Recycled Plastics for Performance Graded Asphalts

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ACKNOWLEDGEMENTS

- Dow
  - Gerardo Cespedes
  - Sean Doughty
  - Ann Johnson
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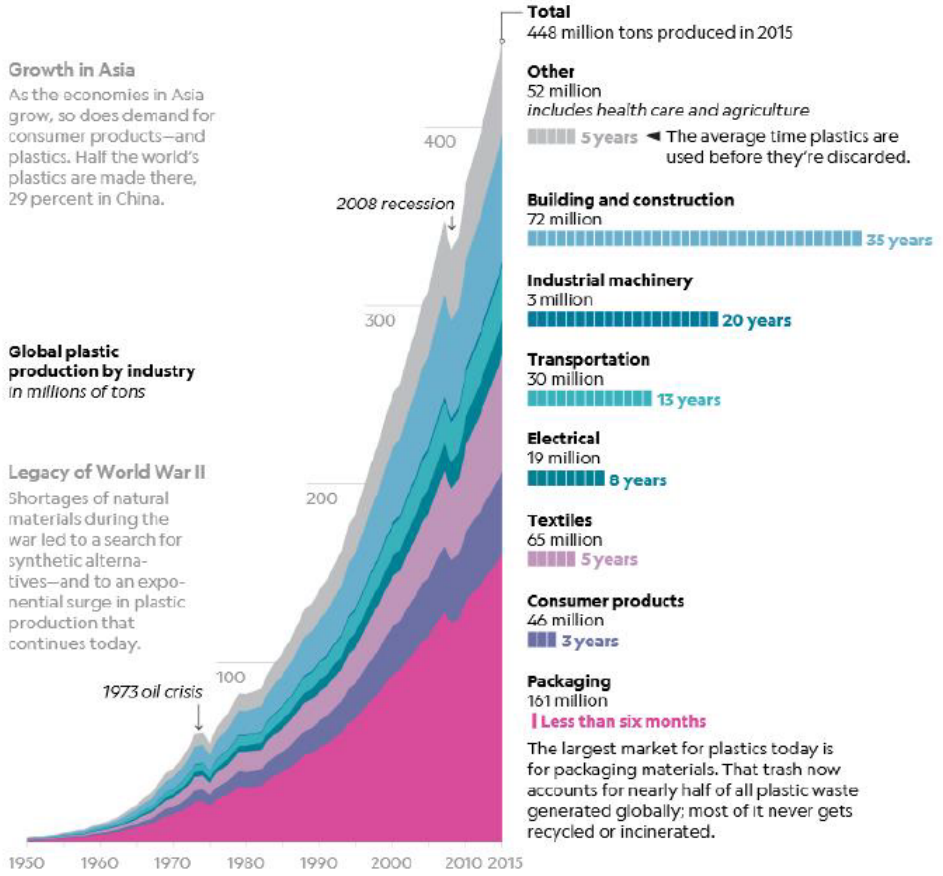
- Commercial Partners
  - Martin Asphalt
  - American Materials
  - Vernor Material & Equipment
  - Bit-Mat Products/K-Tech Specialty Coatings
  - Central Asphalt - Fisher Companies
  - Midland County Road Commission
- Testing Support - Andrew Hanz, MTE

What applications are PLASTICS used?



JASON TREAT AND RYAN WILLIAMS, NGM STAFF
SOURCE: ROLAND GEYER, UNIVERSITY OF CALIFORNIA, SANTA BARBARA

RECYCLING RATES IN US (2015 EPA DATA)

Key Commodities

Recycling Rates

- Paper and paperboard recycling was 66.6%
- Metals recycling was 34.3%
- Glass recycling was 26.4%
- Plastics recycling was 9.1%
  - PET bottles and jars recycling was 29.9%
  - HDPE Natural (white translucent) bottle recycling was 30.3%

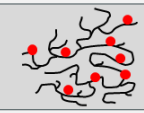
INTEREST IN RECYCLED PLASTICS IS GROWING

- Recycled plastic use in pavement has bipartisan support in US House and Senate
- US Senate Environmental and Public Works Committee is considering funding research to study recycled plastics as part of the 2019 Highway Bill
- Save Our Seas 2.0 also has research monies allocated in the latest draft
- Key stakeholder groups such as AI, NAPA, and NCAT have kicked-off work groups

WHAT COMPONENTS ARE WE TALKING ABOUT?

Polyethylene (PE) in Asphalt Binders

- Pure saturated hydrocarbon in most cases, but insoluble in asphalt
- Semi-crystalline: Poorer intermediate and low temperature performance
- Elastic properties of a PE-modified binder are inferior
- Commercial attempts have been unsuccessful

Type	Process	MWD	SCB	LCB	Co-monomer	Description
LDPE	Free Radical	Broad	Back-biting	Some	None	
ECP **EVA, EBA**	Free Radical	Broad	Back-biting	Some	Polar	
HDPE	Catalyst	Broad	Little	None	None	
ZN-LLDPE	Catalyst	Broad	α-olefin	None	α-olefin	
mLLDPE	Catalyst	Narrow	α-olefin	None or Sparse	α-olefin	

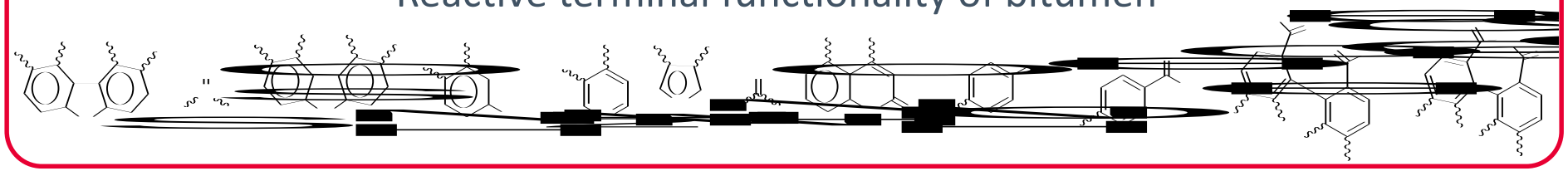
Can a compatibilizer solve separation and improve low/intermediate temperature performance while enabling the blend to meet all other performance properties?

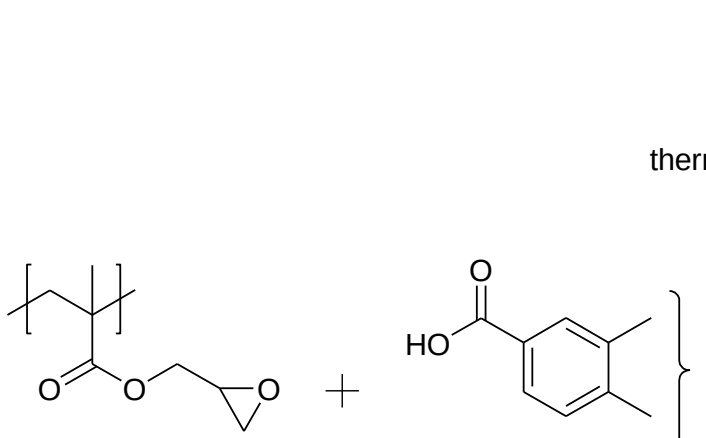
SUMMARY

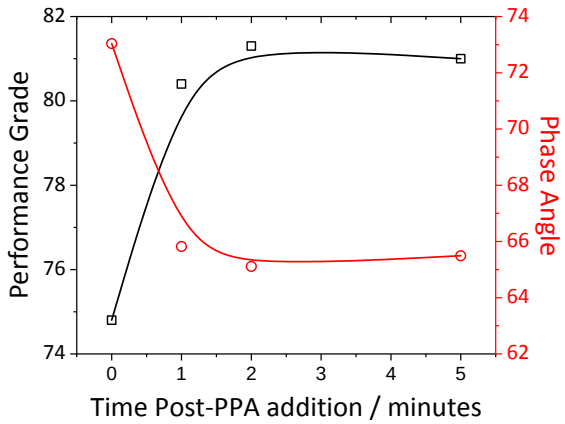
- RET enables the use of polyethylene-rich recycled plastics (RPE) in Performance Graded Asphalts
  - Exceed TX DOT PG 70-22 and MDOT PG64-28P performance specifications
- Alone RPE does not pass
  - ASTM D5976 – 48 hour separation test
  - AASHTO M320 or M332 – Performance Grading
- Binders containing RPE with RET meet above
  - Including intermediate and low temperature performance criteria

RET REACTS CHEMICALLY WITH ASPHALT FUNCTIONAL GROUPS

Reactive terminal functionality of bitumen





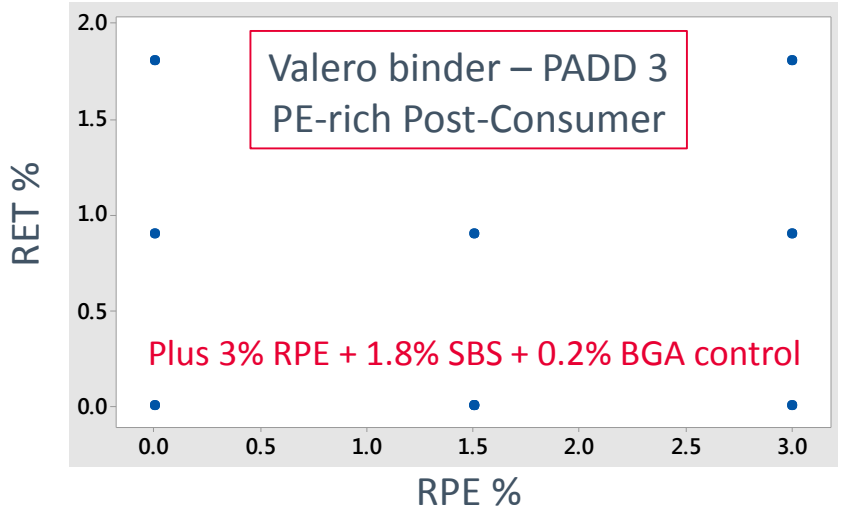


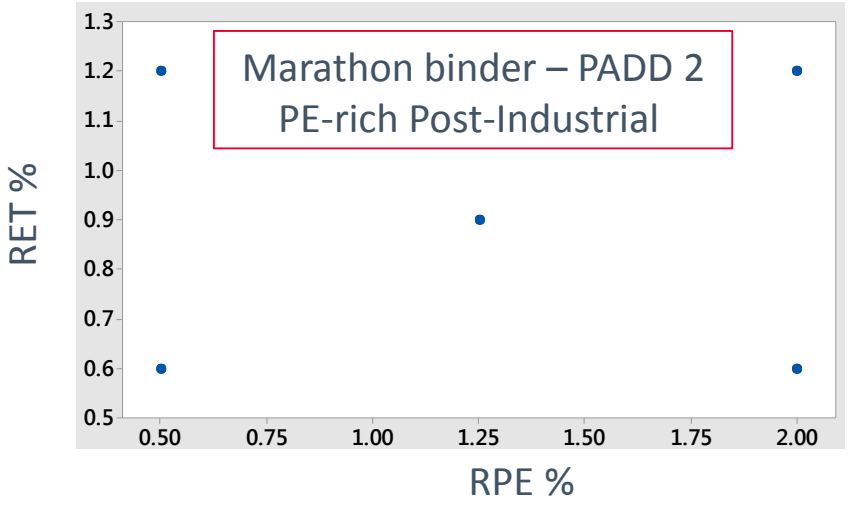
Non-Polar/Polar sections → soluble in asphalt
Reactive → elastic properties
Controlled crystallinity → tunable temperature performance

EXPERIMENTAL SUMMARY

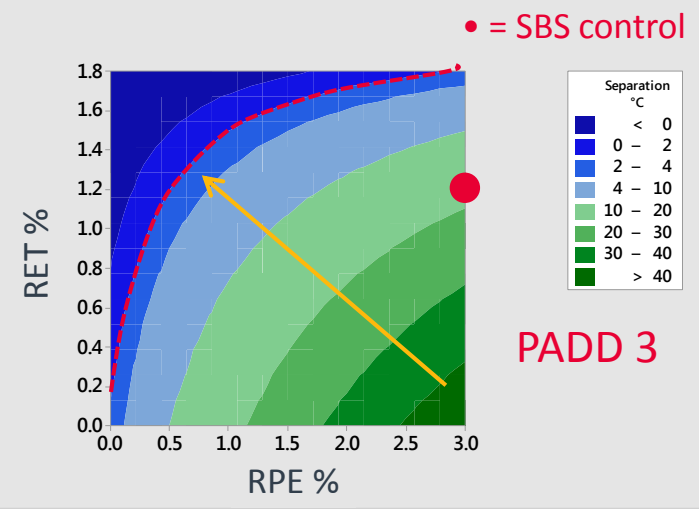
Design of Experiment

- Two asphalt binders – PADD 2 (Marathon Detroit) and PADD 3 (Valero)
- One RPE for each
  - Valero – linear low density PE-rich system (LLDPE)
  - Marathon – low density PE-rich system (LDPE)
- Partial factorial DOE chosen to balance exploration of RPE/RET dosage interaction and minimize experiments
  - PPA fixed at 20 wt % of RET

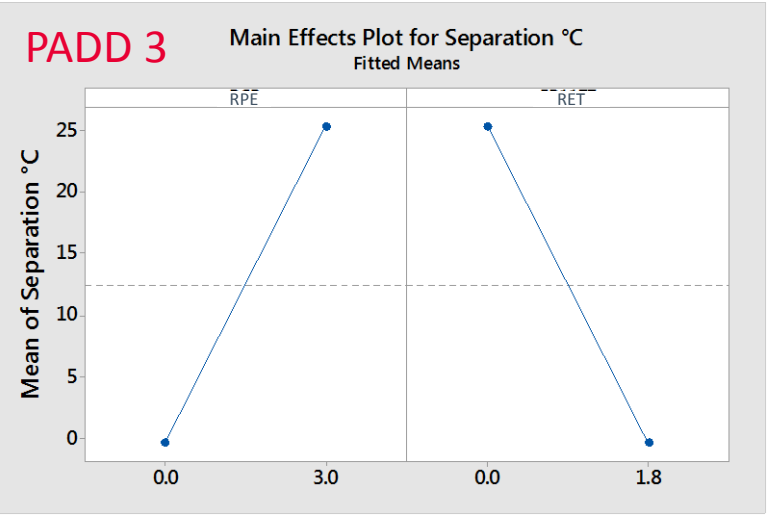




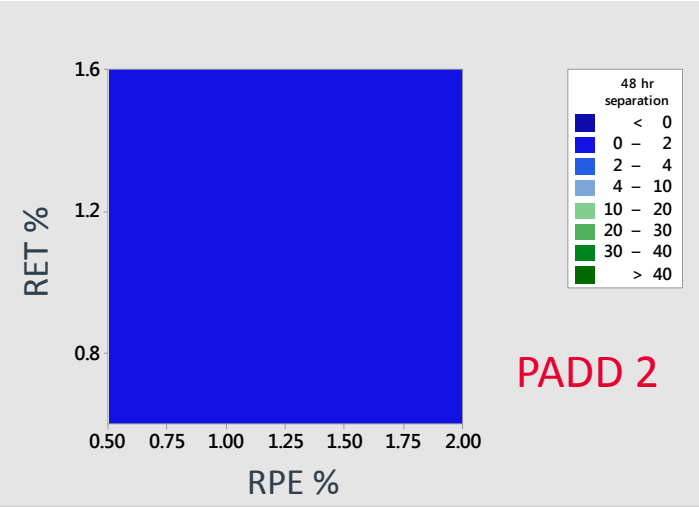
ASTM D5976 (48 HOUR SEPARATION TEST) – RET IMPROVES SEPARATION VALUES



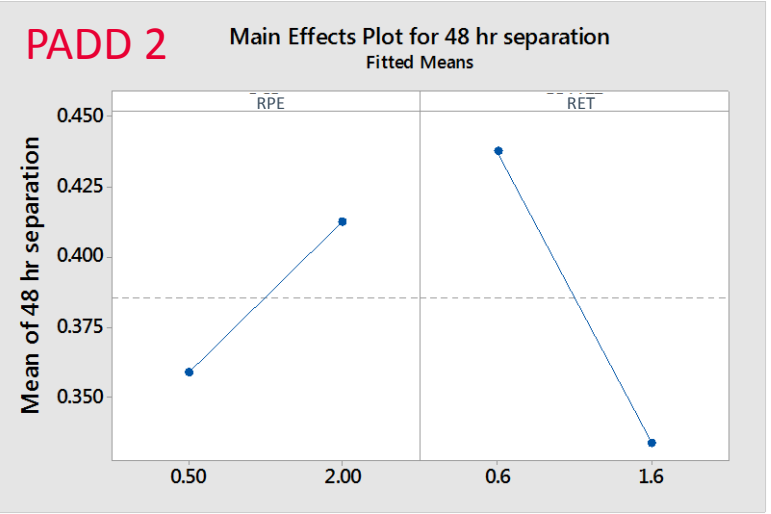
PADD 3 binder exhibits a large response vs RET and RPE dosage



Separation - PADD 2 and 3 binders display increased with RPE and decreased with RET

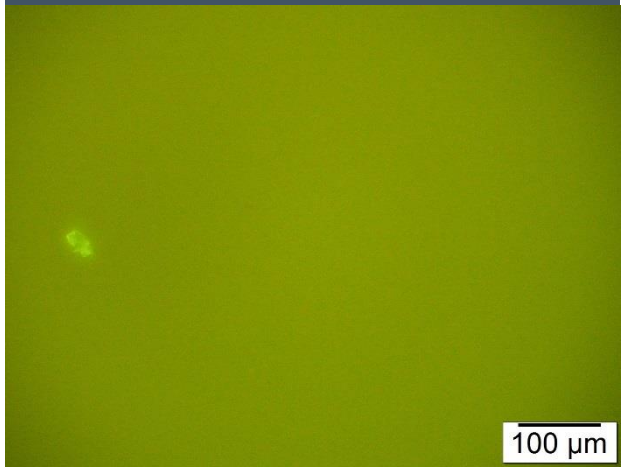
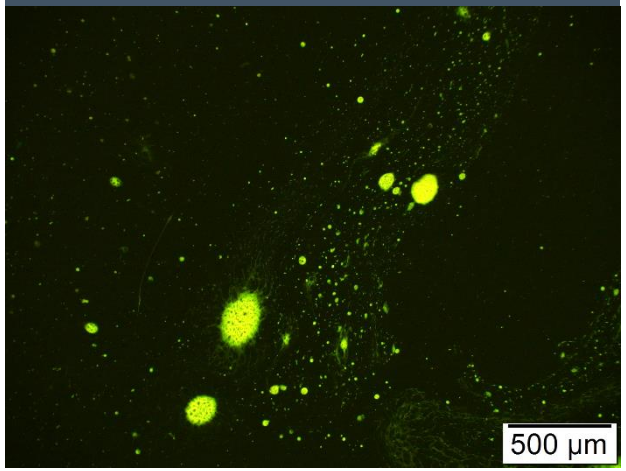
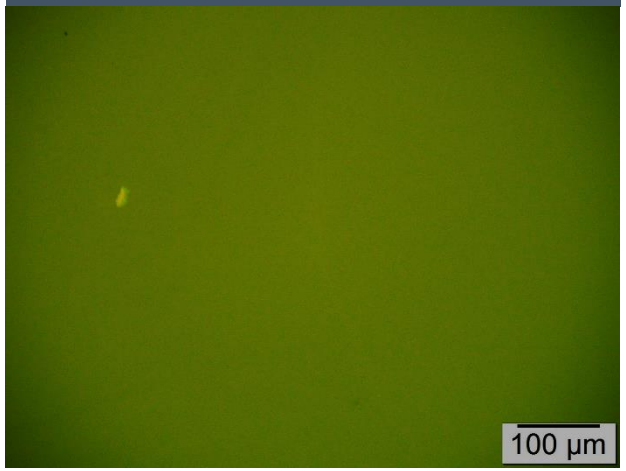
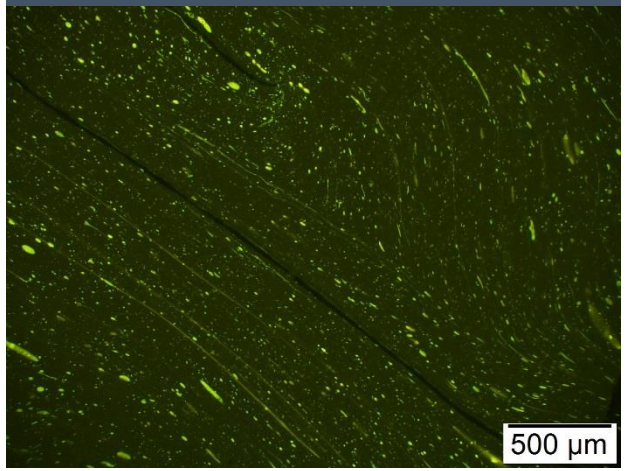


PADD 2 binder exhibits minimal response vs dosage



Optical microscopy comparison of modified asphalt – PADD 3 binder

Low Magnification epi-Fluorescence Optical Images

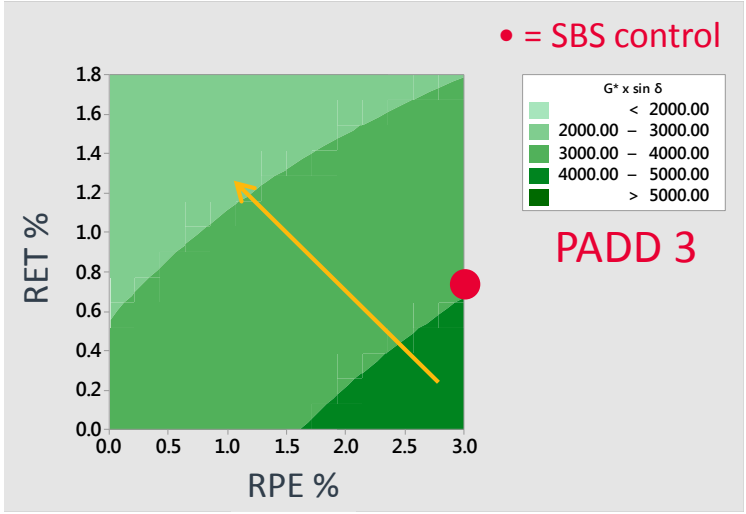
Binder + 0.2% PPA	3% RPE + 0.2% PPA	0% RPE + 1.8% RET + 0.2% PPA	3% RPE + 1.8% RET + 0.2% PPA
			
No specific domains visible	Large domains visible	No specific domains visible	Domains smaller than RPE control

- No distinguishable differences between base binder and RET-only sample
- RPE-only sample displayed distinguishable domains
- Combination of RPE and RET demonstrated differences vs RPE-control

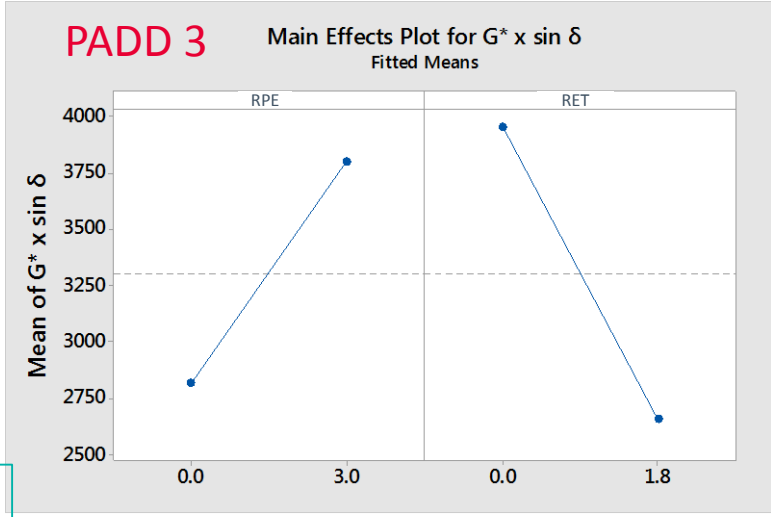
Acknowledgement – Ann Johnson and Preston McDaniel

Low/Intermediate Temperature Testing

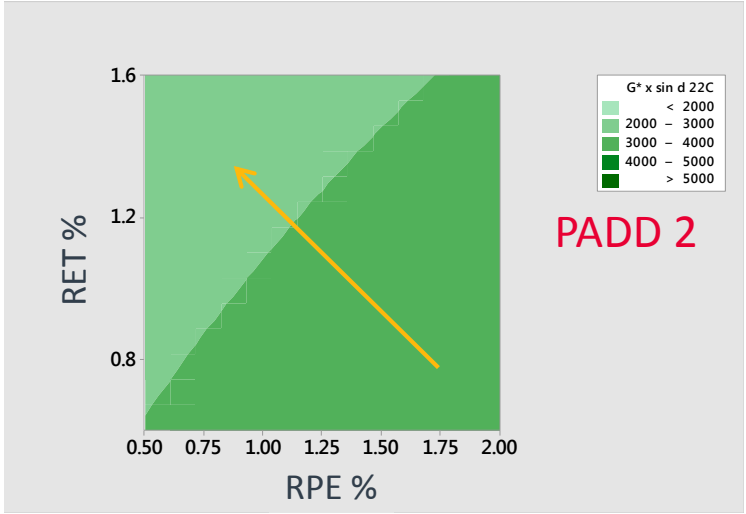
INTERMEDIATE TEMPERATURE TESTS – ALL DOSAGES MET SPECIFICATION



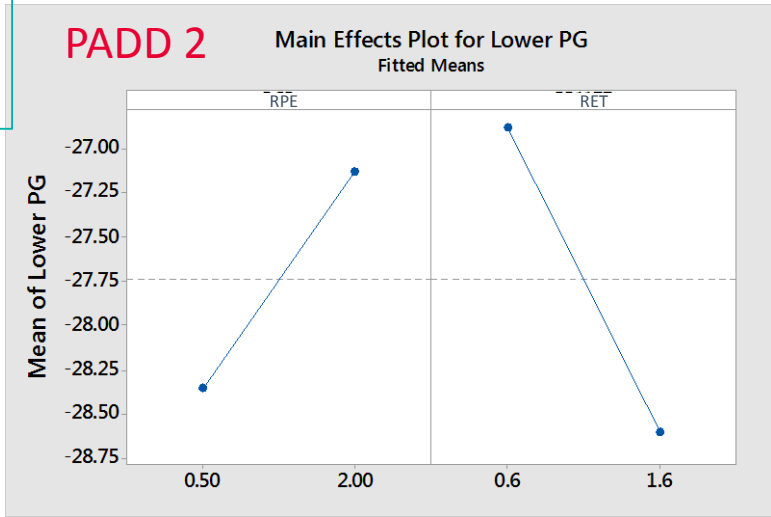
PADD 3 binder similar response vs dosage



PADD 2 and 3 binders display increasing values with RPE and decreasing with RET

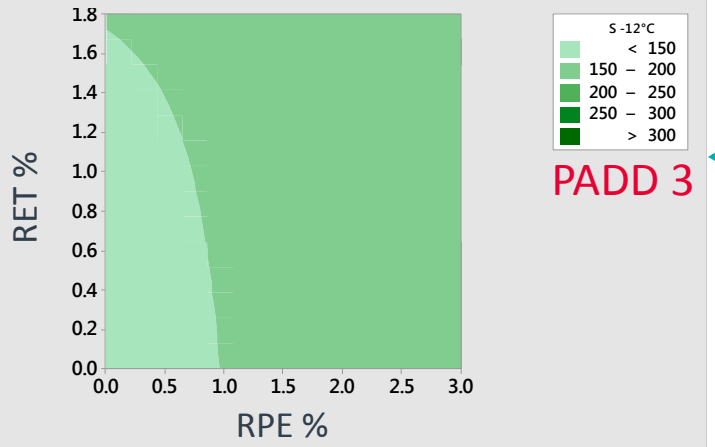


PADD 2 binder similar response vs dosage



LOW TEMPERATURE TESTS – HIGHER RET % ENABLES RPE TO MEET SPECIFICATION

• = SBS control (off-scale) 149 MPa

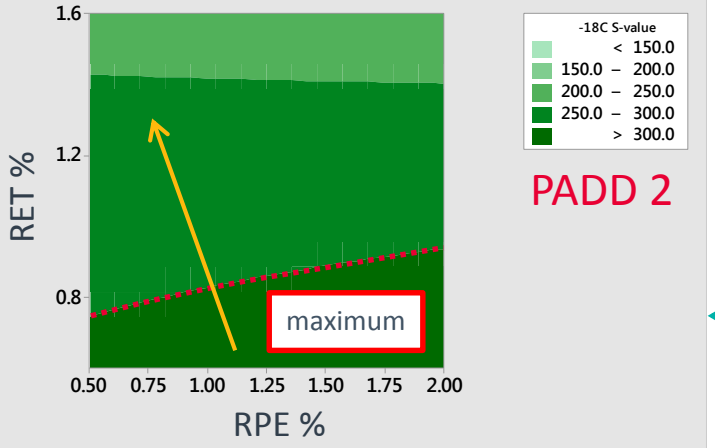


PADD 3

PADD 3 binder slight RPE dosage effect

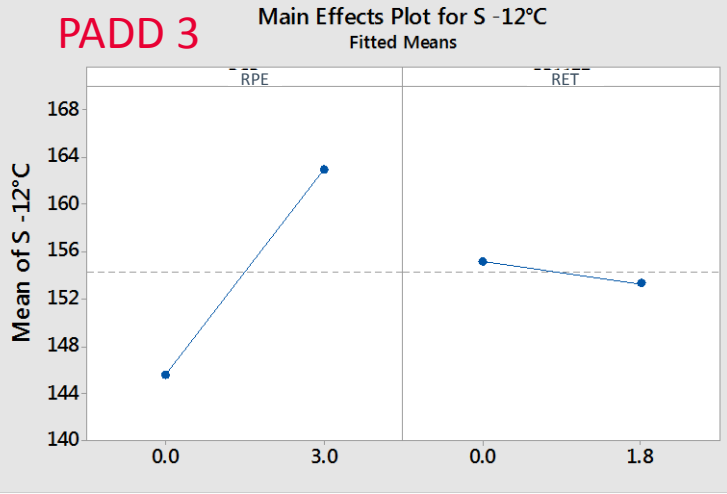
PADD 2 and 3 binders display different dosage responses

PADD 2 binder significant dosage effect with RET



PADD 2

PADD 3



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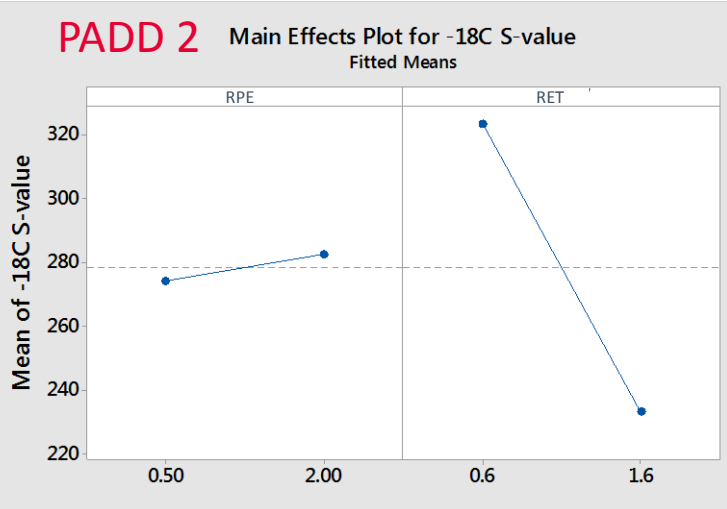
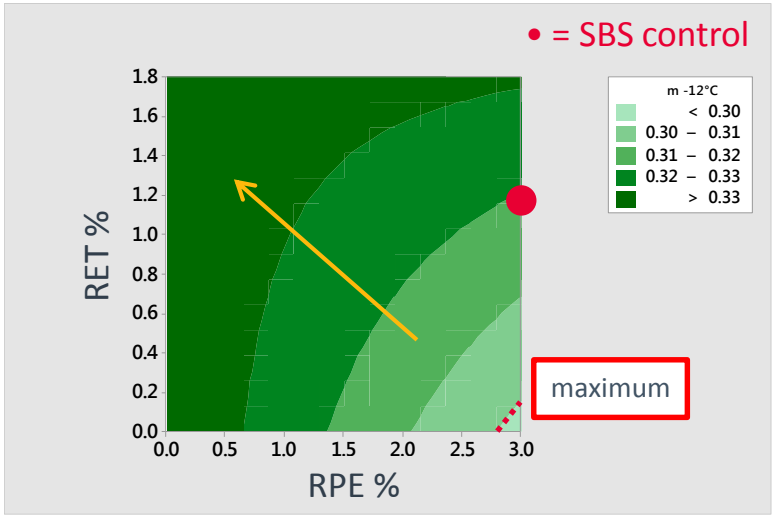
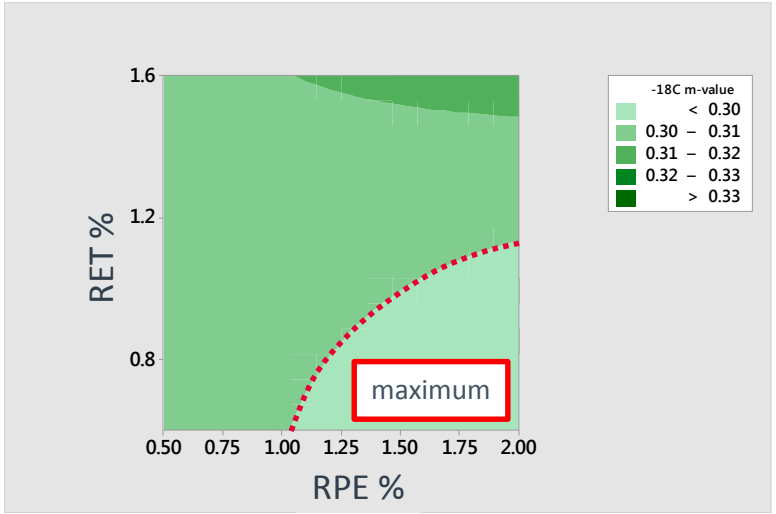


LOW TEMPERATURE TESTS – HIGHER RET % ENABLES RPE TO MEET SPECIFICATION



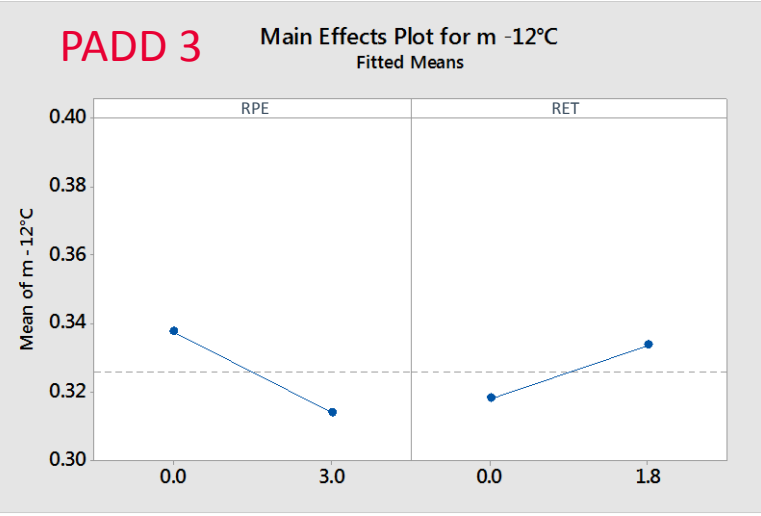


PADD 3 binder significant RPE dosage effect

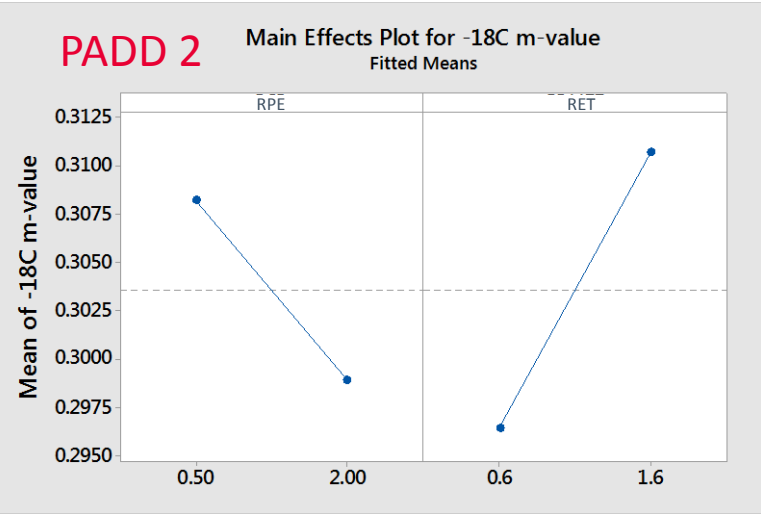
PADD 2 and 3 binders display similar dosage responses

PADD 2 binder small RPE dosage effect

PADD 3

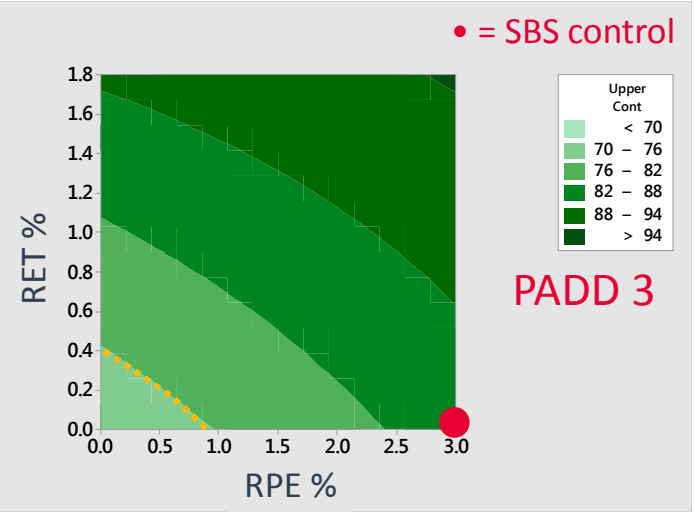


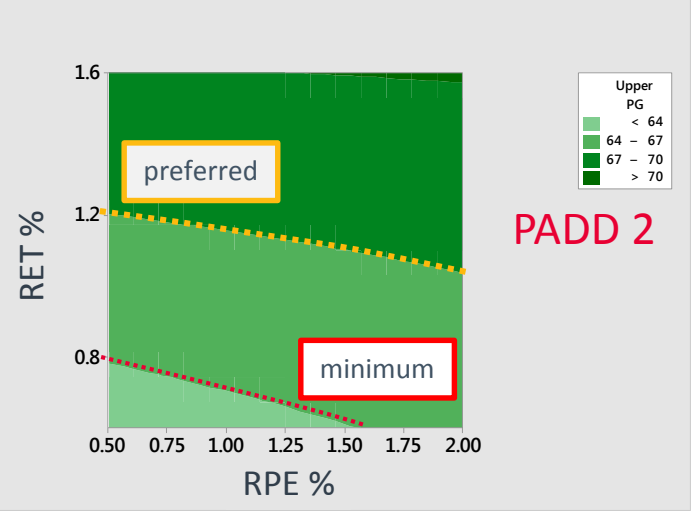
PADD 2



STIFFNESS-BASED TESTING

Upper Continuous Grading – both RPE and RET improve perforance

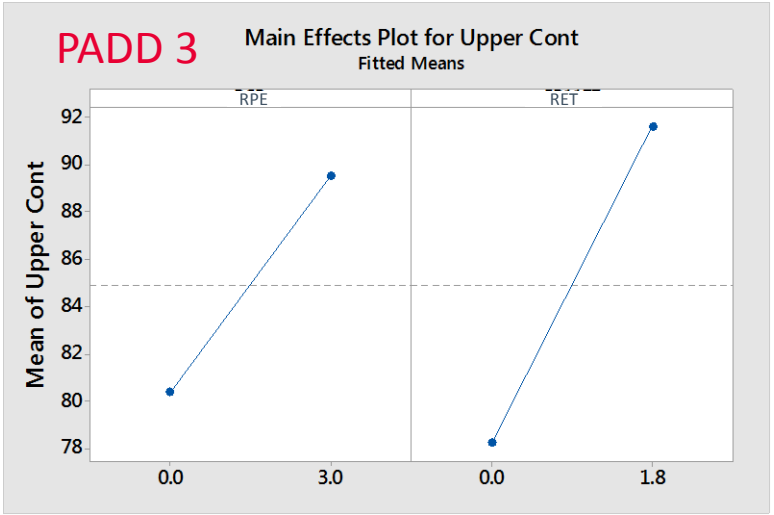


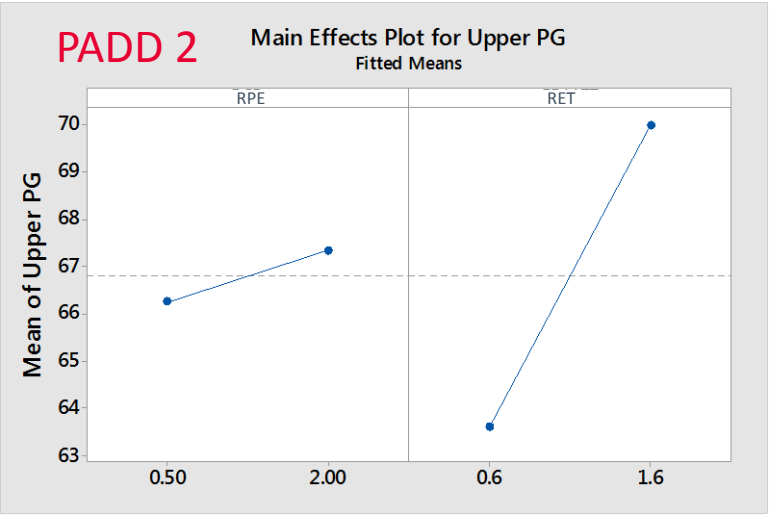


PADD 3 binder significantly more responsive vs dosage

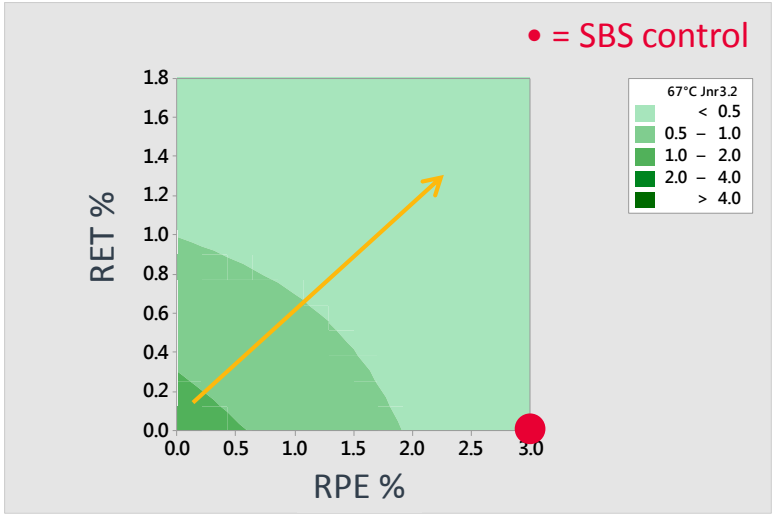
PADD 2 and 3 binders display increased upper PG with both RPE and RET

PADD 2 binder significantly less responsive vs dosage

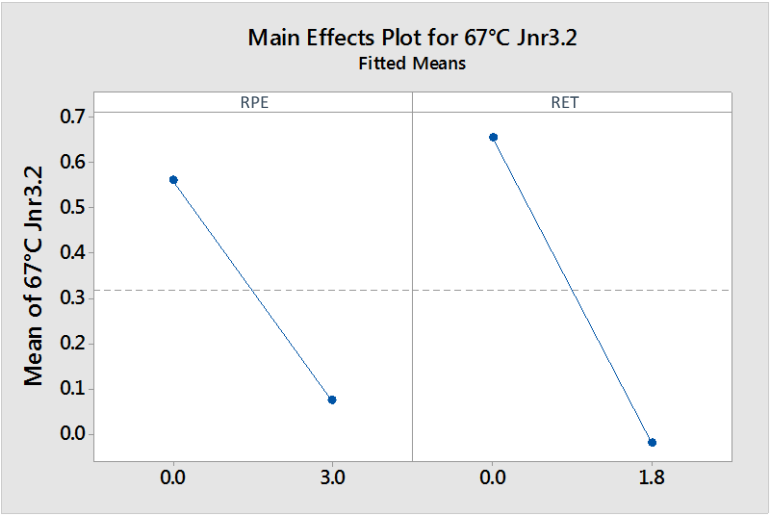




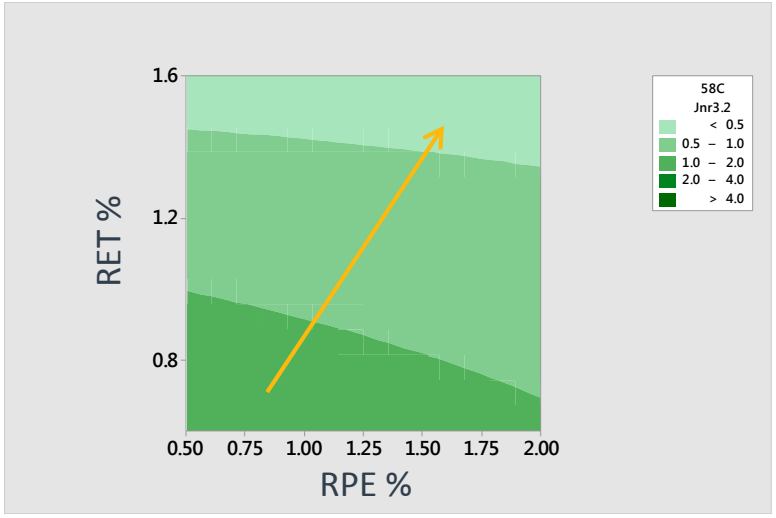
NON-RECOVERABLE CREEP – BOTH MATERIALS IMPROVE PERFORMANCE



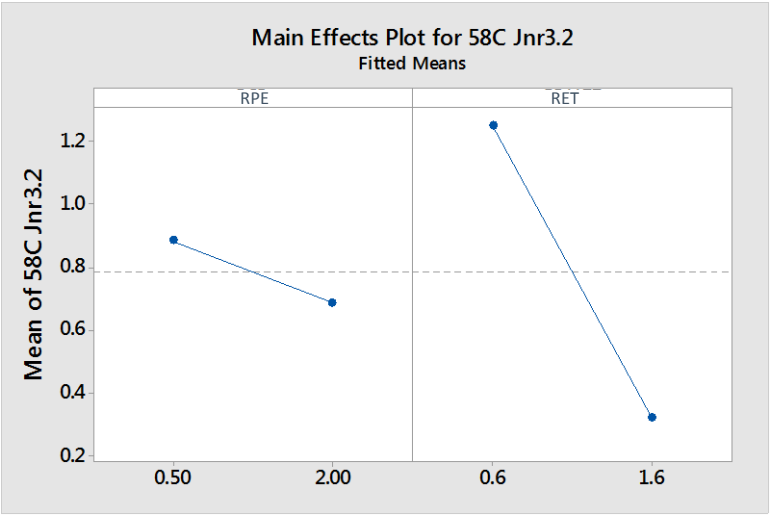
PADD 3 binder significantly more responsive vs dosage



PADD 2 and 3 binders display improved $J_{nr,3.2}$ with both RPE and RET

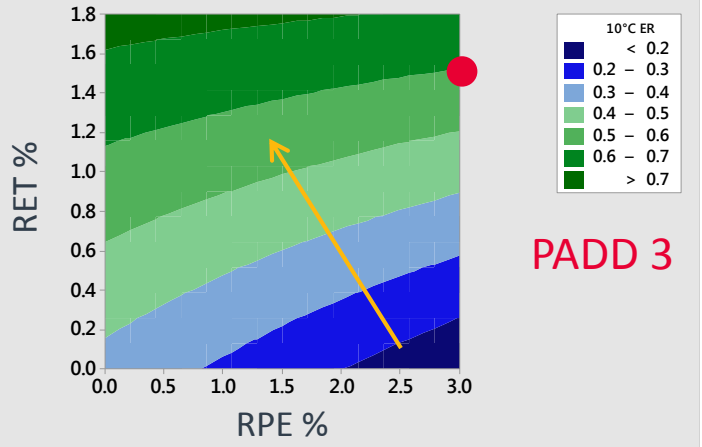


PADD 2 binder more response to RET vs dosage



ELASTIC PROPERTY TESTING

Elastic Recovery – combination of RET and RPE meet performance

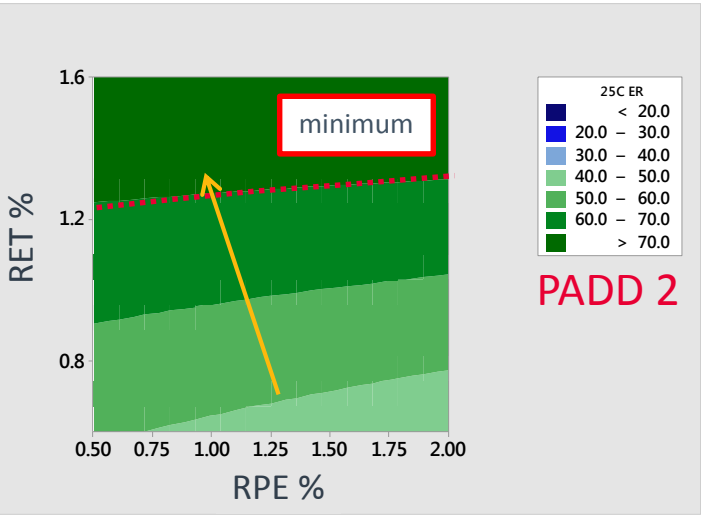


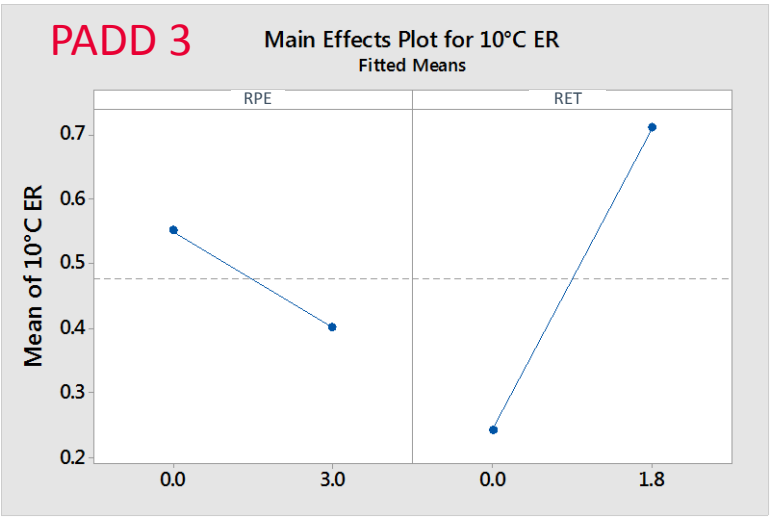
PADD 3 binder most responsive to RET vs dosage

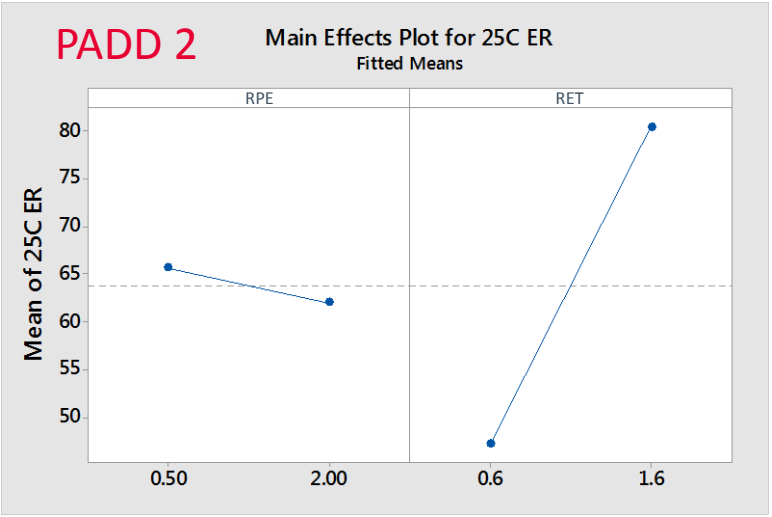
SBS control with RPE = 52%

PADD 2 and 3 binders display similar dosage responses

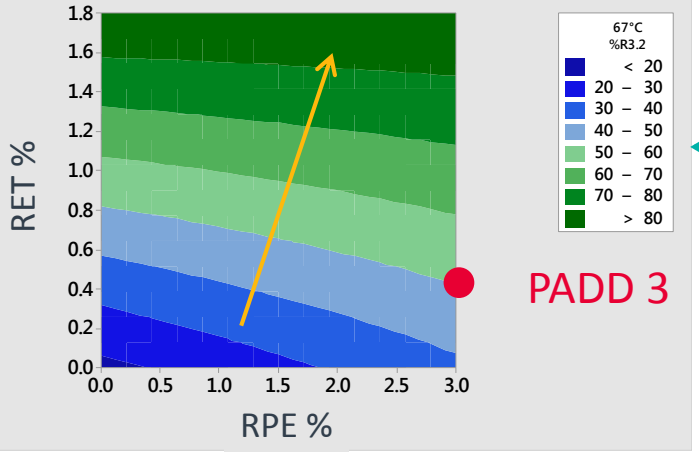
PADD 2 binder most responsive to RET vs dosage





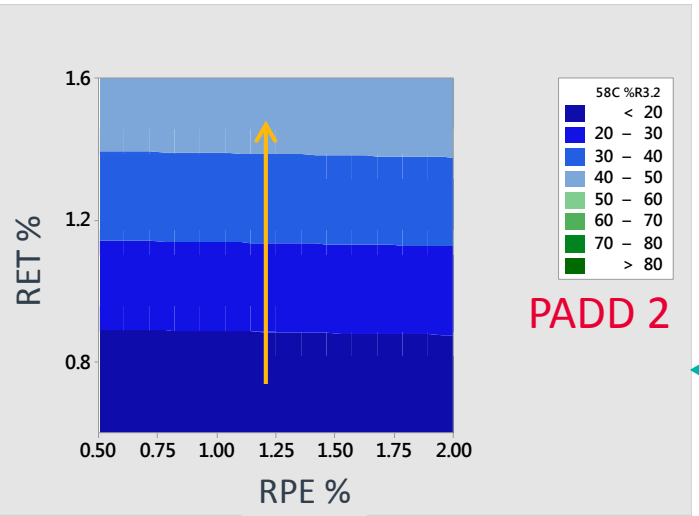


MSCR %R – COMBINATION OF RET AND RPE MEET PERFORMANCE



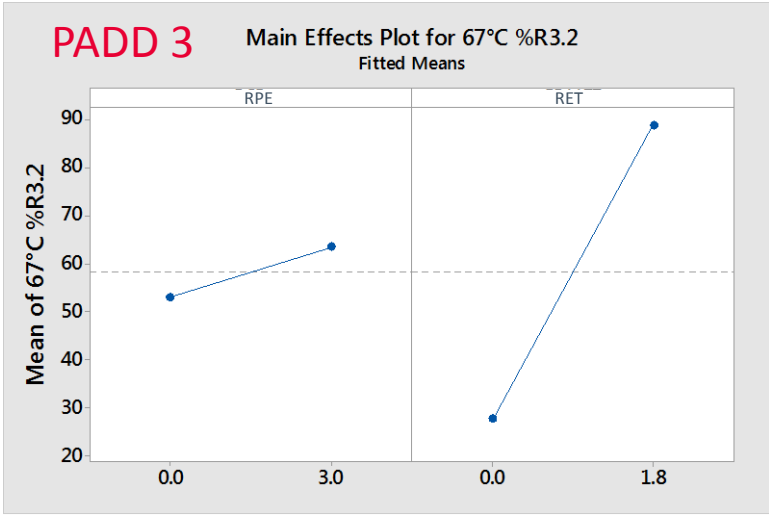
PADD 3 binder is highly reactive to RET

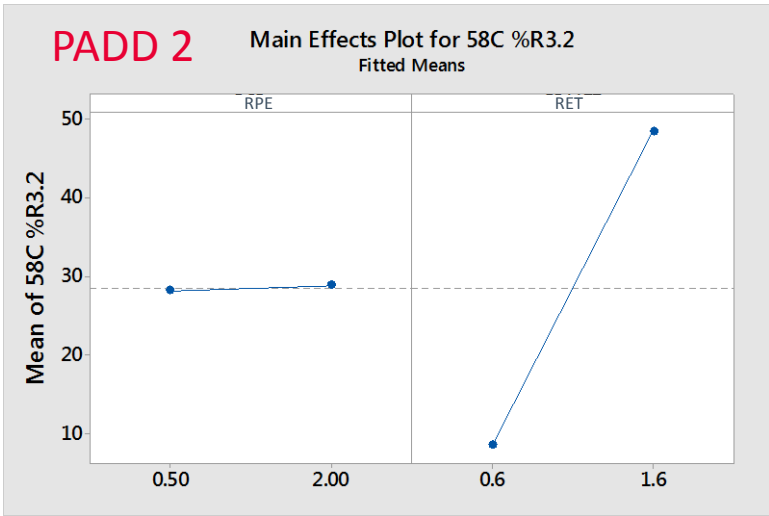
SBS control with RPE = 52%



PADD 2 and 3 binders most responsive to RET dosage

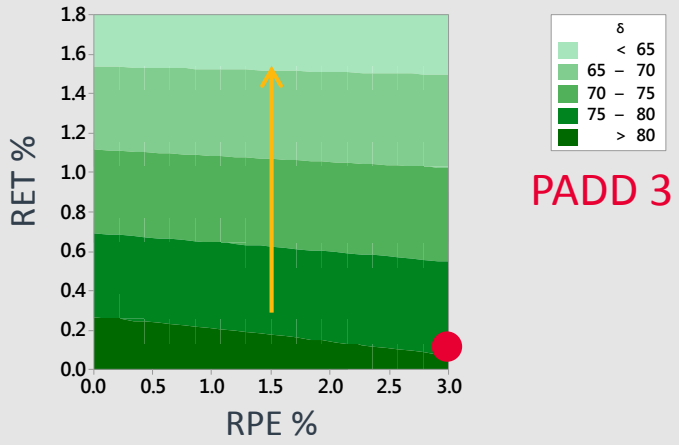
PADD 2 binder has high reactivity to RET





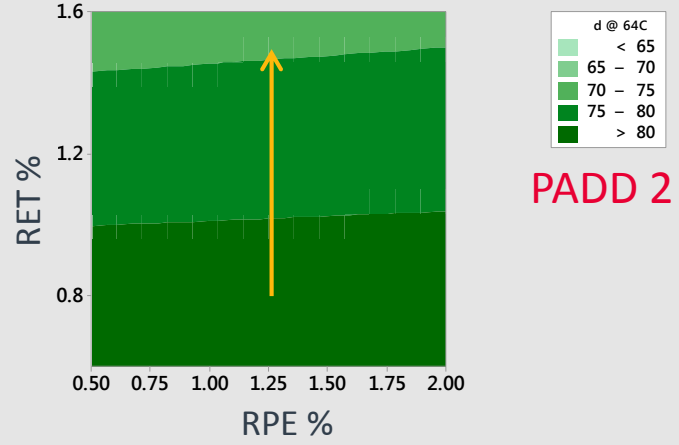
PHASE ANGLE – COMBINATION OF RET AND RPE MEET PERFORMANCE

• = SBS control



PADD 3

PADD 3 binder is highly reactive to RET

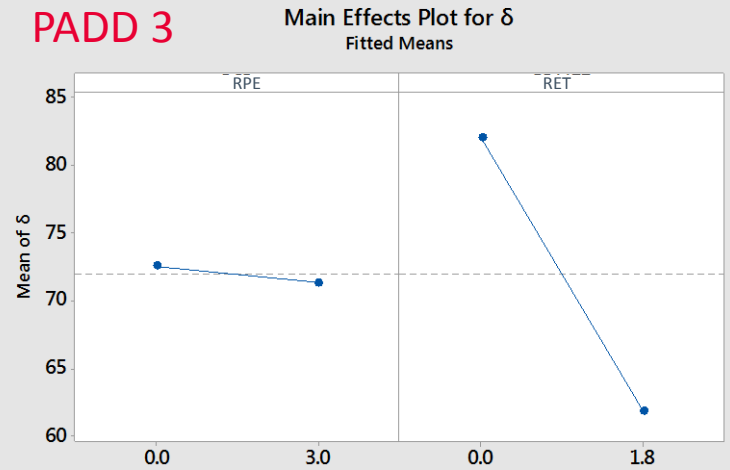


PADD 2

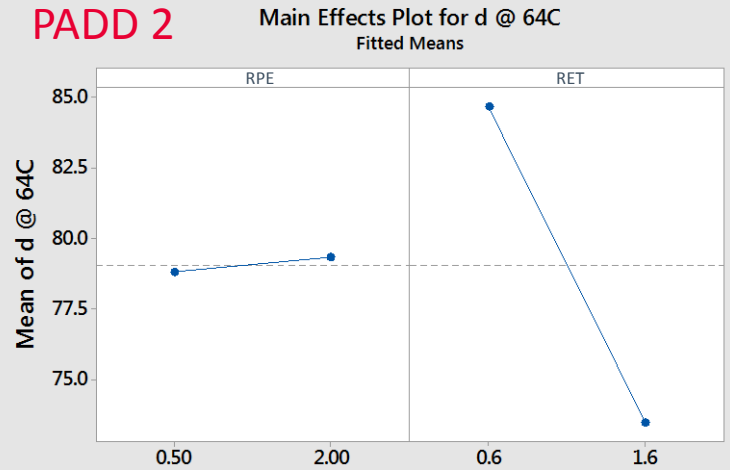
PADD 2 binder has high reactivity to RET

PADD 2 and 3 binders most responsive to RET dosage

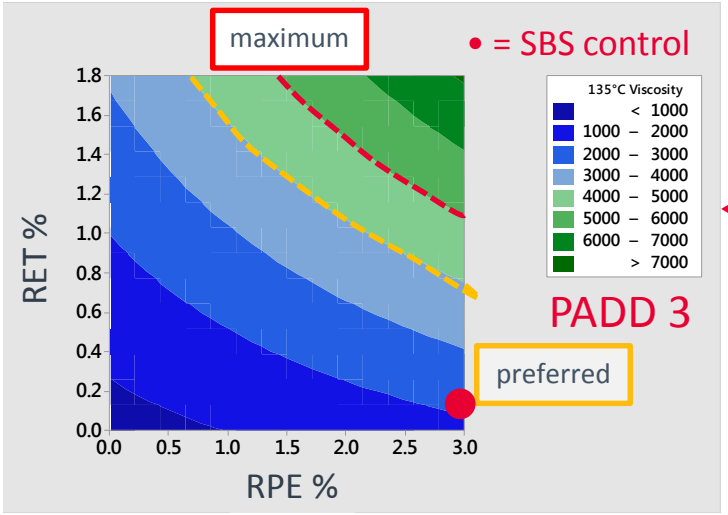
PADD 3



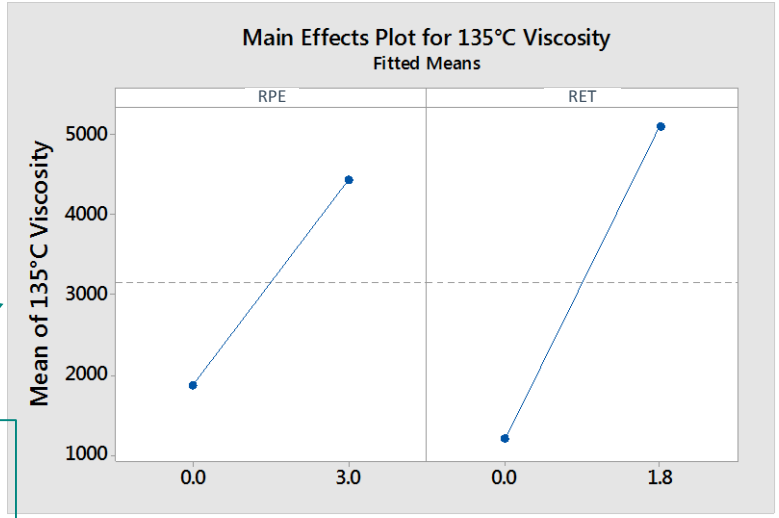
PADD 2



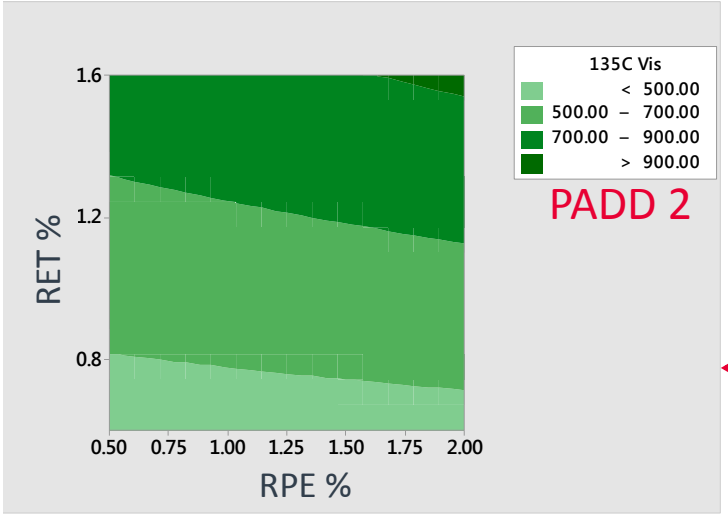
135°C Viscosity – RET has the largest dosage response



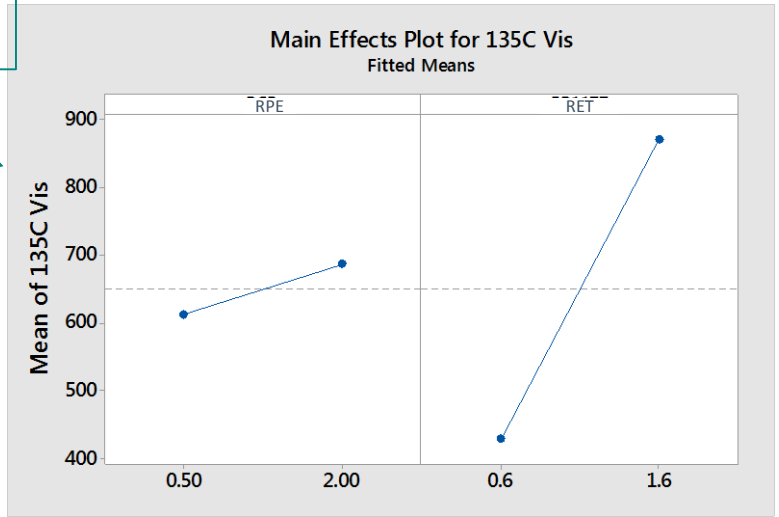
PADD 3 binder significantly more responsive vs dosage



PADD 2 and 3 binders display increased viscosity with both RPE and RET



PADD 2 binder significantly less responsive vs dosage



FIELD PROJECTS

MET TX DOT PG70-22 BINDER SPECIFICATION

- Utilized 750 kg of LLDPE-rich recycled plastic in total 1 kT hot mix
- Blend of LLDPE-rich 1.5% Post-Consumer Recycle + 0.6% RET + 0.2% PPA
  - PCR supplier: Avangard Recycling (Houston TX)
- Texas DOT type D (340-DG-D) mix design - 1.50” lift thickness
- 5.2% asphalt binder with 19.1% RAP
- Limestone/dolomite aggregate
- Passed – AASHTO T322 Indirect Tensile (IDT) Strength Test

*Mix also contained 19% recycled asphalt pavement

Field Placement at Job Site – no differences than normal project

THIS IS ONLY A STARTING POINT …

Planned Future Work

- Mix testing to validate performance - in progress
  - Hamburg
  - IL-SCB
  - IDEAL-CT
  - DCT
- Glover-Rowe/Blackspace study of modified binders
- Optimize formulations to determine maximum recycled plastics loadings in asphalt binders with RET while meeting performance specifications
- More controlled demonstration projects to generate field data!

Any physical properties described in this presentation are typical values and should not to be construed as specifications. Users should confirm results by their own tests.

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