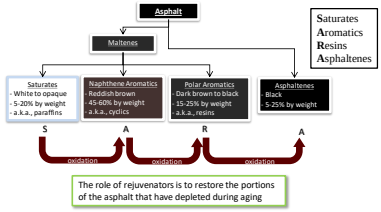
Source	Residual
Boscan, Venezuela	58
Ca Valley, Kern River	66
Ca Costal, Hondo	48
Alaskan, North Slope	31
Arabian, Heavy	27
Nigeria, Light	1

Fractional Product Yield from Crude Sources

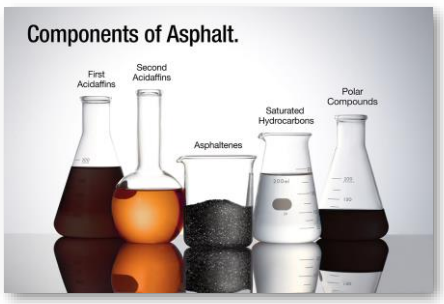


Asphalt Chemistry Basics

ASTM D 4124 Corbett separation method (SARA analysis)



The role of rejuvenators is to restore the portions of the asphalt that have depleted during aging



http://www.tricorrefining.com/cyclogen.php

Why Use Rejuvenators?

Basics of Asphalt Binder Aging – Short Term

- **Short Term**
  - Environment
    - Mixing, silo storage, transportation and laying processes due to exposure to high temperatures
  - Causes
    - Oxidation of the thin binder film in oxygen rich environments
    - Evaporation of low molecular weight volatile fractions (volatilization)
    - Absorption of oily constituents, resins and asphaltenes by aggregates.

From: Zaumanis et. al., Evaluation of different recycling agents for restoring aged asphalt binder and performance of 100 % recycled asphalt, RILEM 2014

Basics of Asphalt Binder Aging - Long Term

- **Long Term**
  - Environment
    - In service within pavement
    - Aging increased closer to surface
  - Causes
    - Oxidation because of constant supply of fresh air
    - Polymerization (i.e., formation of monomer chains)
    - Photo-oxidation (i.e., UV light) for surface layers
    - Thixotropy (i.e., steric hardening) due to the formulation of a structure within asphalt binder over a long period
      - Occurs with pavements with little to no traffic (e.g., left turn only lanes).

From: Zaumanis et. al., Evaluation of different recycling agents for restoring aged asphalt binder and performance of 100 % recycled asphalt, RILEM 2014

Binder Composition Change During Aging

- What Happens to Binder During Aging (Oxidation)?
  - Asphalt is comprised of 1) asphaltenes and 2) maltenes
    - Asphaltenes
      - (Viscosity building blocks, provide **stiffness** to binder)
    - Maltenes
      - (Disperses the asphaltenes, provide **flexibility** to binder)
        - Resins
          - Turns to asphaltenes after oxidation
        - Oils
          - Turns to asphaltenes and resins after oxidation
  - **Result:**
    - As binder ages 1) the ratio of asphaltenes to maltenes increases, 2) asphaltenes flocculation increases, 3) and the binder stiffness increases.

We May Have a Problem

T5RC with 20% RAP	PG78-20
T5RC with 27%RAP/3% RAS	PG90-12

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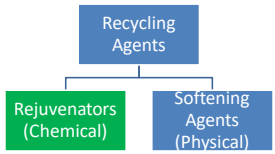
Recycling Agents



- **Softening Agents**
  - Asphalt flux oils (generally blended with bitumen to reduce the viscosity).
  - Lube stock (a fraction of crude oil that has a viscosity similar to lube oils).
  - Lubricating or crack case oil (usually highly aliphatic).
  - Slurry oil (bottoms from the catalytic cracking process).

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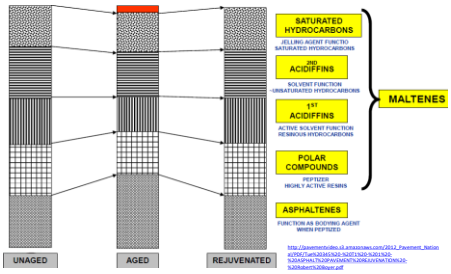
Rejuvenator vs Recycling Agent – The Differences

Rejuvenator	Softening Agent)
Improve the low temperature PG grade and increase crack resistance in the HMA	Also capable of reducing the viscosity and improving the low temperature properties of the high RAP binder.
Improve workability/compaction of the RAP mix design	
Restore the aromatic resins to the high RAP asphalt binder that were lost due to oxidative field aging	A recycling agent does not add the aromatic resins to balance the properties of the high RAP binder and repair the oxidative aging
Do not cause continuous age softening of the RAP asphalt binder which could lead to increased rutting potential	Without the aromaticity restored, the high RAP mix design will exhibit premature rutting due to continued age softening of the RAP binder
Increase aromatic resins lost during oxidation	
Reduce the high temperature Performance Grade (PG)	

http://www.hollyfrontierlsp.com/SiteData/docs/Rejuvenati/b4e52dae2716a2159/Rejuvenation%20vs%20Recycling_0811.pdf

Asphalt Binder – Unaged / Aged / Rejuvenated



Types of Rejuvenators

- Aromatic Oils
- Fuels
- Tall
- Bio-based
- Pig Sh*T
- Waste Products
- REOB

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Evaluation

What to Look For

- Safety
  - Environmental
- Ease of Use
- Performance
- Cost

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Your Nose Knows

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Nobody Likes Melting

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Devastatingly Deadly to Aquatic Life

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Rejuvenator Dosage Types

- Percent of the following:
  - Recycle
  - Recycled binder
  - Virgin binder
  - Total binder
  - Total mix
- How do they compare?
- Different dosage types can cause confusion!

Dosage Type Comparison - Rejuvenator Economic Analysis Tool

Rejuvenator Dosage Type Cost Comparison	
Parameter	*Value*
RAP, %	40.0
Binder in RAP, %	5.0
Mix RAP Binder, %	2.0
Total Binder, %	5.0
Virgin Binder, %	3.0
Chosen Dosage Type	%VirginBinder
Dosage (%) for Chosen Dosage Type	6.00
Rejuvenator lb / Mix Ton	3.60
Cost per Rejuvenator per lb	$ 1.00
Rejuvenator Cost per Mix Ton	$ 3.60
Dosage Types	*Dosage Rate Equiv. %*
%RAPMass	0.45
%MixRAPBinder	9.00
%VirginBinder	6.00
%TotalBinder	3.60
%TotalMix	0.18

INSTRUCTIONS

Spreadsheet is designed to calculate the rejuvenator cost per ton based on the user inputs (yellow fill) of the following
1. RAP, % (RAP as a % of the total mix)
2. Binder in RAP, %
3. Total Binder, %
4. Chosen Dosage Type Options:
- Added as a percent of RAP mass = **%RAPMass**
- Added as a percent of the Mix RAP Binder mass or binder contribution in mix from RAP = **%MixRAPBinder**
- Added as a percent of the mix virgin binder mass = **%VirginBinder**
- Added as a percent of the mix total binder mass = **%TotalBinder**
- Added as a percent of the mix total mass = **%TotalMix**
5. Rejuvenator cost per lb.

Spreadsheet calculates the cost per ton for the chosen dosage type and also provides the equivalent dosage rate for the other dosage type options for reference.

How to Get the Sauce on the Rocks

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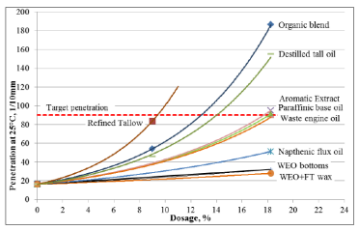
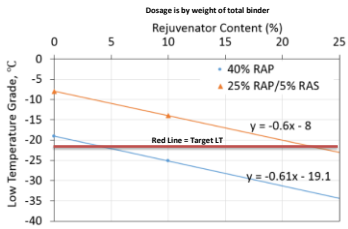
Dosage Determination by Target Penetration

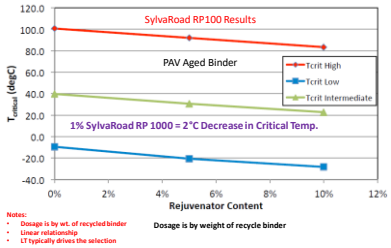


From: Zaumanis et. al., Evaluation of different recycling agents for restoring aged asphalt binder and performance of 100 % recycled asphalt, RILEM 2014

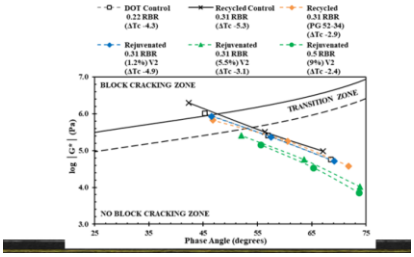
Dosage Determination by Target PG Low Temperature



Dosage Determination by Target PG Low, Int., High Temperature



G-R Black Space (WI PG 58-28, PG 52-34)



Source: Use of Rejuvenators in HMA, TRB Session 1176, 2020, Amy Epps Martin

You Have to Start Somewhere

	orig	RTFO	PAV	RTFO Effect	PAV Effect	Total Age Effect
Virgin 64-22 8-30-12	-30.39	-29.52	-24.86	3%	16%	18%
Virgin w/ 5% Product A	-34.24	-32.41	-29.11	5%	10%	15%
Virgin w/ 8% Product A	-36.23	-35.01	-31.51	3%	10%	13%
Virgin w/ 10% Product A	-38.32	-36.17	-32.41	6%	10%	15%
Virgin w/ 5% Product B	-34.90	-33.22	-30.11	5%	9%	14%
Virgin w/ 8% Product B	-37.10	-35.31	-32.68	5%	7%	12%
Virgin w/ 10% Product B	-39.12	-36.79	-34.76	6%	6%	11%
Virgin w/ 5% Product C	-36.69	-34.54	-31.89	6%	8%	13%
Virgin w/ 8% Product C	-40.73	-36.92	-34.77	9%	6%	15%
Virgin w/ 10% Product C	-45.29	-37.85	-35.91	16%	5%	21%

Don't Call in a Comeback

T5RC with 0% RAP PG78-20
T5RC with 27%RAP/3% RAS PG90-12

Add Rejuvenator

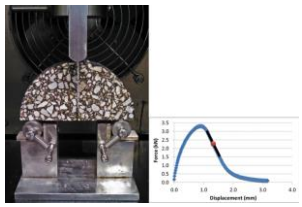
T5RC WITH 27%RAP/3% RAS PG75-23
T5RC WITH 25%RAP/5% RAS PG81-22

Performance Testing

All for Naught Without a Proper Baseline

Hamburg

Illinois Flexibility Index Test IFIT



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Disc-Shaped Compact Tension Test DCT(T)

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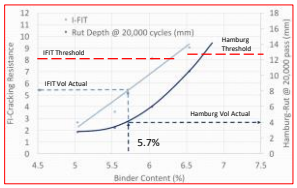
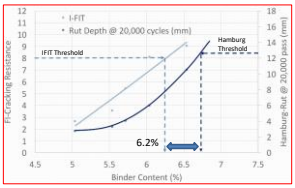
Volumetric Mix Design vs Balanced Mix Design (Example)

VOLUMETRIC



BALANCED



Note: Example for Illustration Purposes.

Source: NCAT Balanced Mix Design Training Course

	Mix	TS 40 -1	TS 40 -2	TS 60 -1	TS 60 -2
Design	Virgin AC Grade	PG 52-34	PG 52-34	PG 58-28	PG 58-28
	FRAP, %	40	40	60	60
Volumetrics	Targeted Total AC, %	4.8	4.8	4.8	4.8
	As Measured Total AC, %	4.6	4.7	4.6	4.4
	Added AC, %	2.7	2.7	1.7	1.7
	Binder Replacement, %	44%	44%	65%	65%
	Additive, %	0.0	0.0	0.2	0.2
	Air Voids, %	2.7	4.4	2.0	2.4
Performance Testing	TSR	N/A	91.3	N/A	99.2
	SIP, # passes	11,691	19,894	11,840	9,321
	Rut depth @10,000 passes, mm	7.1	3.3	6.0	7.6
	SCB Fl	4.4	1.6	2.7	3.2
	DCT Energy, J/m²	347	324	446	386
	Continuous PG	72.1-26.1	69.2-28.0	70.8-27.3	70.8-29.3
	Delta Tc, °C	-6.6	-5.3	-2.8	-2.0

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Obligatory Data Page

	Mix Type				
	190 C	125 SMA I-435	095 SMA I-435	TS City Overlay 40R	TS City Overlay 60R
Virgin AC PG	64-22	64V-22 GTR	64V-22 GTR	52-34	58-28
Virgin AC %	3.50%	6.50%	6.00%	2.60%	1.50%
Additive %	0.00%	0.00%	0.00%	0.00%	0.20%
Recycle AC %	1.50%	0.00%	0.00%	2.00%	2.90%
Total AC %	5.00%	6.50%	6.00%	4.60%	4.60%
Air Voids	3.00%	4.80%	4.80%	2.70%	2.00%
Rut Depth (mm)	3.19	4.13	6.88	12	10
Stripping Inflection	NA	17,761	11,271	10,211	9,086
Passes	20,000	20,000	20,000	12,662	16,112
Flexibility Index	< 1	10	3	3	3
DCT (J/m2)	320	714	626	347	446
Continuous Grade	NA	NA	NA	72.1-26.1	70.8-27.3

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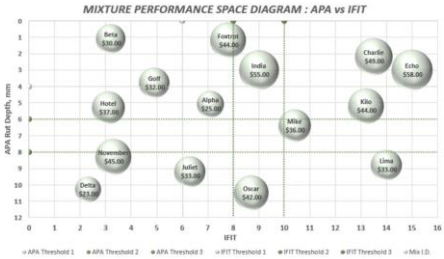

Rejuvenator Economics (Per Ton Basis)

1. Raw cost of rejuvenator product
2. Dosage required (must compare on same baseline)
3. Additional equipment cost for addition
4. Recycle used (relative to control)
5. Additional benefits from rejuvenator (e.g., WMA, anti-strip, etc.)

Summary

1. Rejuvenators can potentially provide a more crack resistance mixture while maintaining the rut resistance of the mixture.
2. Rejuvenator use should be evaluated via laboratory performance testing to help establish optimum dosage and performance characteristics.
3. Decision to utilize rejuvenators should be based on the anticipated benefit (e.g., performance gains) versus the cost associated with the rejuvenator use.

Resources

- AAPT
- NCAT
- NAPA, APA, SAPAs
- NCHRP 09-58 Effects of Recycling Agents…..
- NCHRP 20-07/Task 406 Balanced Mix Design
- Manchester Pavement Solutions

Contact

Grant Wollenhaupt
Chief Commercial Officer
XBE
Grant-Wollenhaupt@x-b-e.com

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