TEXAS DEPARTMENT OF TRANSPORTATION




IMPACTS OF MIX REJUVENATORS ON PERFORMANCE

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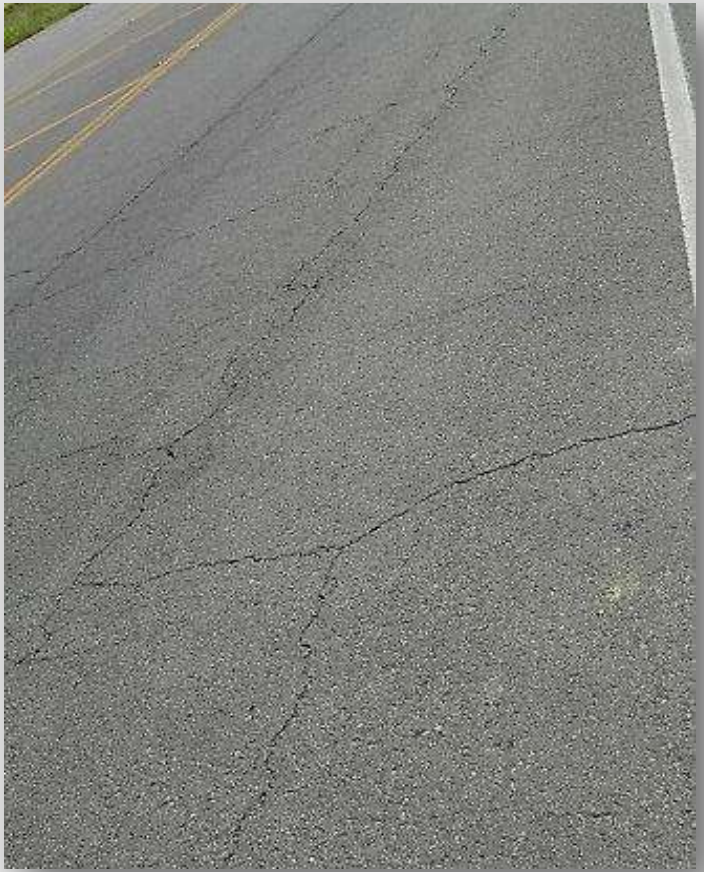
Asphalt Paving 42nd Annual Conference

Table of Contents

The Problem is…

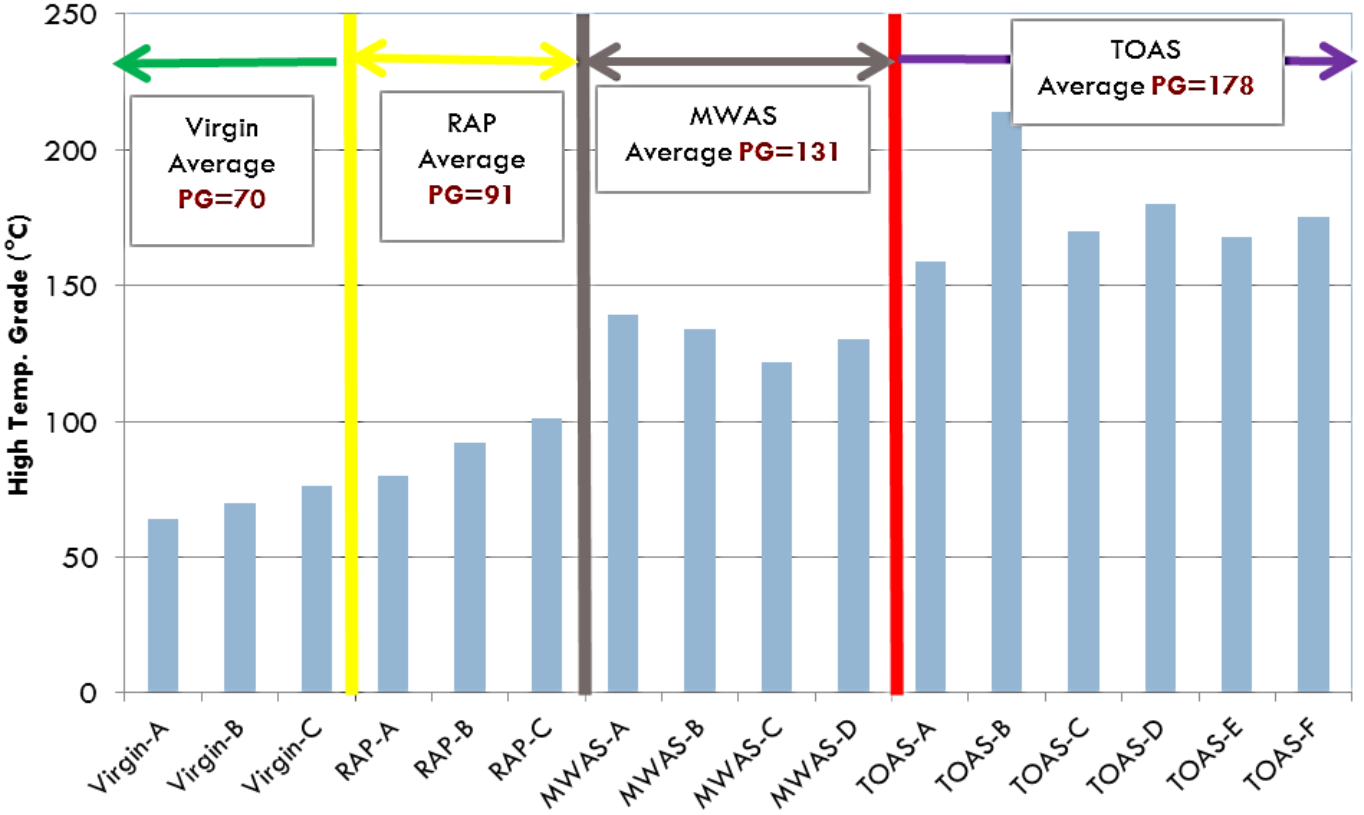
- Cracking
  - Although there are many causes…traffic conditions, pavement structure, poor drainage, climate
  - Focus is on how recycled materials are used
    - Reclaimed asphalt pavement (RAP)
    - Recycled asphalt shingles (RAS)



RAP and RAS

- Benefits
  - Economics
  - Reduced rutting
  - Environment
  - Source of aggregate
- Disadvantages
  - Stiffens mix
  - Dry mixtures
  - Mixes may be more prone to cracking

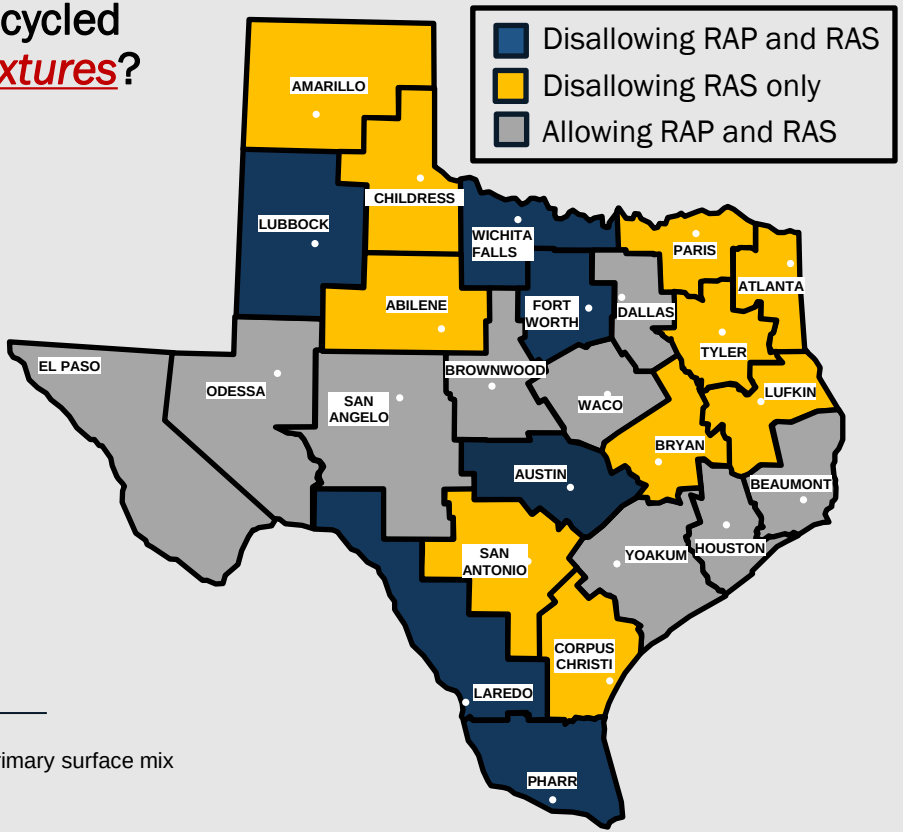
RAP and RAS PG Grade Determination



Courtesy of Fujie Zhou, TTI

Recycled Materials Usage Statewide

- What is the latest on recycled materials in *surface mixtures*?
  - No recycle
    - 6 districts
  - No RAS
    - 16 districts
      - Additional 2 districts without RAS producers, 1 only 1 contractor uses
  - Allow RAP
    - 19 districts
  - Allow RAP and RAS
    - 9 districts



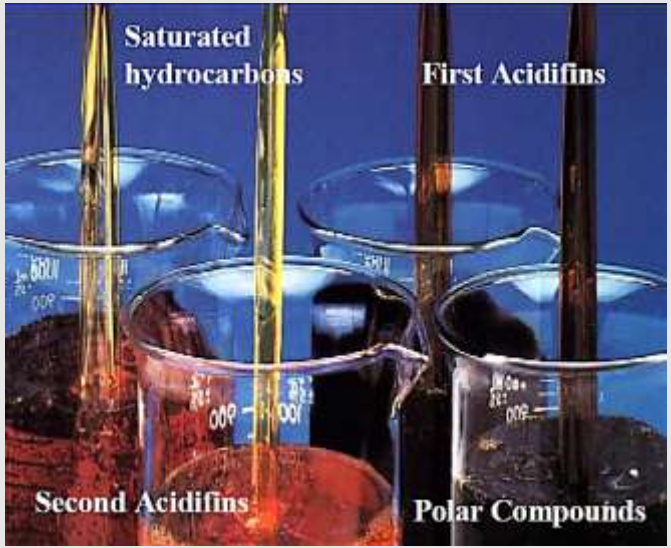
Notes:
LBB does not allow RAP in SMA which is their primary surface mix
YKM most producers don't use RAS
ELP no RAS producers
ODA no RAS producers

Methods to Address Cracking

- Limit the quantity of RAP/RAS
  - Maximum recycled binder ratio
- Discount the effective asphalt content of RAP/RAS
  - TxDOT currently uses 100% effective for designing with RAP and RAS
- Use Superpave mix design procedure to allow more asphalt
  - TxDOT shift is towards using Superpave gyratory compactor
- Use softer virgin binders
  - PG 58-28
  - Consider lower temperature grade binders (e.g. PG XX-28, PG XX-34)
- Use a balanced mix design approach
  - Overlay test (cracking)
  - Hamburg wheel tracking test (rutting)
- Add rejuvenators to the mix

Rejuvenator Types

- Bio-based
  - Arizona Chemical, Green Asphalt Technologies, Ingevity, Cargil, Collabortive Aggregates, Sonneborn, Roadscience
- Aromatic extracts
  - HollyFrontier, Reclamite
- Re-refined waste materials
  - Re-refined engine oil bottoms (REOB)
  - Re-refined waste fast food vegetable oil

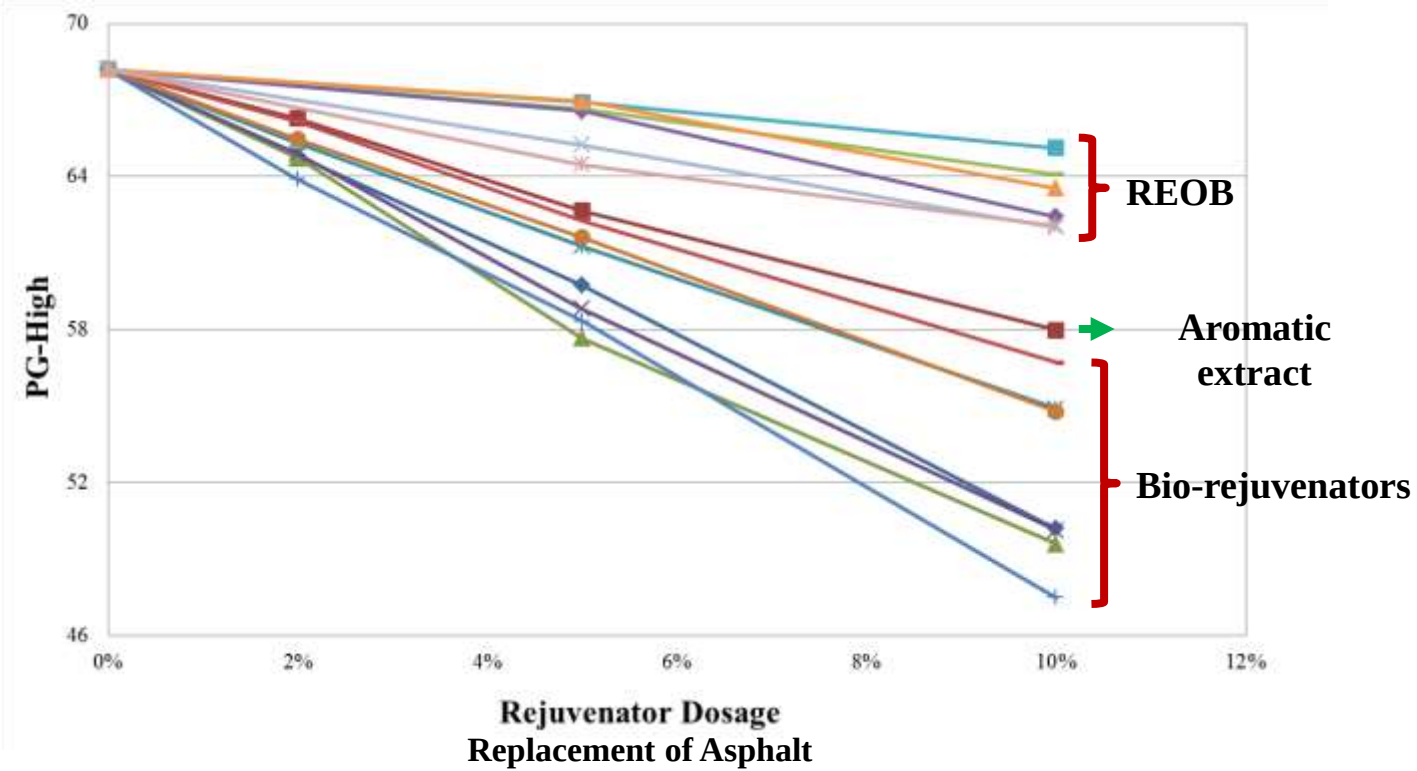


Rejuvenator Function

- Asphalt composition
  - Asphaltenes (insoluble, brittle, not affected by oxidation)
  - Maltenes (oily, flexible, affected by oxidation)
  - *Aging* unbalances the ratio of asphaltenes to maltenes
- Role of *rejuvenators*
  - Re-balance the ratio of asphaltenes to maltenes
  - Rheological effect:
    - Lowers high temp. PG grade (DSR)
    - Softens aged binders (BBR creep stiffness, S)
    - Improves relaxation (BBR m-value)

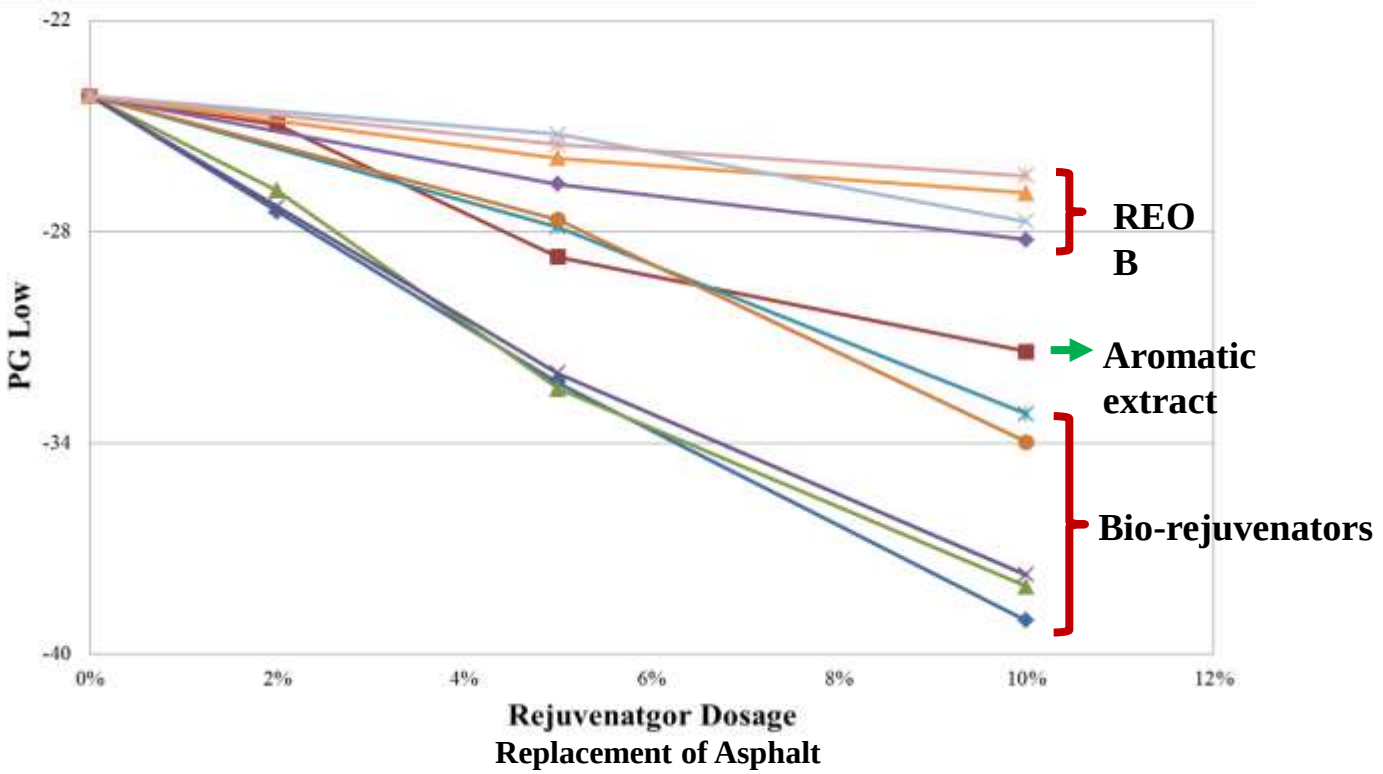
Rejuvenator Effectiveness

- Virgin Binder PG 64-22

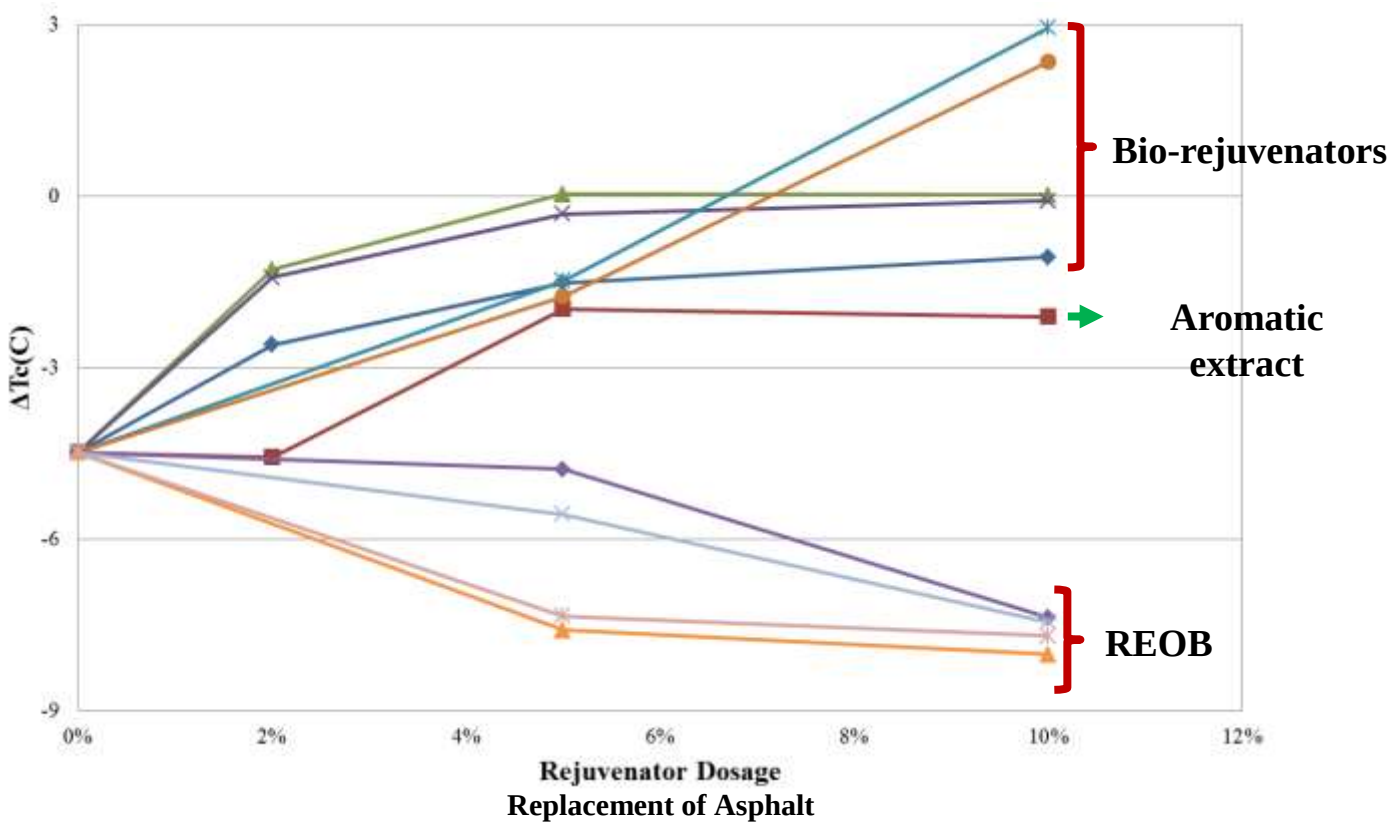


Rejuvenator Effectiveness

- Virgin Binder PG 64-22

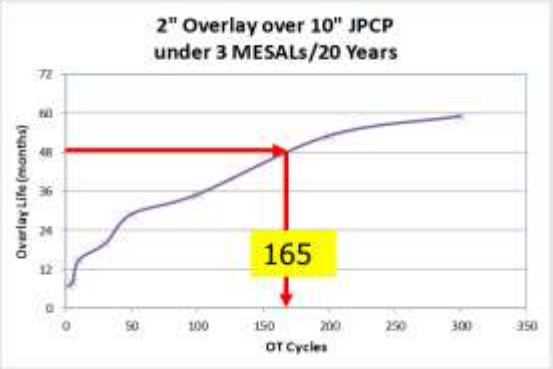


Bio-Based, Aromatic Extract, and REOB vs. ΔTc



Four Step Design Process

- Step 1 – Select rejuvenator
- Step 2 – Select rejuvenator dosage range (binder testing)
- Step 3 – Obtain balanced mix design data (mix testing)
- Step 4 – Select dosage based on engineering judgement



Step 1 – Select Rejuvenator

- Arizona Chemical/Kraton
- Manchester Pavement Solutions
- Ingevity
- Cargill
- Collabortive Aggregates
- Sonneborn
- Roadscience
- Texas Road Recyclers
- HollyFrontier
- Reclamite

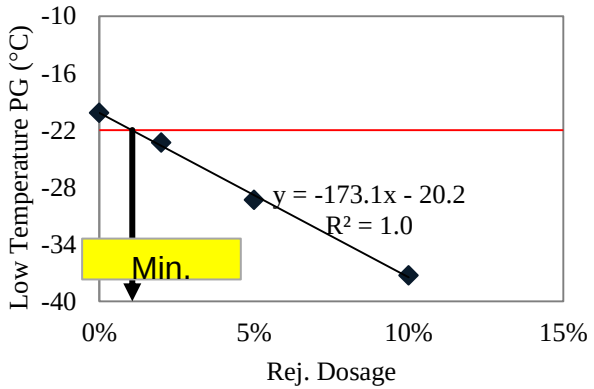
Step 2 – Select Rejuvenator Dosage Range

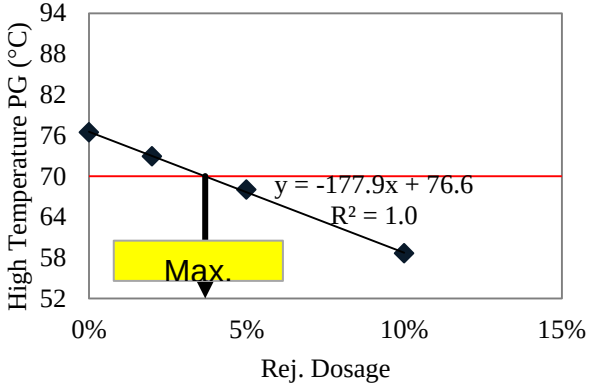
- Three aspects:
  - Rheological properties:
    - PG high grade requirement
    - PG low grade requirement
  - Binder quality requirement
    - ΔTc requirement
  - Aging characteristics of the blended binder
    - Similar (or even better) aging characteristics of virgin binder

- Example: FM468
  - A new construction in Laredo District, Texas;
  - Very heavy oil truck traffic
  - Hot weather all year long

Step 2 – Select Rejuvenator Dosage Range

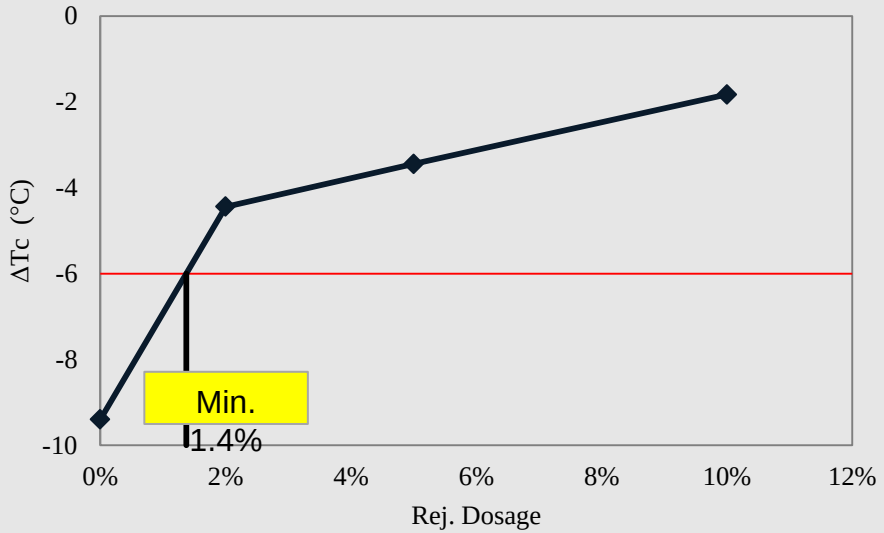
- Example : Original Binder Specified = PG 70-22
- Proposed: 30% RAP (PG 94 -10) and PG 64-22
  - Extract and combine asphalt from RAP with virgin binder at proposed binder ratios according to the mix design
- Add rejuvenator until DSR high temperature grade and BBR low temperature grade match original specified binder: PG 70-22
  - Dosage range = 1.1% – 3.7%





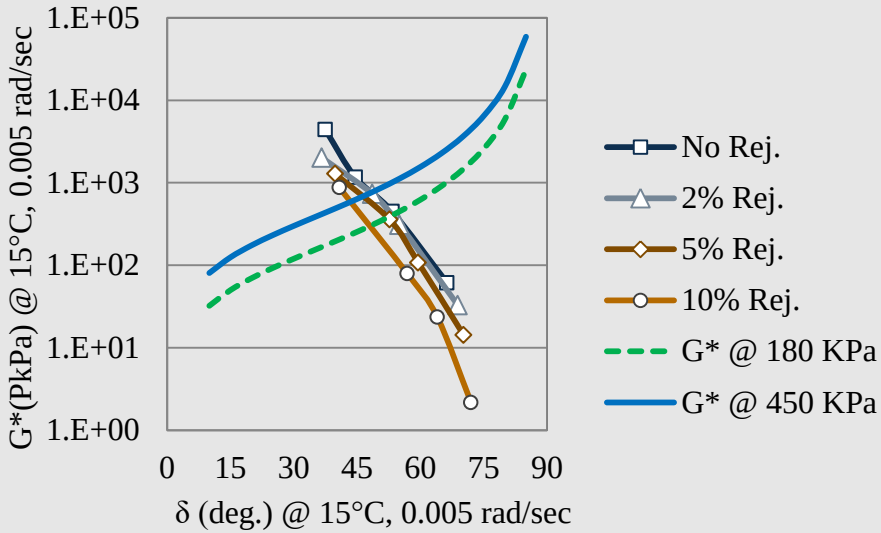
Step 2 – Select Rejuvenator Dosage Range

- Binder quality requirement: $\Delta Tc \geq -6°C$
  - Minimum rejuvenator dosage: 1.4%



Step 2 – Select Rejuvenator Dosage Range

- Check aging characteristics
  - Glover-Rowe parameter
  - Goal is to match aging characteristics of virgin binder



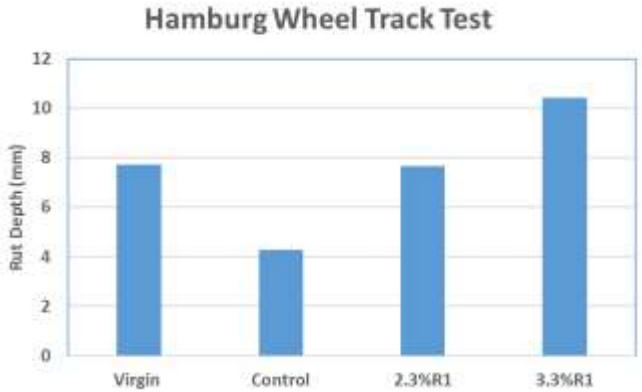
Step 2 – Select Rejuvenator Dosage Range

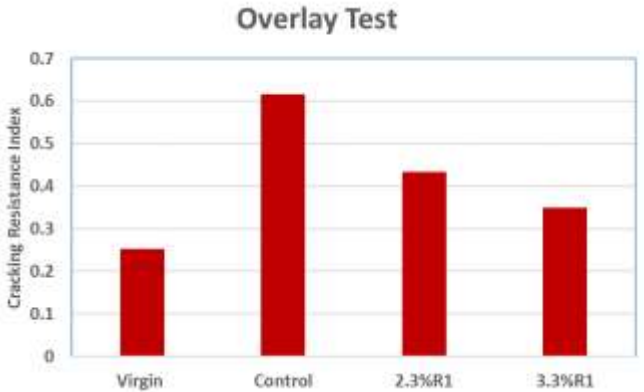
- Summary table for rejuvenator dosage range: binder testing
  - R1: 1.8-3.7%
  - R2: 1.7-4.8%
  - R3: 2.6-3.6%

Blend	Rejuvenator	Maximum	Minimum				
		PG High =70	PG Low =-22	ΔTc=-5	Damage Onset for PG70-22	Significant Damage for PG70-22	Overall
70%PG64-22 + 30%PG94-10 RAP	R1	**3.7%**	1.1%	1.4**%**	0.7%	**1.8**%	**1.8%**
	R2	**4.8%**	**1.7%**	1.4%	1.0%	**1.7%**	**1.7%**
	R3	**3.6%**	0.7%	1.6**%**	0.8%	**2.6**%	**2.6%**

Step 3 – Obtain Data from Balanced Mix Design

- Perform Hamburg wheel tracking tests and Overlay tests on mix produced in the laboratory
  - Overlay requirements are determined by Overlay program (TxACOL)
  - New constructions are determined by TxME pavement design
  - Cracking resistance index is project specific (traffic, climate, pavement structure, etc.)





Step 4 – Select Rejuvenator Dosage

- Use data gathered from Steps 1-3 to select rejuvenator dosage
  - Use engineering judgement to decide actual dosage
    - Higher rejuvenator dosage in areas more prone to cracking
    - Lower rejuvenator dosage in areas less prone to cracking
  - Factors include:
    - Traffic conditions
      - Interstate/high traffic levels
        - » May consider lower rejuvenator dosage
      - FM roads with less traffic levels
        - » May consider higher rejuvenator dosage
    - Pavement structure
    - Climate

Test Sections

- Test sections
  - Tyler District, SH31, included 5 test sections, 6/14/2014
  - Laredo District, FM468, included 5 test sections, 9/15/2015
  - Houston District, FM1463, included 4 test sections, 7/16/2016
  - San Angelo, US67, included 5 test sections, 4/12/2017




Tyler District – SH31

- Dense Grade Type C Mix Designs:
  - Virgin mix, PG 70-22, AC = 4.5%
  - 10% RAP, 5% RAS, PG 64-22, AC = 4.6%
  - 10% RAP, 5% RAS, PG 64-22, 2.6% R01, AC = 4.5%
  - 10% RAP, 5% RAS, PG 64-22, 3.7% R02, AC = 4.7%
  - 10% RAP, 5% RAS, PG 64-22, 2.0% R03, AC = 4.9%
- Reflective cracking was observed on all sections
- After 2.5 years, cracking was similar with all sections



Tyler District – SH31

- Lessons learned
  - Dosage of rejuvenators may have been too conservative
  - Two lift overlay was constructed over jointed concrete pavement
    - Crack attenuating mix (CAM) was placed before winter and had previously cracked prior to placing test sections
    - Solution – Construct both sections at the same time

Laredo District – FM468

- Superpave Type C Mix Designs
  - Virgin mix, PG 70-22, AC =6.1%
  - 30% RAP, PG 64-22, AC = 6.3%
  - 30% RAP, PG 64-22, 3.0% R1, total AC = 6.3%
  - 30% RAP, PG 64-22, 3.2% R2, total AC = 6.3% (accidentally removed)
  - 30% RAP, PG 64-22, 2.2% R3, total AC = 6.3%
- No cracking; no visible rutting, although heavy trucks

Oct. 9, 2017

Houston District – FM1463

- Dense Grade Type D Mix Designs
  - 17% RAP, 3% RAS, PG 64-22, AC = 5.2%
  - 17% RAP, 3% RAS, PG 64-22, 3.5% RR1, AC = 5.2%
  - 17% RAP, 3% RAS, PG 64-22, 4.0% RR2, AC = 5.2%
  - 17% RAP, 3% RAS, PG 64-22, 7.5% RR3, AC = 5.2%
- Overall good: No rutting but a few fine longitudinal cracks were spotted on Jan. 8, 2018.

San Angelo District – US67

- Dense Grade Type C Mix Designs
  - 13% RAP, PG 64-22, AC = 5.3%
  - 21% RAP, PG 64-22, AC = 5.3%
  - 21% RAP, PG 64-22, 3.0% RRR1, AC = 5.3%
  - 21% RAP, PG 64-22, 3.0% RRR1, AC = 5.3%
  - 21% RAP, PG 64-22, 11.0% RRR1, AC = 5.3%
- No rutting; no cracking

July 3, 2017

Conclusions

- Rejuvenators have been shown to improve cracking resistance of RAP/RAS mixes in the laboratory
- Use of rejuvenators may impact lab molded density and compaction effort in the field
  - Consider changing lab molded density requirements/decrease number of gyrations
  - Roller patterns will need to be adjusted (less compaction effort)
- Too early to determine their effectiveness in the field
  - No problems were encountered with meeting air void requirements
  - Difficult to know cost savings
    - Performance based (more service life)
    - Will allow use of more recycled materials
- Continuation of monitoring field test sections is needed

Questions

SUPERIOR BOWEN

March 12, 2018

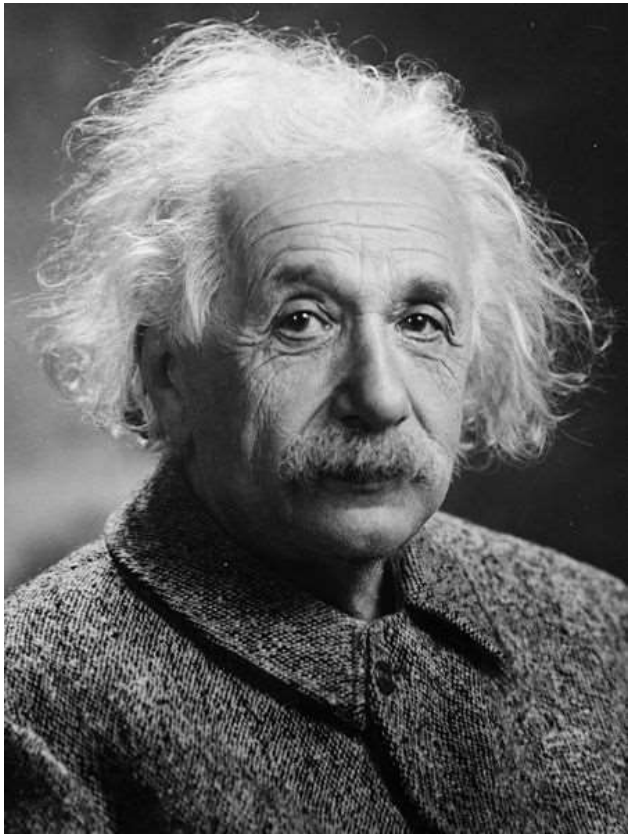
GAINING PERFORMANCE WITH RECYCLING AGENTS

Grant Wollenhaupt
Vice President of Strategy & Innovation
Superior Bowen

Benchmarking

Let’s Set Some Realistic Expectations Here

Less Like



More Like

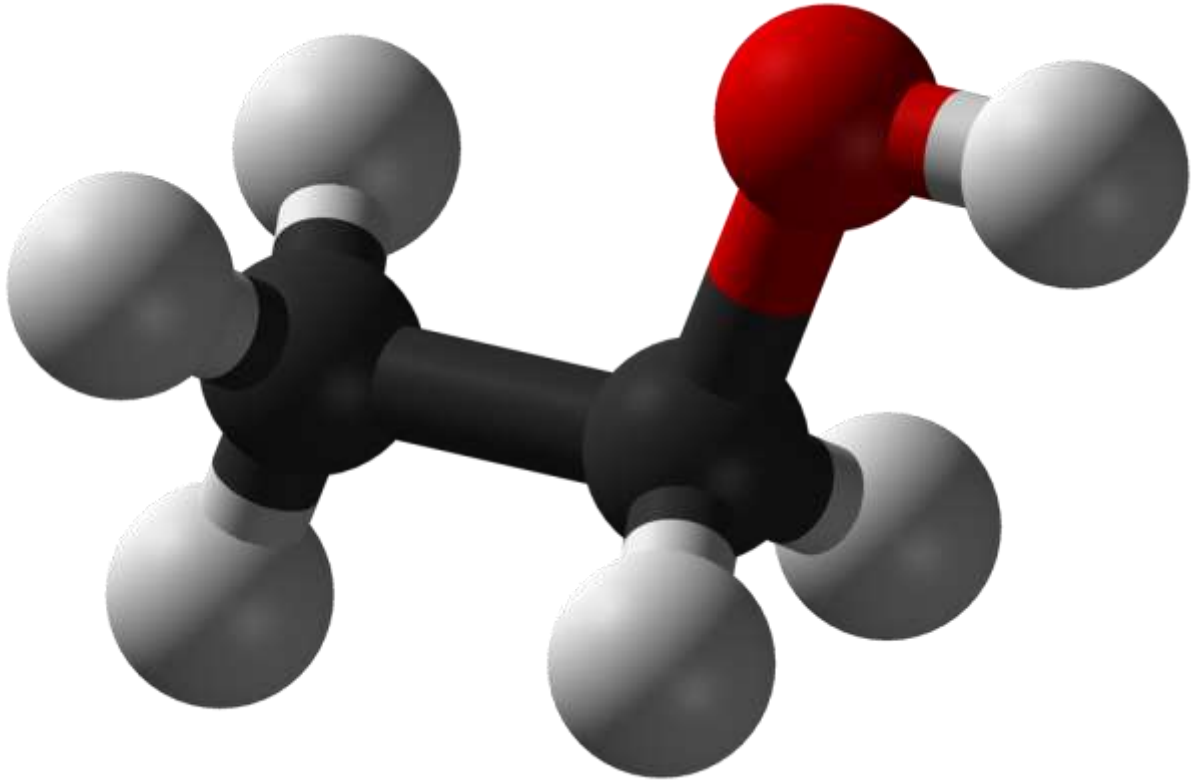
Objective

TO LEARN THE BASICS or JUST ENOUGH TO ASK QUESTIONS

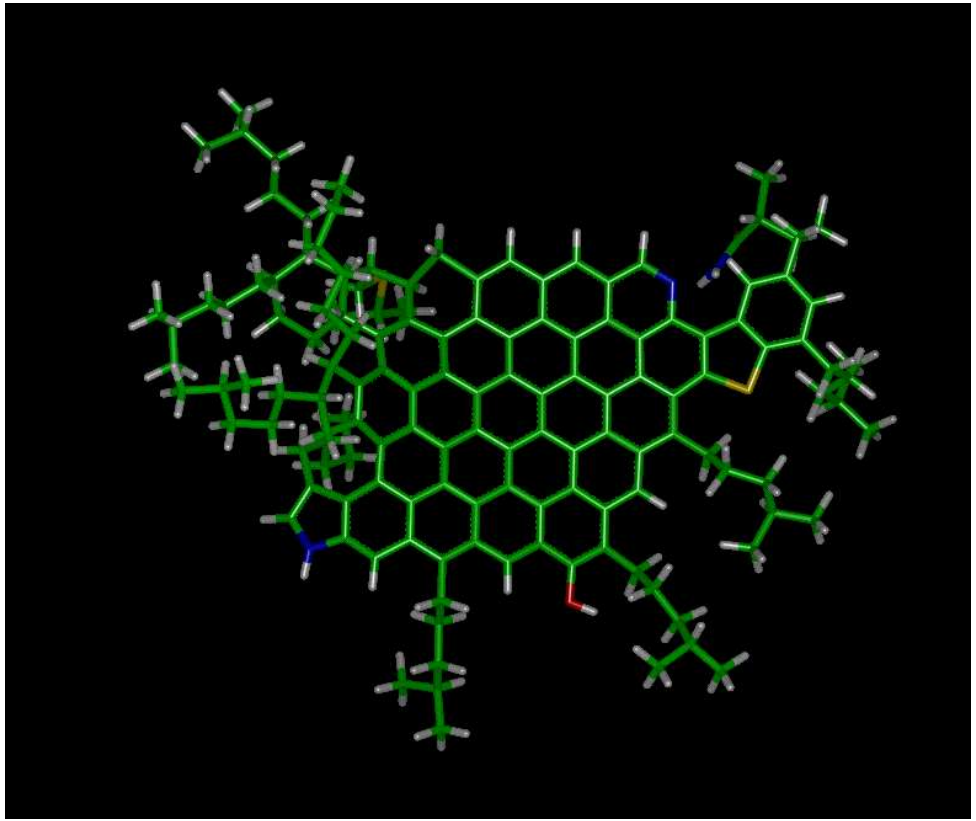
Oil

Totally not a politically loaded word…

Oil



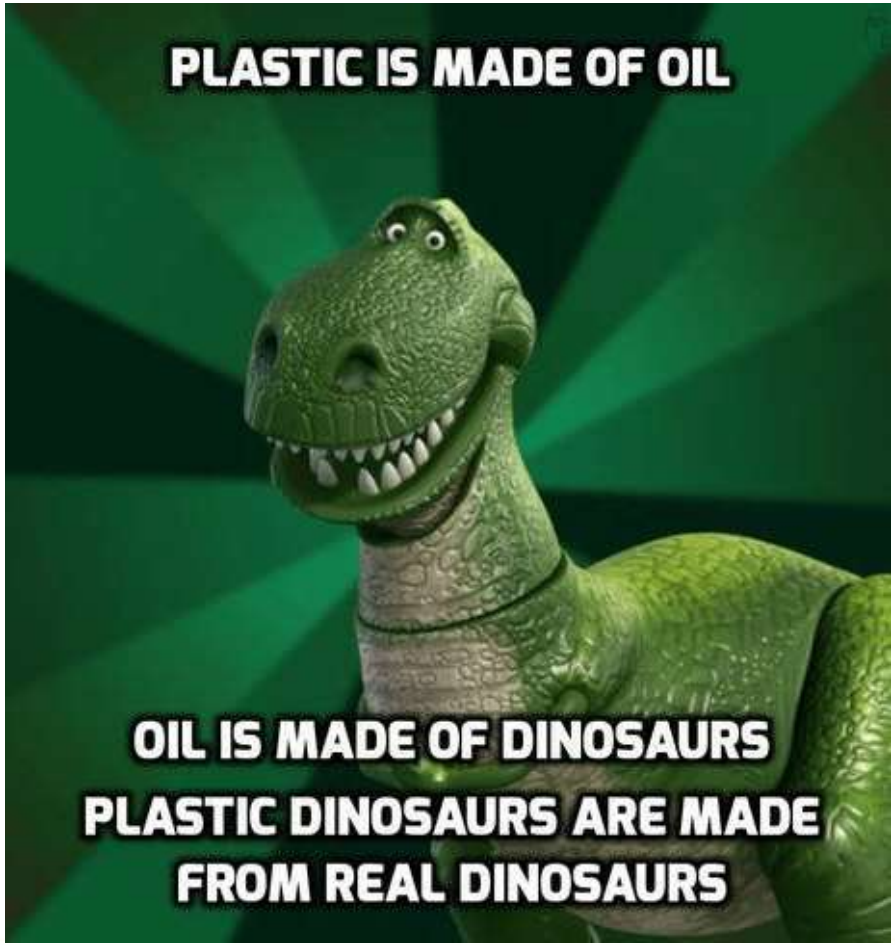
Oil



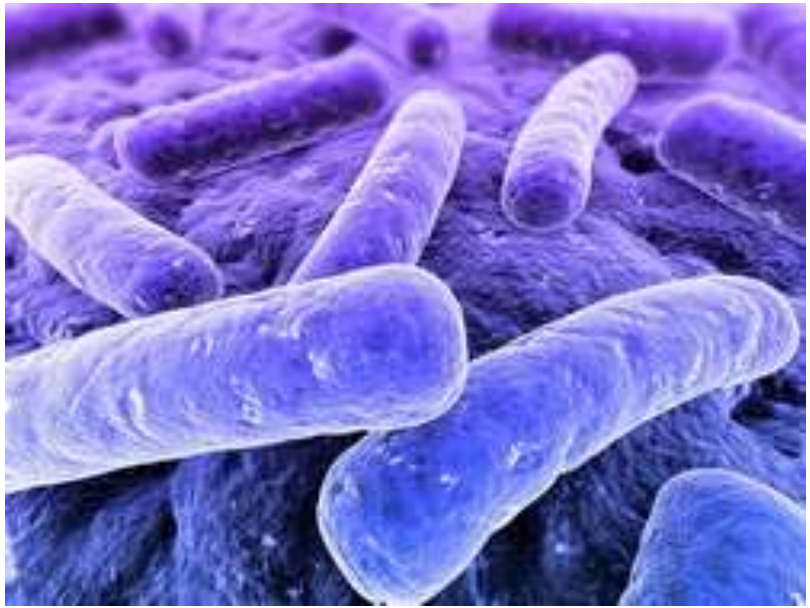
Oil

Oil

Oil?

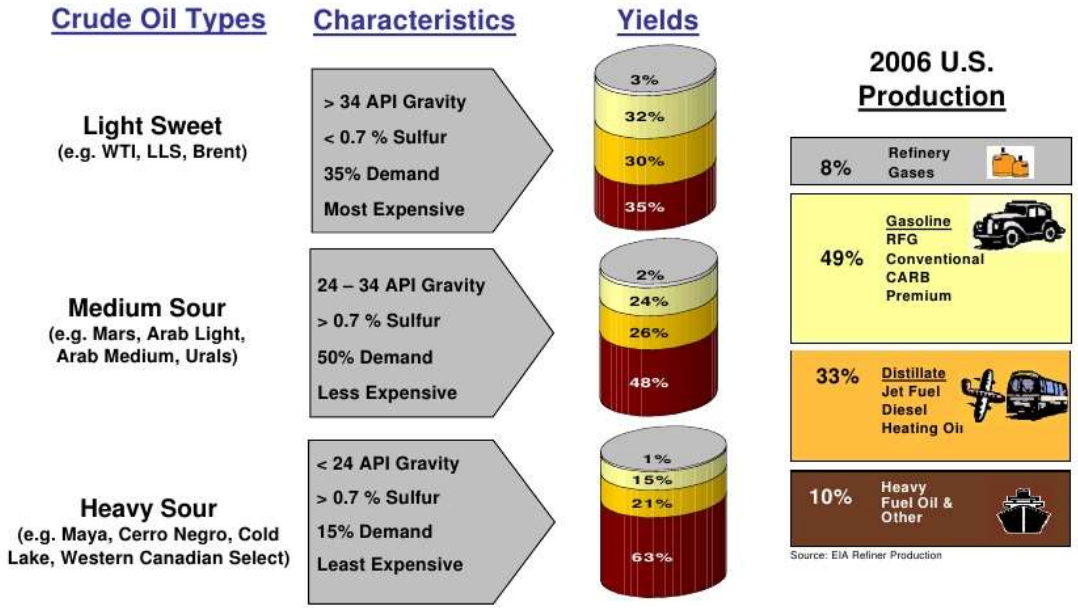

PLASTIC IS MADE OF OIL
OIL IS MADE OF DINOSAURS
PLASTIC DINOSAURS ARE MADE FROM REAL DINOSAURS

Oil



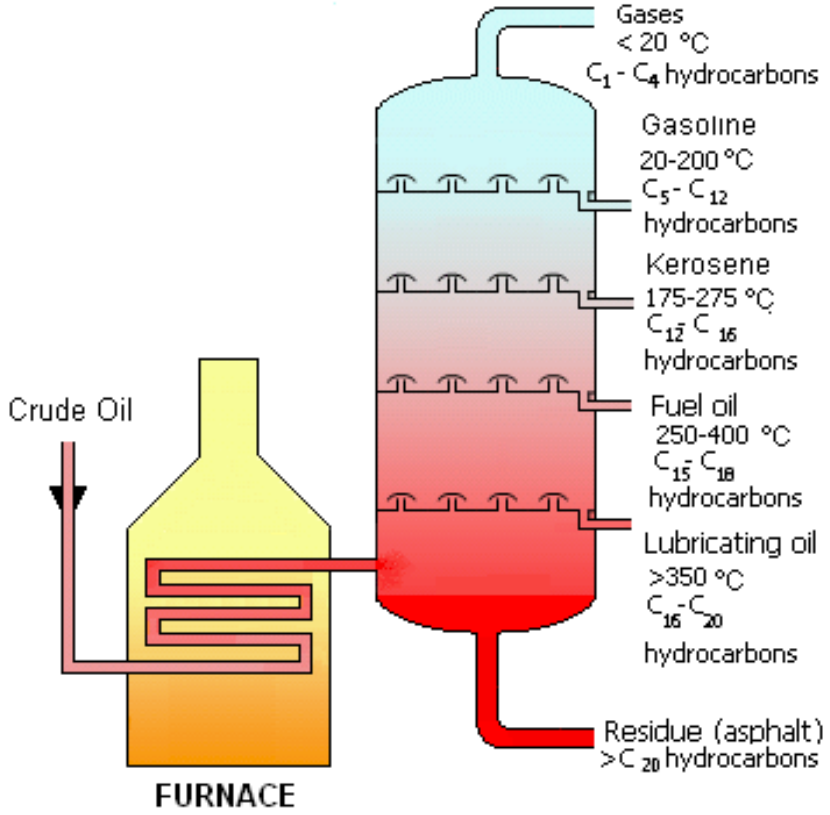
Oil

What's in a Barrel of Crude Oil?



Refineries upgrade crude oil to higher value products

Oil


Gases
< 20 °C
C_1 - C_4 hydrocarbons
Gasoline
20-200 °C
C_5 - C_{12}
hydrocarbons
Kerosene
175-275 °C
C_{12} - C_{16}
hydrocarbons
Fuel oil
250-400 °C
C_{15} - C_{18}
hydrocarbons
Lubricating oil
>350 °C
C_{16} - C_{20}
hydrocarbons
Residue (asphalt)
>C_{20} hydrocarbons
Crude Oil
FURNACE

Asphalt


Components of asphalt.
Second acidaffins
First acidaffins
Saturated hydrocarbons
Polar compounds
Asphaltenes

Binder is Different…

- Performance Grading: 64-22, 58-28
  - Think of it more 64 -22
- Expanding the PG range: 64-28, 70-22, 58-34
  - That’s modification

Modifiers

To accent or augment performance

Cost savers

Why We Modify

- Performance
  - Stripping (TSR, Hamburg)
  - Rutting (Hamburg)
  - Cracking (SCB, DCT, TSRST)
  - Aging
- Cost
- Environmental Benefit

Types of Modification

- Stripping
  - Hydrated Lime
  - Liquid Anti-Strips
- Rutting
  - SBS
  - GTR
- Recycled Materials
  - RAP
  - RAS

Recycling Agents

- Pig Sh*t
- Plant-Based
  - Tall Oil
  - Vegetable Oil
- Petroleum Based
  - Flux
  - Fuel Oils
  - REOB

We May Have a Problem

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

Evaluation

You Can’t Just Swipe Left or Right for Looks

That’s a Tinder Joke, Folks

What to Look For

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

Your Nose Knows

Nobody Likes Melting

Devastatingly Deadly to Aquatic Life

How to Get the Sauce on the Rocks

An Argument Against Old Cucumbers

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%

When You Don’t Want What You Ask For

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

When You Don’t Want What You Ask For

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

Add Rejuvenator

When You Don’t Want What You Ask For

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

Add Rejuvenator

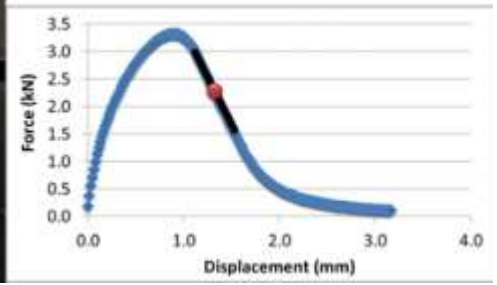
T5RC WITH 27%RAP/3% RAS	PG75-23
T5RC WITH 25%RAP/5% RAS	PG81-22

Performance Testing

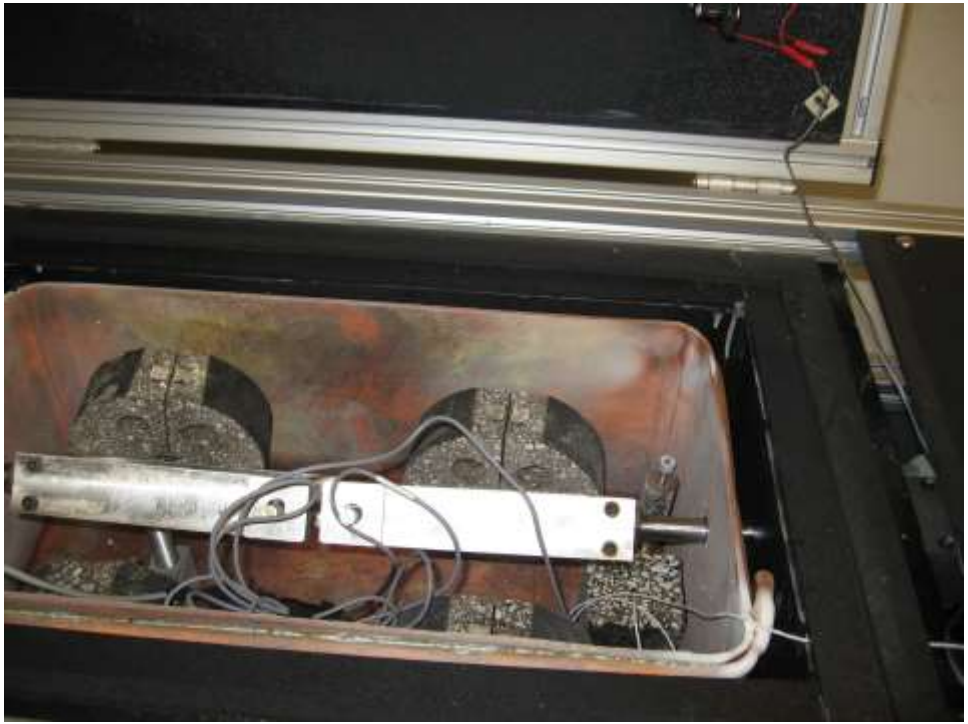
All for Naught Without a Proper Baseline

Hamburg

Illinois Flexibility Index Test IFIT



Disc-Shaped Compact Tension Test DCT(T)



Obligatory Data Page

	Mix Type				
	190 C	**125 SMA I-435**	**095 SMA I-435**	**T5 City Overlay 40R**	**T5 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

Ranking

	190 C	095 SMA I-435	125 SMA I-435	T5 City Overlay 40R	T5 City Overlay 60R
Hamburg	1	3	2	5	4
DCT	5	1	2	4	3
IFIT	3	2	1	2	2
Average	**3**	**2**	**1.7**	**3.6**	**3**
Price	**3**	**5**	**4**	**2**	**1**

Elementary Grant: The road to hell is paved with good intentions

High School Grant: The road to heaven is also paved with good intentions

College Grant: The vast majority of roads are paved with good intentions

Contractor Grant: Good intentions are low caliber roadbuilding materials

Resources

Resources

- AAPT
- NCAT
- NAPA, APA, SAPAs
- CMTG (Kansas City)
- Manchester Pavement Solutions

Questions?

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