Recycled Plastic in Asphalt Binder and Mixtures

Presented By:

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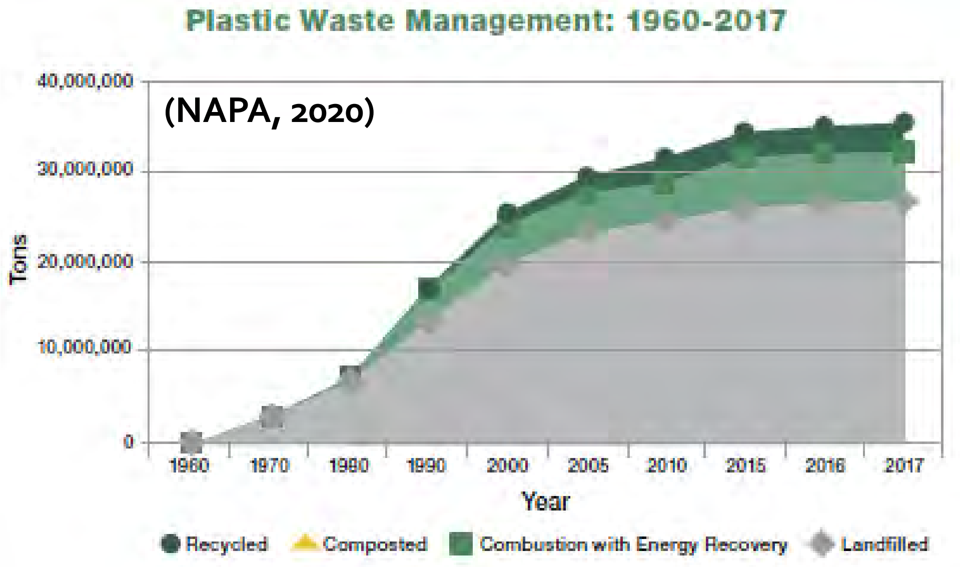
Northeast Asphalt Users Producers Group (NEAUPG)
October 27th 2021
(Somewhere from my house)

Acknowledgements

- Asphalt Binder: Nick Cytowicz, Chris Ericson
- Asphalt Mixture: Ed Haas, Drew Tulanowski, Ed Wass Jr.
- Funding provide by University Transportation Research Center (UTRC) grant

Recycled Plastic in HMA

- Obvious interest in finding a means to reduce landfilling of used plastic
  - Limited alternative uses
- NAPA asked if recycled plastic could be incorporated within HMA
  - Recycled rubber tires
  - Recycled asphalt shingles
  - Need to make sure pavements do not become linear landfills!



Recycled Plastic in HMA

- Some general issues to consider;
  - Consistency & Handling
    - Plastic waste stream highly variable
      - Melting points ≈212F to ≈500F
      - Differences in impact on asphalt performance
  - Micro-plastics
    - Literature shows majority of field projects have used recycled plastics with a dry process
    - Can micro-plastics be generated during production? Milling?

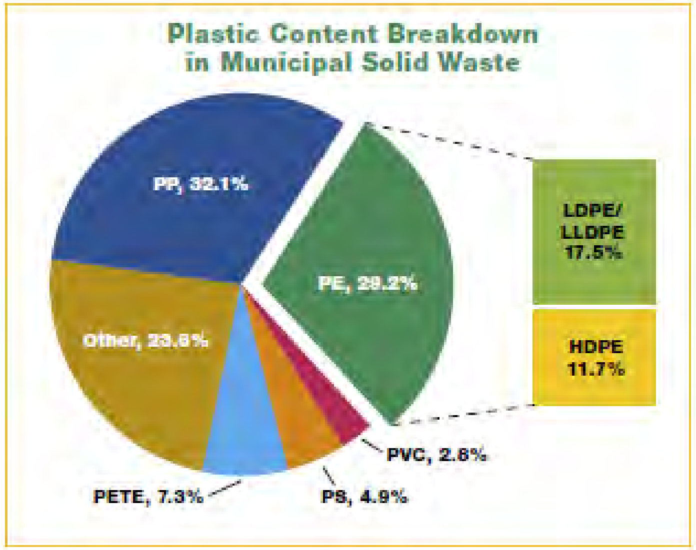
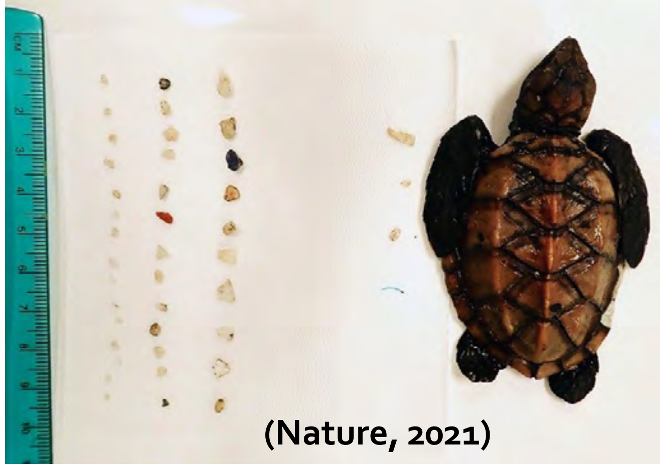


Figure 2-1. Plastic Content Breakdown in Municipal Solid Waste (DuBois, 2020; Based on EPA 2017)



(Nature, 2021)

Recycled Plastic in HMA

- Some efforts in plastic industry to pelletize and process different waste streams
  - Provides level of sorting and consistency
  - Volume reduction & transport ease

Test Run 1:
Back Store Material
Significant Paper Label
Contamination
Some colored bags

Test Run 2:
Front Store Material (customer drop off)
Some Paper, Pouches, Mixed
Material Contamination
Colored bags

Test Run 3:
Back Store Material
Limited Paper Label Contamination
Red printed large bags

(Plastics Industry Assoc., NEMO Meeting, 2019)

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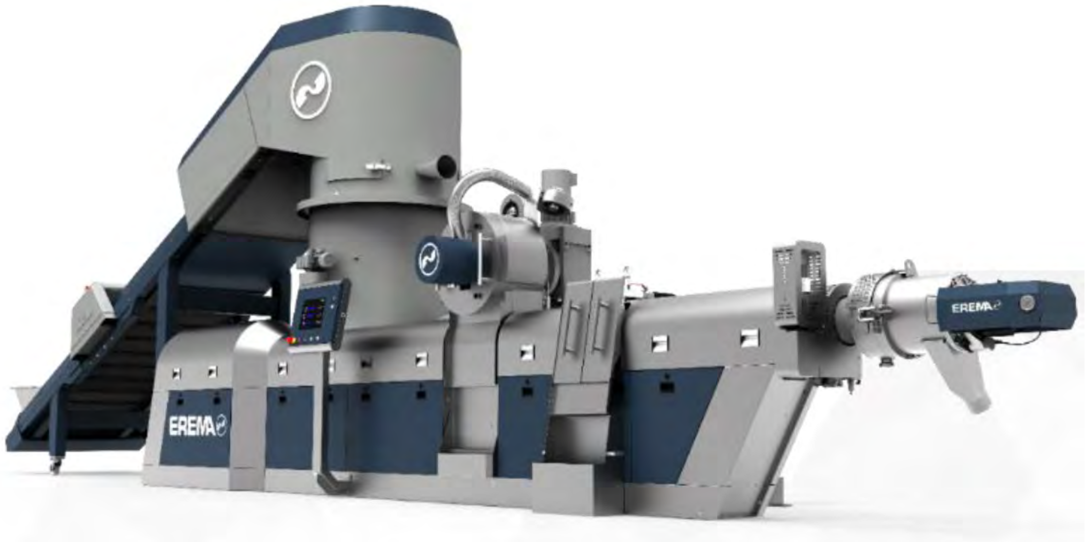


Recycled Plastic in HMA

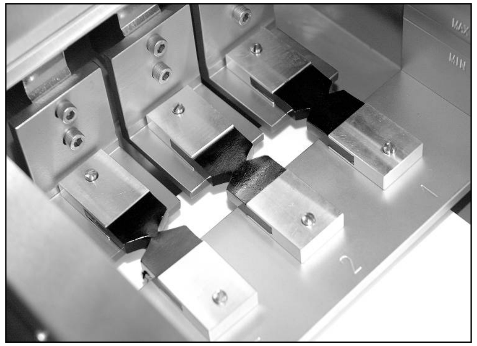
- Study evaluated "processed" recycled plastic material of European company
  - MR6 – "complex arrangement of polyolefins"
    - Bags, electrical cable coating, food packaging, crates/boxes, outdoor furniture
  - MR8 – "thermoplastic polymer"
    - Sports equipment, CD/DVD's, drinking bottles, car parts, toys (LEGO's)
  - MR10 – "co-block polymer"
    - PVC, Teflon, injection molding

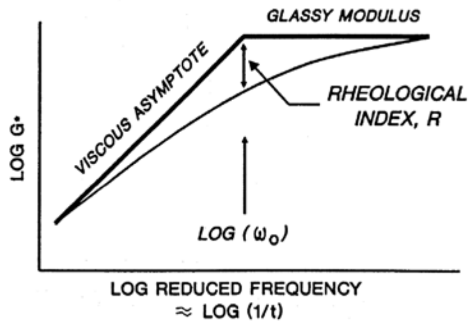


MR6 **MR8** **MR10**


Recycled Plastic in HMA

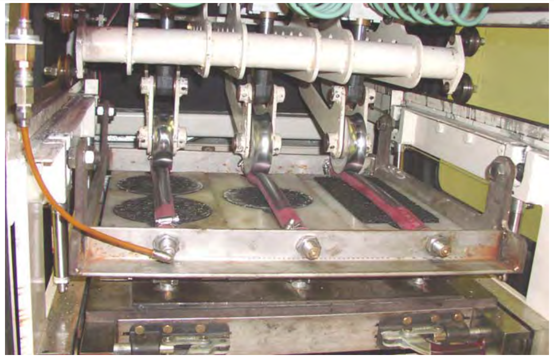
- Research workplan
  - Asphalt binder testing
    - Used to determine “optimum” dosage
    - Separation was of major importance
    - High temperature
      - MSCR, PG grading
    - Intermediate temperature
      - DENT, Glover-Rowe, Loss Tangent
    - Low temperature
      - PG grading, ΔTc, ABCD
    - Original, RTFO, 20 Hr PAV, 40 Hr PAV

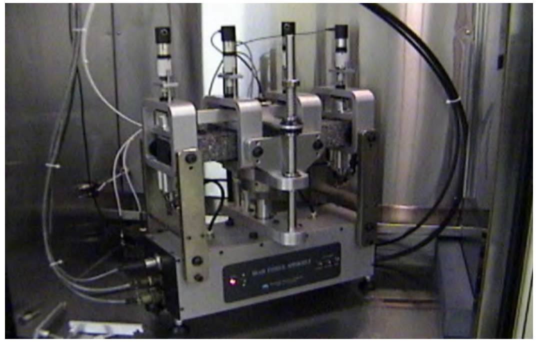


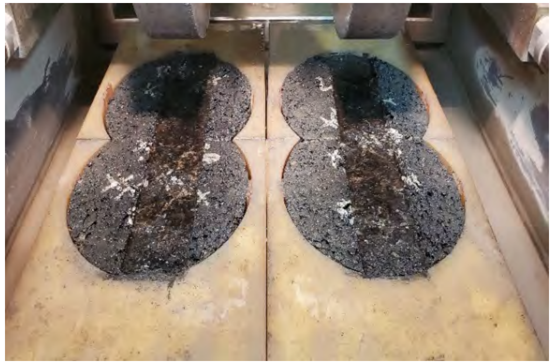


Recycled Plastic in HMA

- Research workplan
  - Asphalt mixture testing
    - Use "optimum" plastic and dosage in a wet process
    - Use a product in the dry process
    - Stiffness
      - E*
    - Rutting
      - APA, Hamburg, Flow Number, HT-IDT
    - Cracking
      - Overlay Tester, IDEAL-CT, SCB FI, Flexural Beam, DC(T)
    - Moisture Damage
      - TSR and Hamburg
    - Short-term and Long-term conditioned







Phase 1 – Asphalt Binder

Asphalt Binder Testing

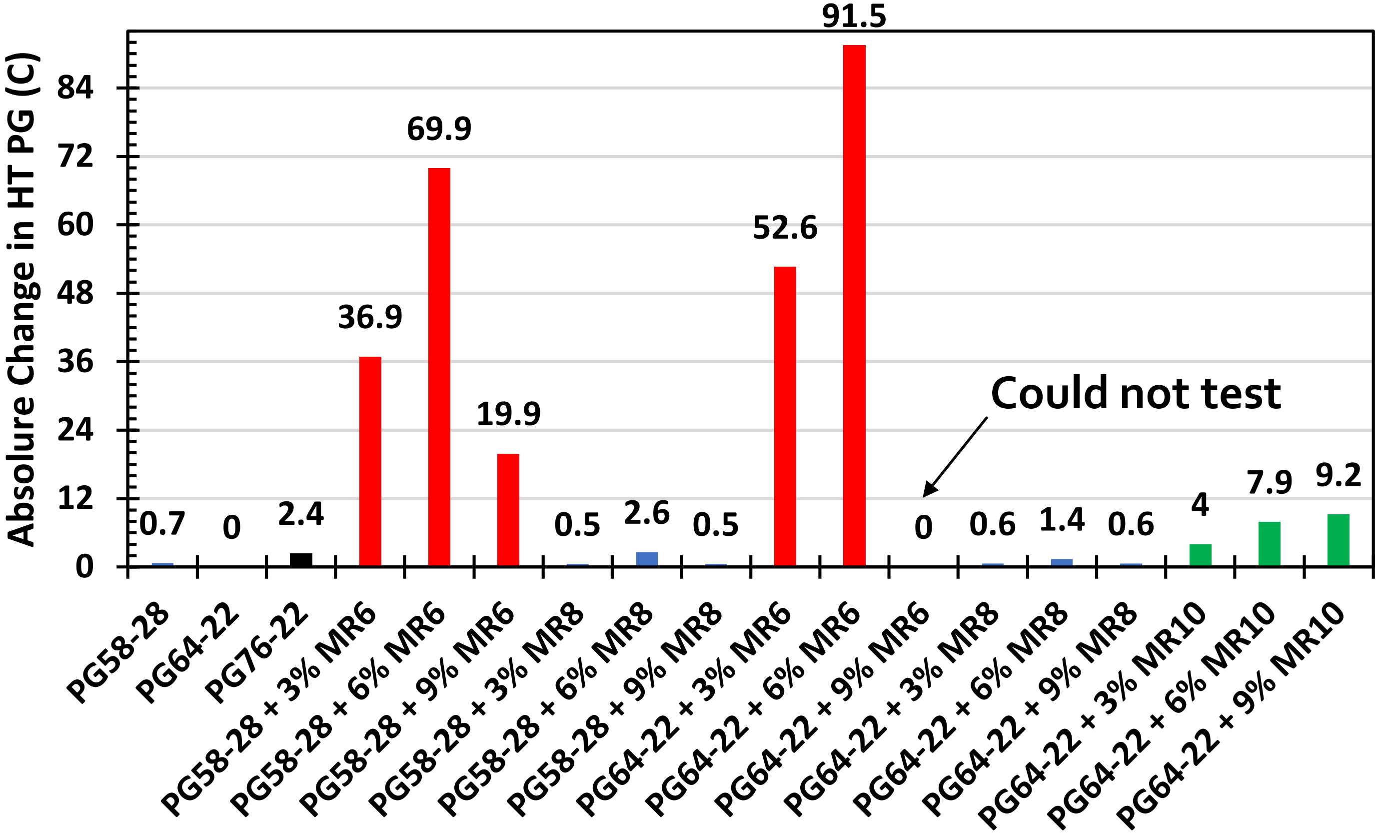
- Binders prepared using high shear mixer
  - 165C for 4 hours (as per manufacturer rec.)
    - Slotted disintegrating head on Silverson mixer
  - No crosslinker or compatibilizer used
  - Dosage rates of 3, 6, 9% by total weight of asphalt binder
  - PG58-28 & PG64-22

Asphalt Binder Testing

- Separation (ASTM D7173)
  - Will the modifier separate from the asphalt binder
    - Pour 50 grams of blended binder in "cigar tube" and seal
    - Maintain vertical in oven for 48 hours @ 163C
    - Remove from oven & place vertically in freezer (0 to -20C) for greater than 4 hrs
  - Remove and cut into 1/3 – place upper and lower 1/3 in container, heat and pour out contents
  - Traditionally used with softening point
    - High temperature DSR

Asphalt Binder Testing

- Separation
  - MR6 showed greatest potential for separation
  - MR8 showed lowest potential (comparable to base binders)



Asphalt Binder Testing

Base Binder	Additive	Dosage Rate	Rotational Viscosity (Pa s)		High Temperature PG Grade				Intermediate Temp PG Grade	Low Temperature PG Grade		
			135C	165C	Original	RTFO	MSCR @ 64C Jnr (1/kPa)	MSCR @ 64C % Rec		Stiffness (S)	m-Value	ΔTc
58-28	N.A.	0%	0.21	0.065	55.7	55.8	12.09	0.0	10.8	-33.1	-36.8	3.7
64-22	N.A.	0%	0.4275	0.117	66.6	67.1	3.28	0.0	21.7	-25.5	-24.8	-0.7
64-22	MR6	3%	0.812	0.282	73.7	74.7	1.1	3.2	26.1	-24	-21.1	-2.9
		6%	1.612	0.519	78.1	85.6	0.286	25	27.3	-23.4	-16.7	-6.7
		9%										
64-22	MR8	3%	0.463	0.127	67.2	67.1	3.04	0.8	22.7	-26.2	-23.9	-2.3
		6%	0.469	0.129	66.4	67.1	3.1	1	22.2	-26.8	-26.3	-0.5
		9%	0.5232	0.142	67.1	66.3	3.01	0.2	19.3	-27.7	-26.9	-0.8
64-22	MR10	3%	0.65	0.175	71.1	71.4	1.66	4	24.1	-24.7	-21.5	-3.2
		6%	0.884	0.243	74	74.2	1.15	9.1	24.7	-25	-20.2	-4.8
		9%	6.75	0.47	79.5	78.9	0.65	16.6	23.9	-24.3	-16.5	-7.8
76-22	N.A.	0%	1.538	0.385	78.1	78.1	0.232	68.3	22.3	-27	-26.1	-0.9

Asphalt Binder Testing

- MR6 (polyolefins)
  - Gain high temperature stiffness
  - Lose m-value (relaxation)
  - Increased viscosity

Base Binder	Additive	Dosage Rate	Rotational Viscosity (Pa s)		High Temperature PG Grade				Intermediate Temp PG Grade	Low Temperature PG Grade		
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Asphalt Binder Testing

- MR8 (thermoplastic)
  - No change in high temp
  - Slight improvement in Int. & low temp
  - No significant change in viscosity

Base Binder	Additive	Dosage Rate	Rotational Viscosity (Pa s)		High Temperature PG Grade				Intermediate Temp PG Grade	Low Temperature PG Grade		
			135C	165C	Original	RTFO	MSCR @ 64C			Stiffness (S)	m-Value	ΔTc
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Asphalt Binder Testing

- MR10 (co-block polymers)
  - Gain high temperature stiffness
  - Lose m-value (relaxation)
  - Increased viscosity

Base Binder	Additive	Dosage Rate	Rotational Viscosity (Pa s)		High Temperature PG Grade				Intermediate Temp PG Grade	Low Temperature PG Grade		
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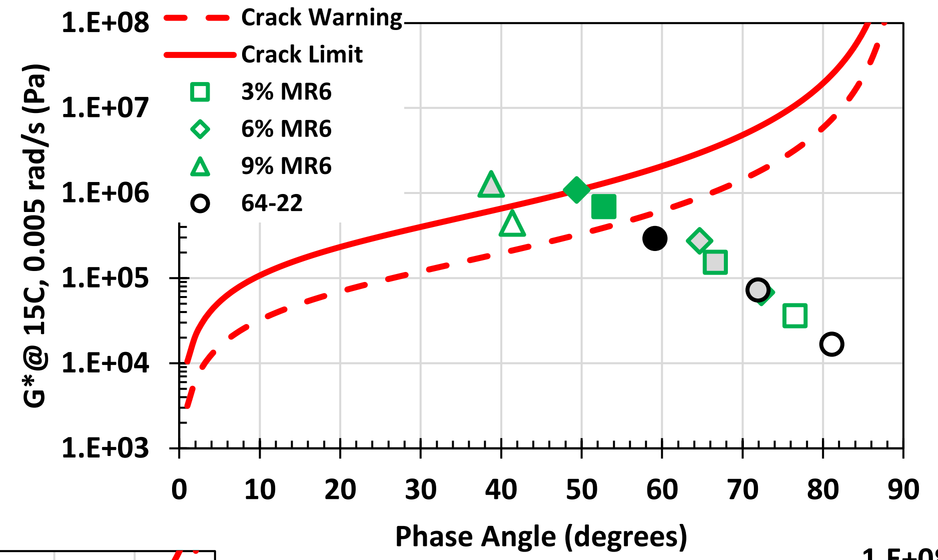
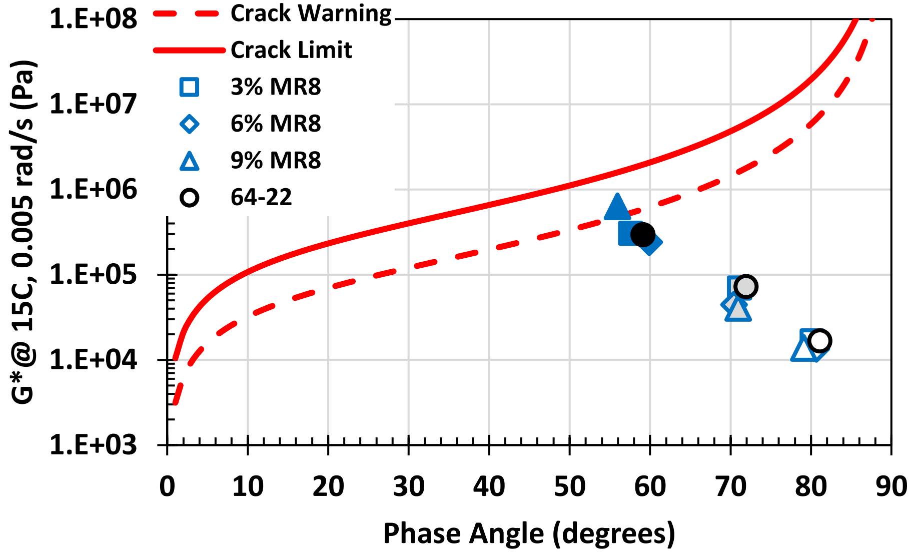
Asphalt Binder Testing

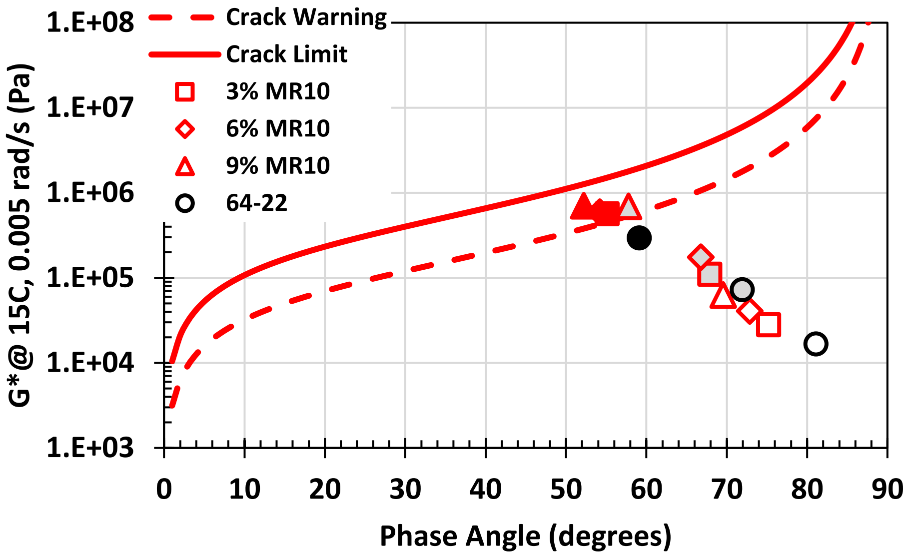
- Glover-Rowe Parameter

$$\frac{G'}{\eta'/G'} = \frac{|G^*| \cdot (\cos\delta)^2}{\sin\delta} \cdot \omega$$



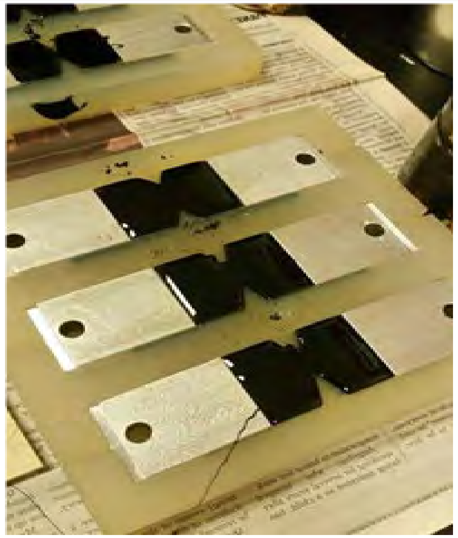
Open symbols = Original
Gray filled = RTFO
Filled = 20 hr PAV

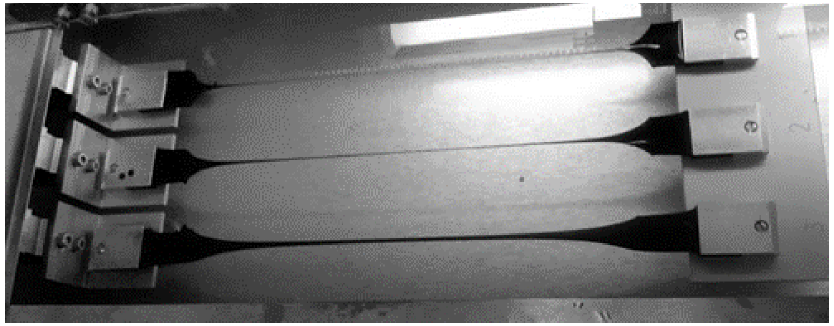


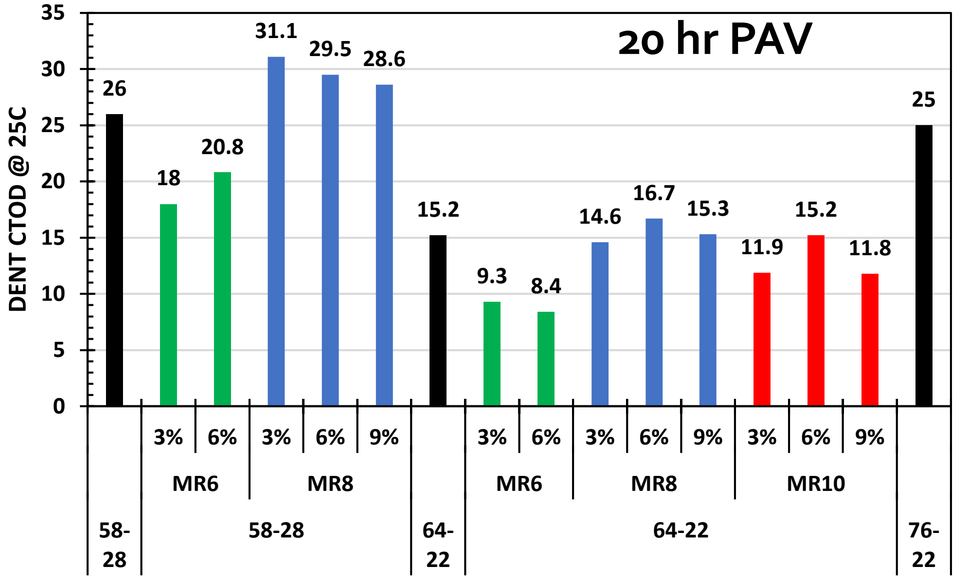


Asphalt Binder Testing

- Double Edge Notched Tension (DENT)
  - Measure of asphalt binder's ductility
  - Conducted at 25C
  - Compared crack tip opening displacement (CTOD)

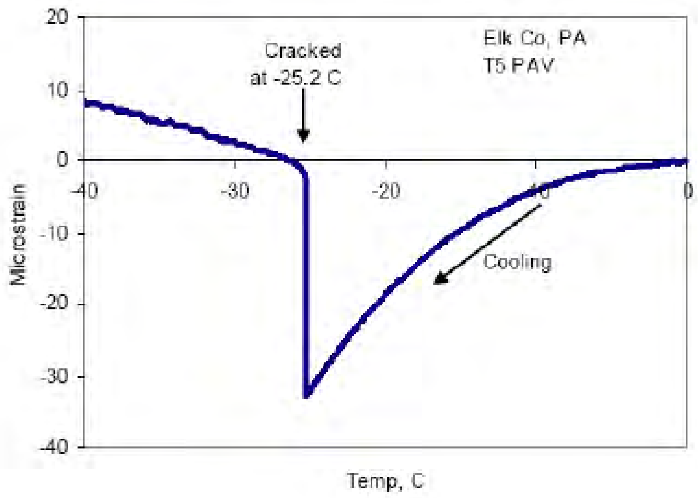


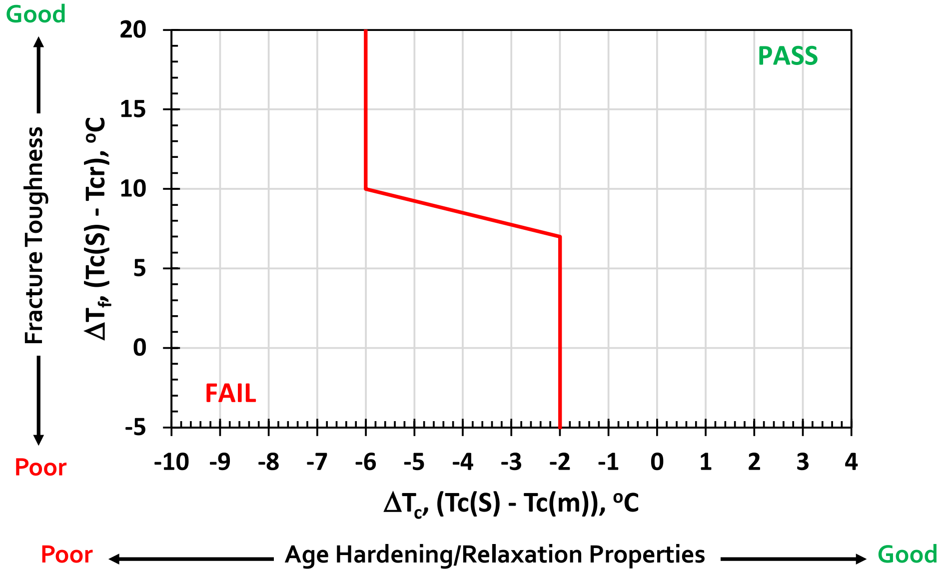




Asphalt Binder Testing

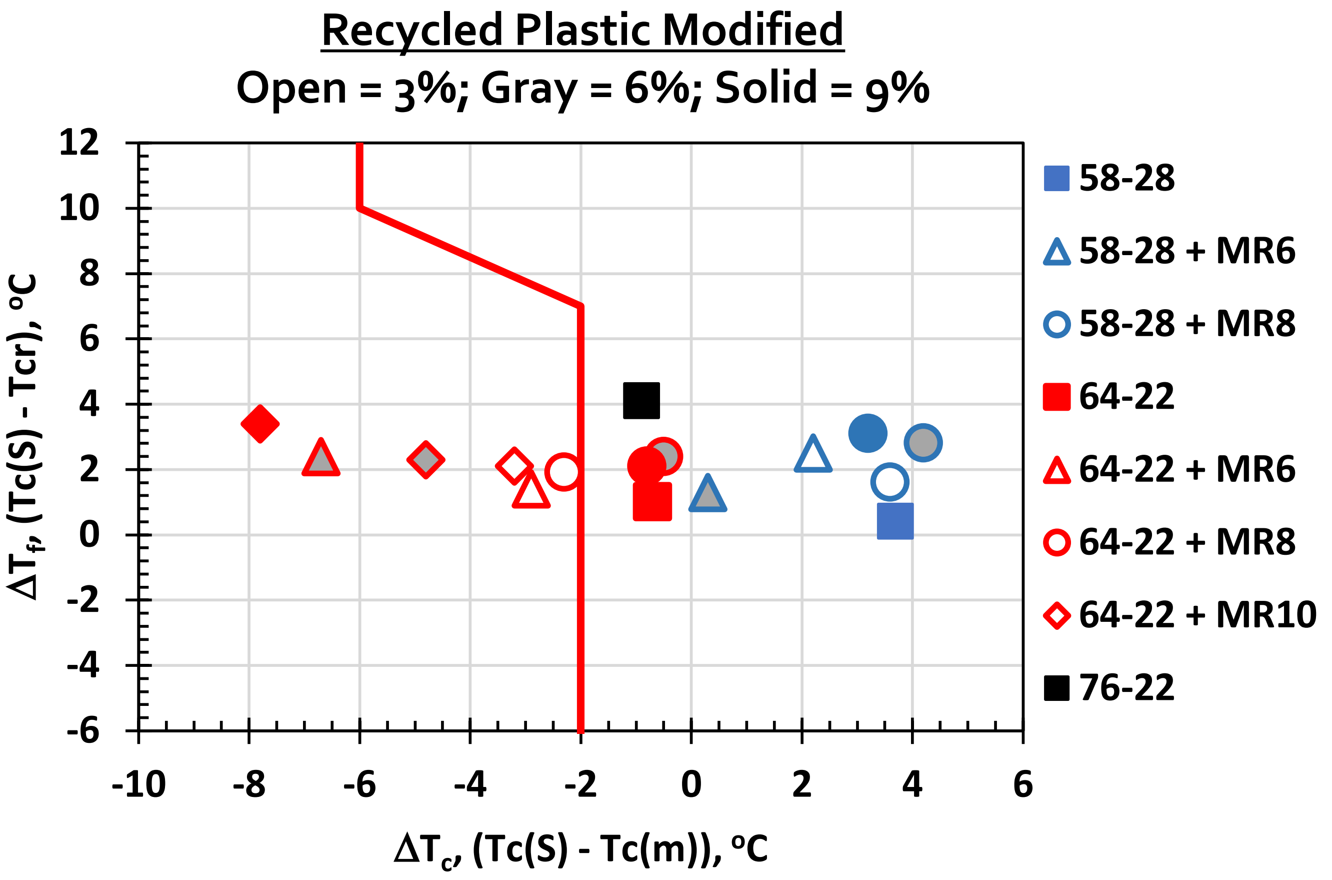
- Asphalt Binder Cracking Device (ABCD)
  - The ABCD determines the critical cracking temperature due to thermally induced stress
  - Asphalt binder poured between an invar and latex mold to form a ring
  - Chamber cools the specimens at -20°C per hr
  - Strain gauge determines when “cracking” occurs; specimen temperature when this occurs is determined as T_{cr}
  - NCHRP 9-60 recommends to use in conjunction with ΔT_c

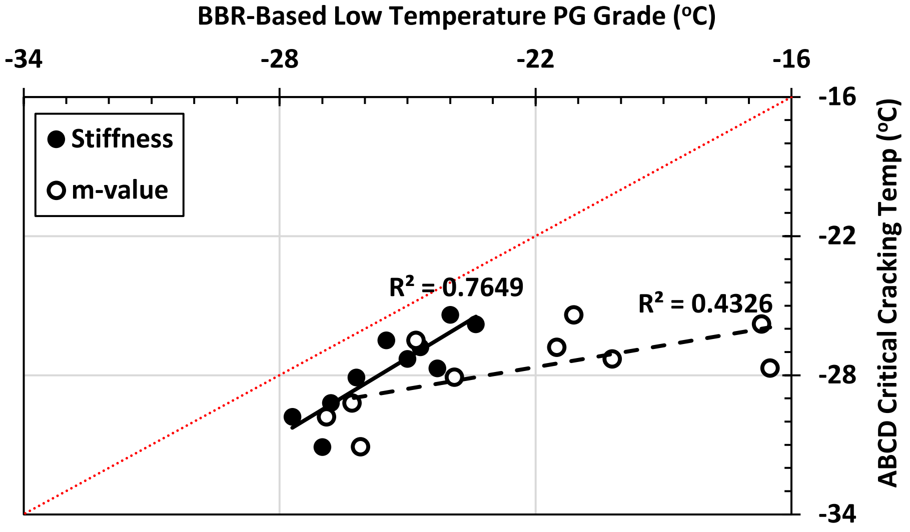


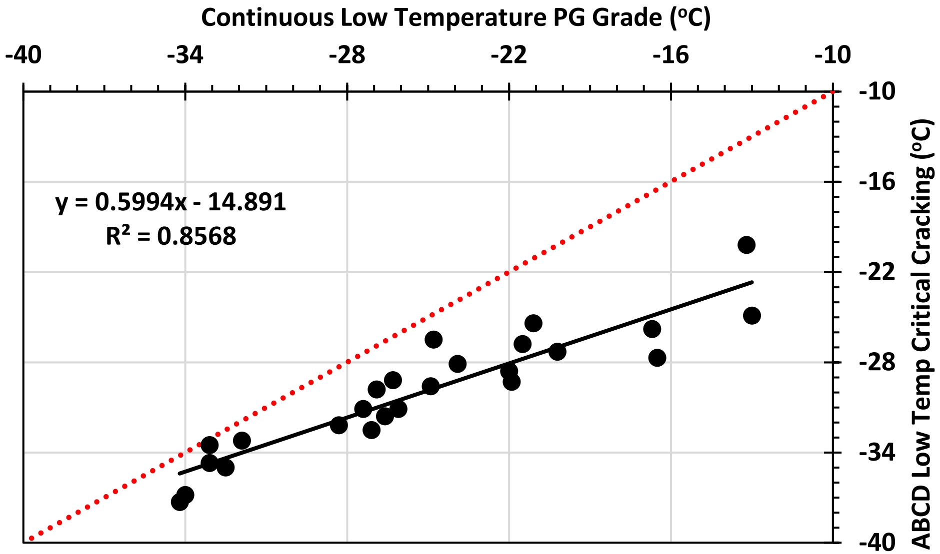


Asphalt Binder Testing

- ABCD Testing Results







Asphalt Binder Conclusions

- The MR8 (Thermoplastic) resulted in the better performance
  - Little to no change in HT; slight improvement in LT; lower potential to separate; best for "fatigue" analysis
- MR6 (PP/PE) pulled PG grade warmer and separated
- MR10 (Co-block) pulled PG grade warmer but not as bad for separation

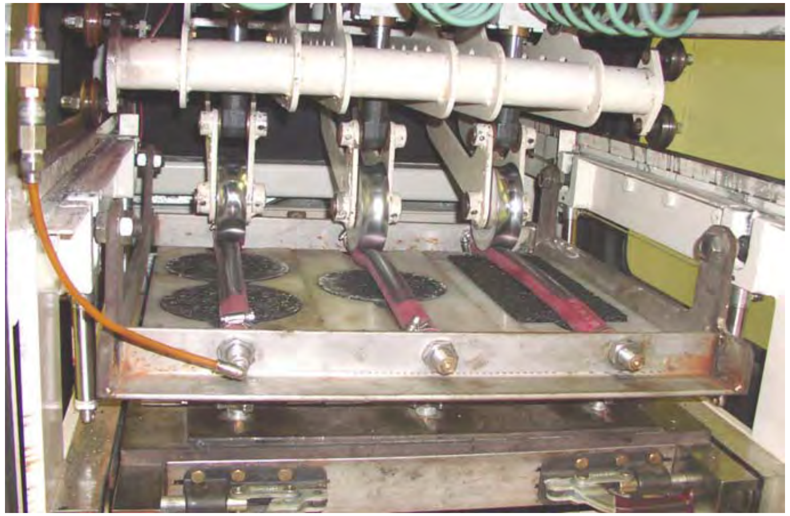
Phase 2 – Mixture Study

Mixture Study

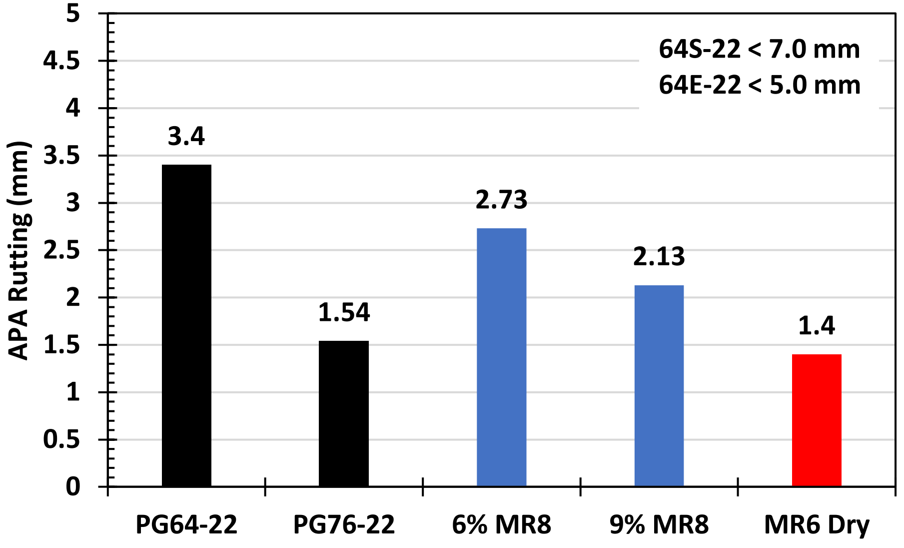
- Wet Process
  - Selected MR8 at 6% to 9% by total weight of binder based on binder results
- Dry Process
  - Selected MR6 at 1% by weight of mix
  - Used dry in other projects (VTRC, 2021)
- 9.5mm NMAS, Trap Rock aggregate
  - 6.1% asphalt content
  - No RAP
  - VMA = 17.1%
- Short-term (4 hrs, 135C) and Long-term Conditioned (24 hrs, 135C)

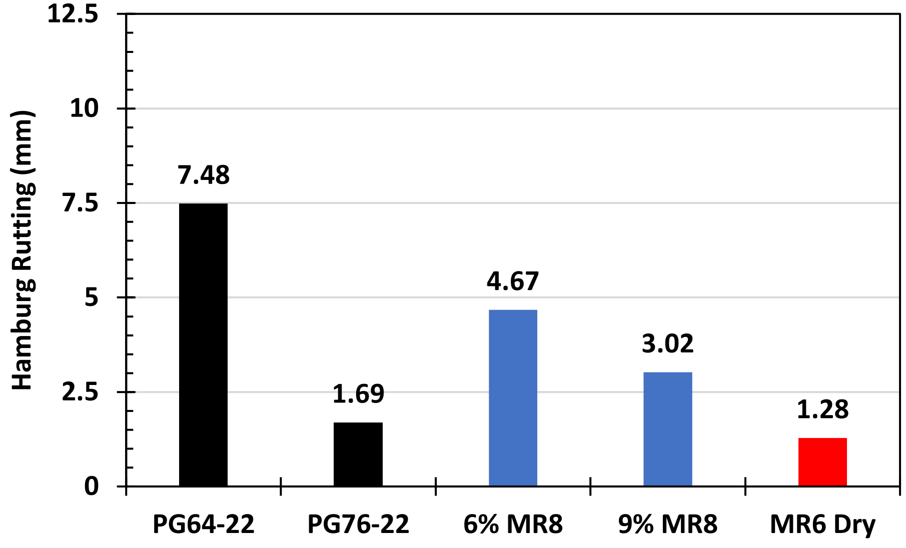
Rutting

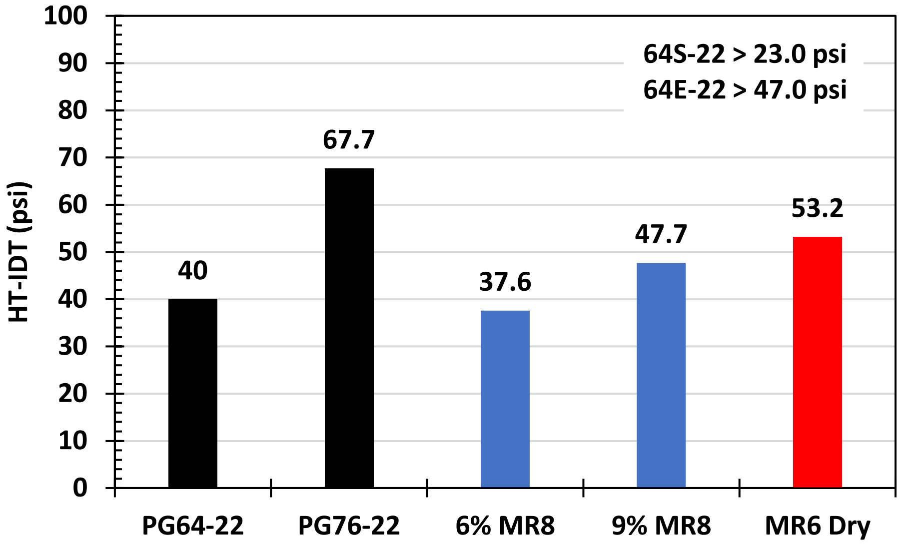
- Rutting evaluated using;
  - Asphalt Pavement Analyzer (64°C)
  - Hamburg (50°C)
  - High Temperature IDT (44°C)
  - AMPT Flow Number (54°C)
- Mixtures were only conditioned for short term conditioning

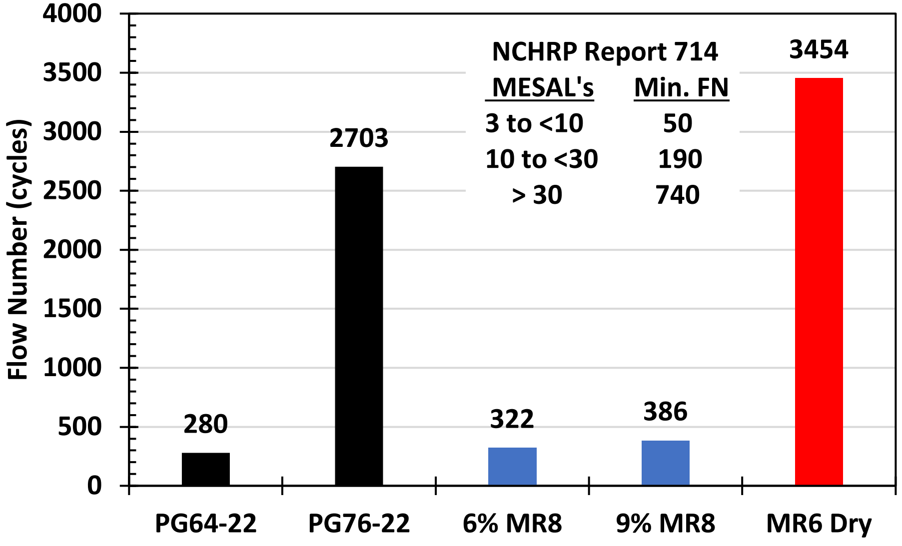


Rutting Results



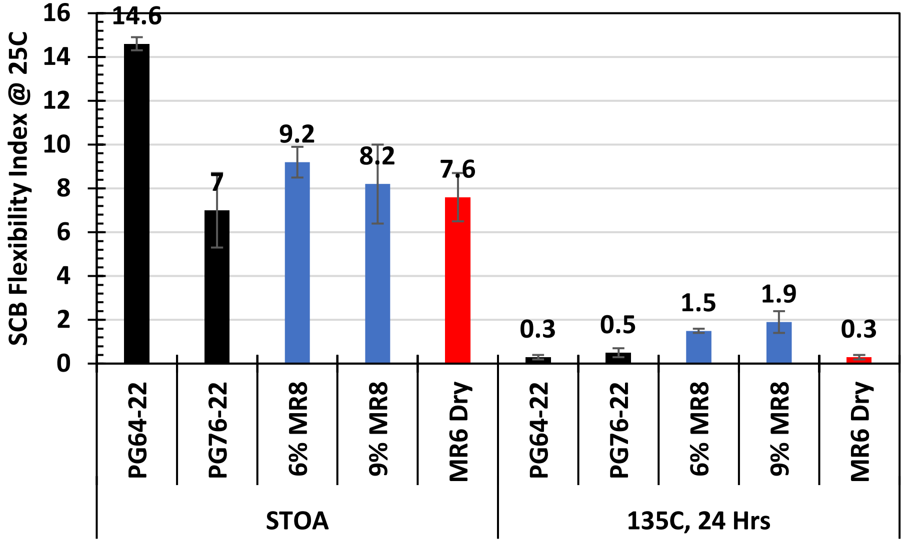




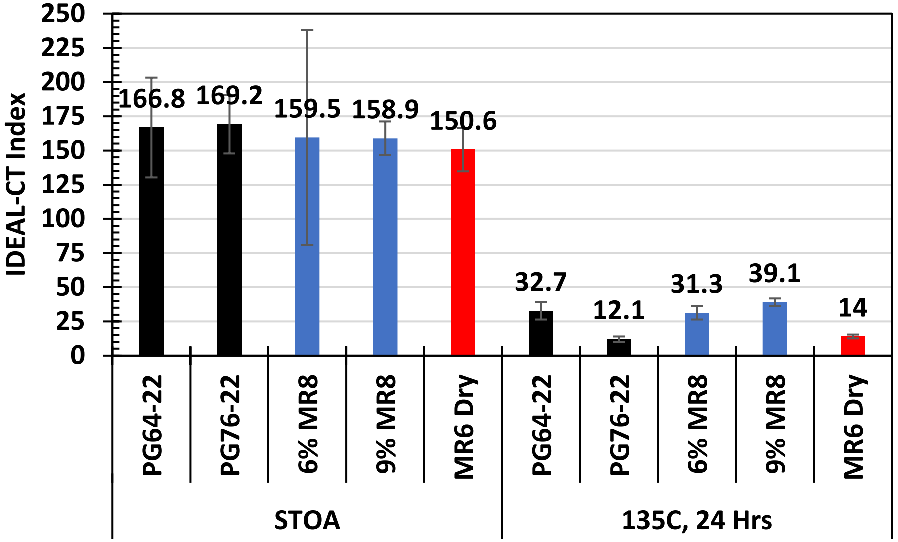


Fatigue Cracking Results

SCB FI



IDEAL-CT



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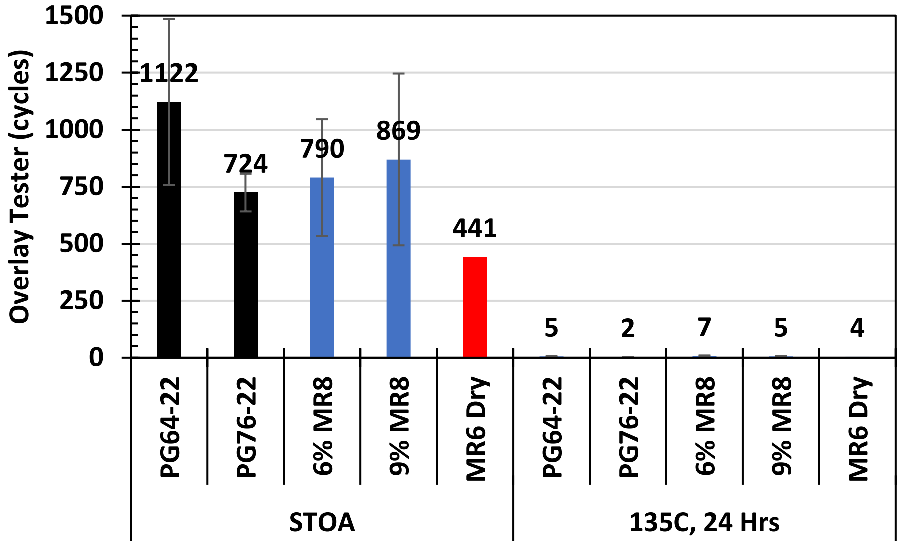
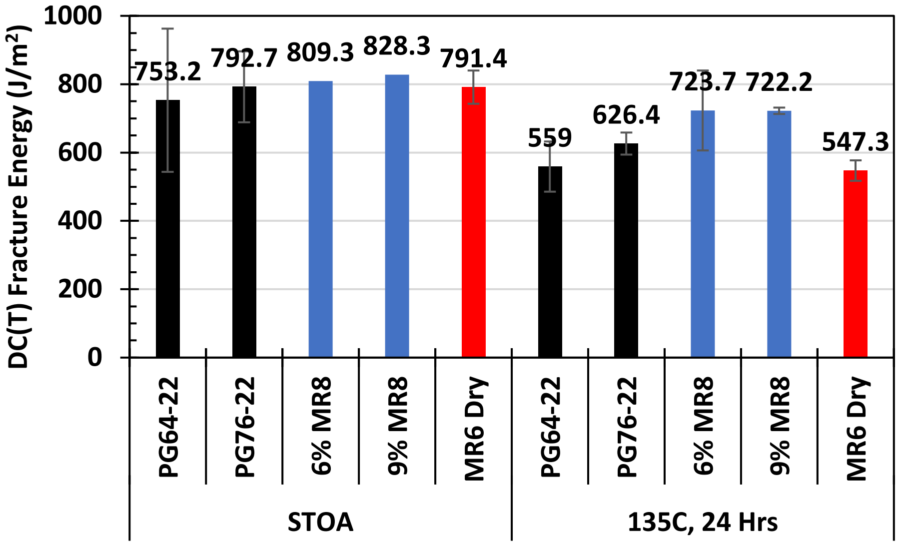
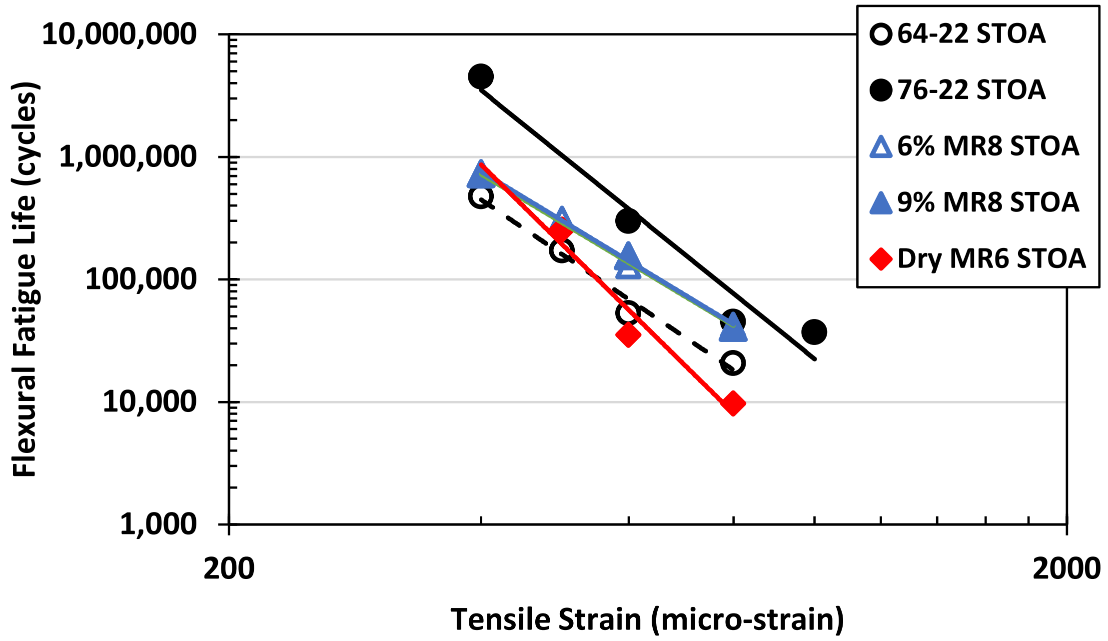
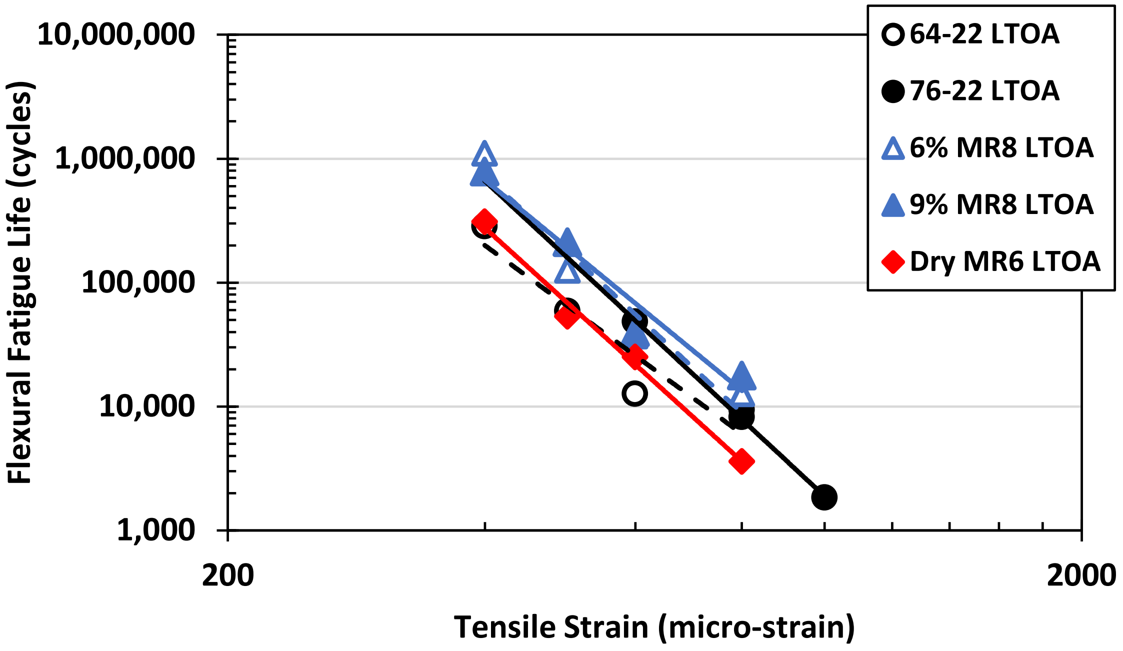


DC(T)



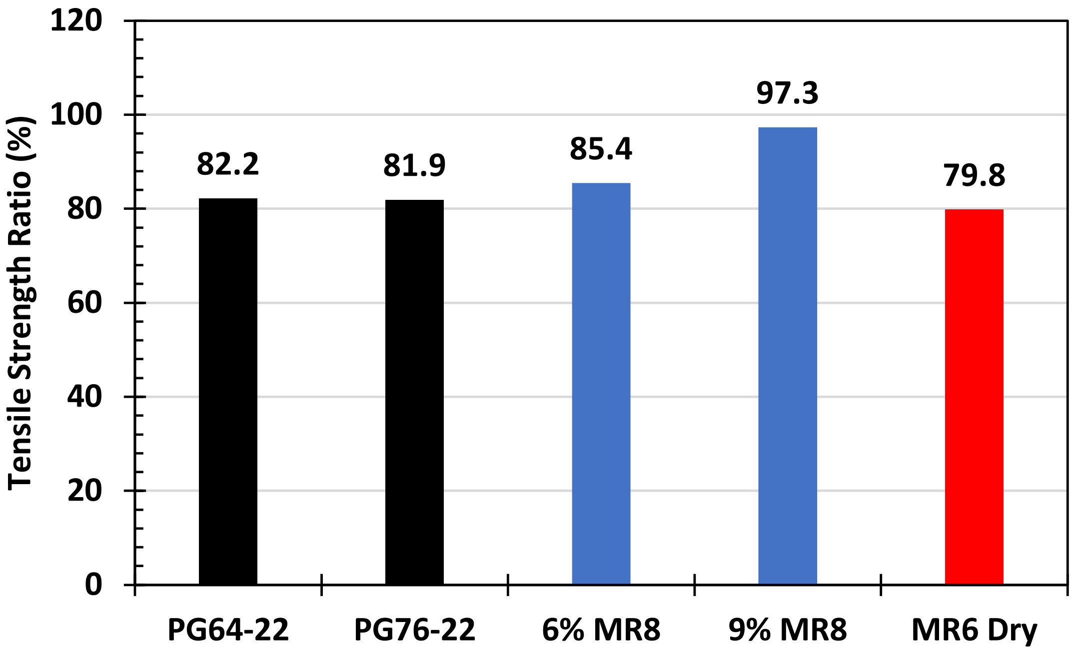
Fatigue Cracking Results – Flexural Beam

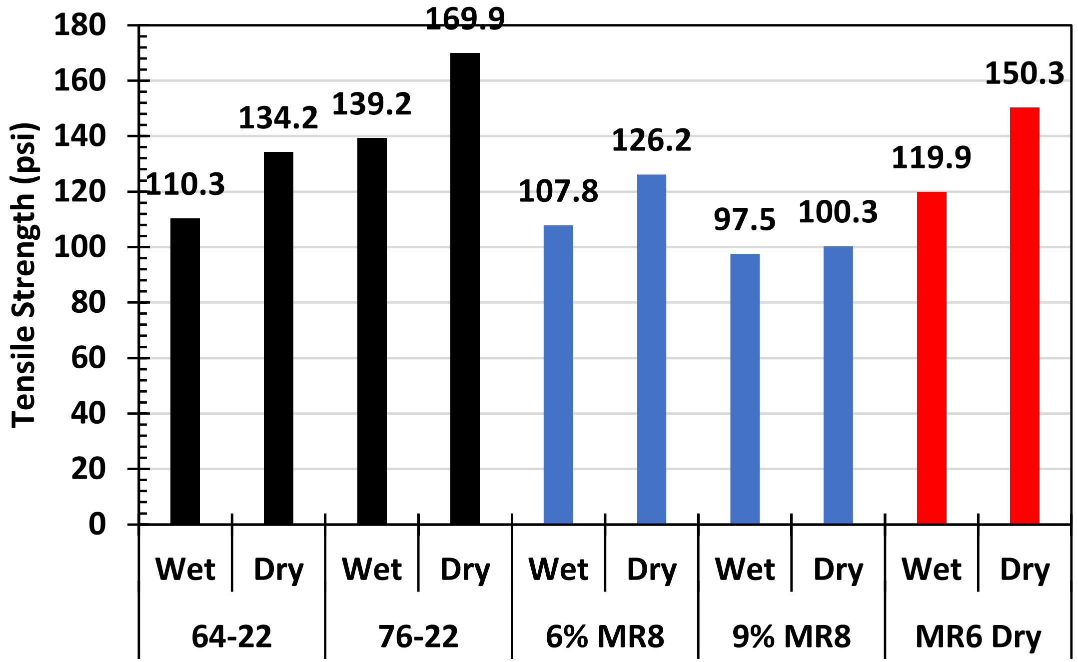




Moisture Damage Potential

- No mix showed an inflection point during Hamburg testing





Moisture Damage Potential

MR8 (Wet Process; 9% by Wt. of Binder)

MR6 (Dry Process; 1% by Wt. of Mix)

Other Considerations

Volumetrics

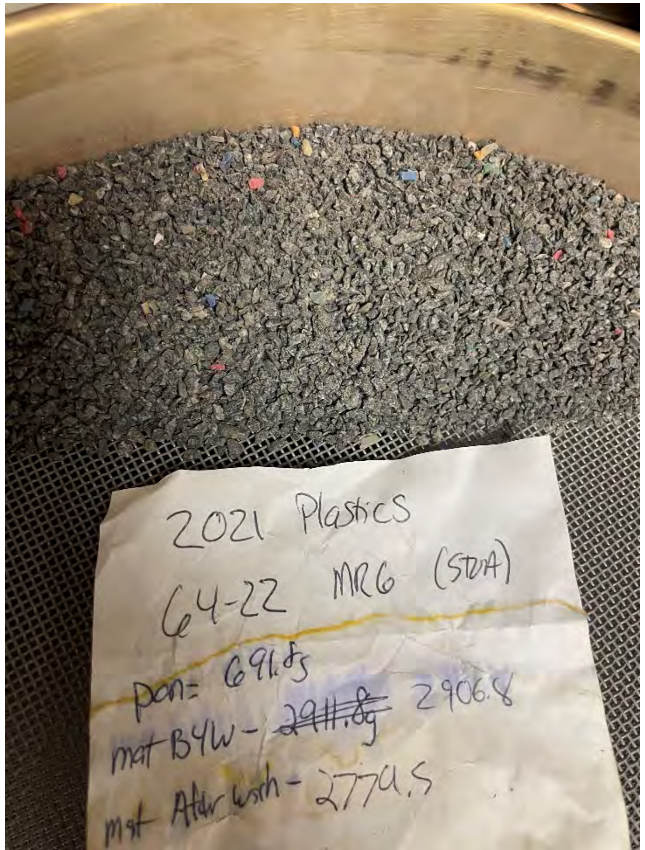
- Inclusion of plastic will impact the volumetrics of your design and production
  - Statistically significant when using the dry process
  - Need to take into account for Gmm and Gsb

Mix Type	Gmm (g/cm3)
64-22	2.670
76-22	2.670
6% MR8	2.683
9% MR8	2.682
1% Dry MR6	2.628

Mix Type	Gsb (g/cm3)
Wet Process	2.964
Dry Process	2.897

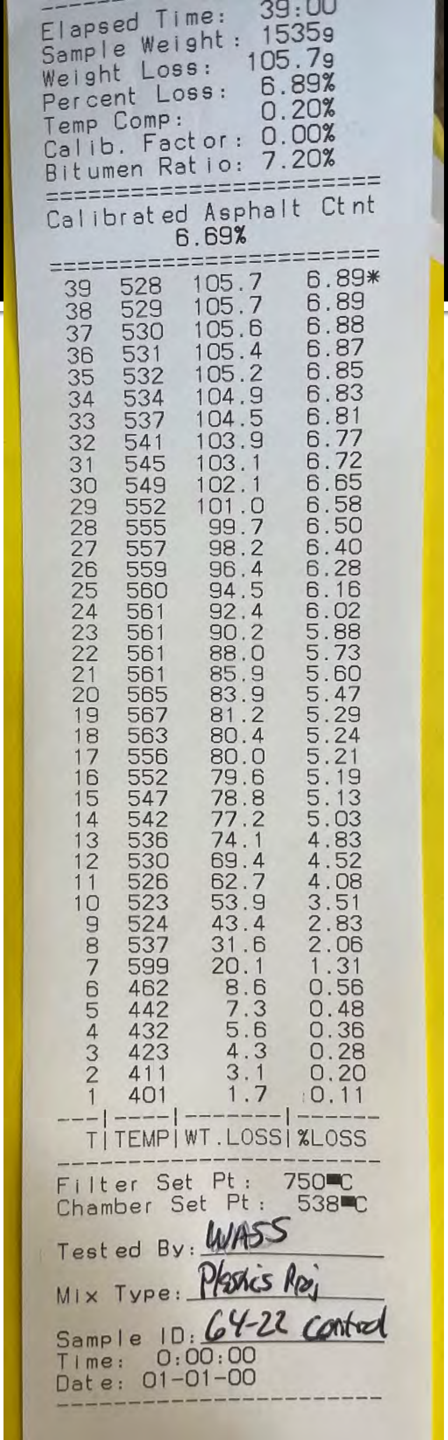
Solvent Extraction

- Recycled plastic remaining as part of aggregate
  - Some will float during washed gradation



Ignition Oven

- Recycled plastic will come up as mass loss in dry process
- Will need to include in correction factor (similar to fibers in SMA and OGFC)
  - Aggregate correction factor was 0.55%
    - Control: 6.14% loss
    - Dry MR6: 7.06% loss

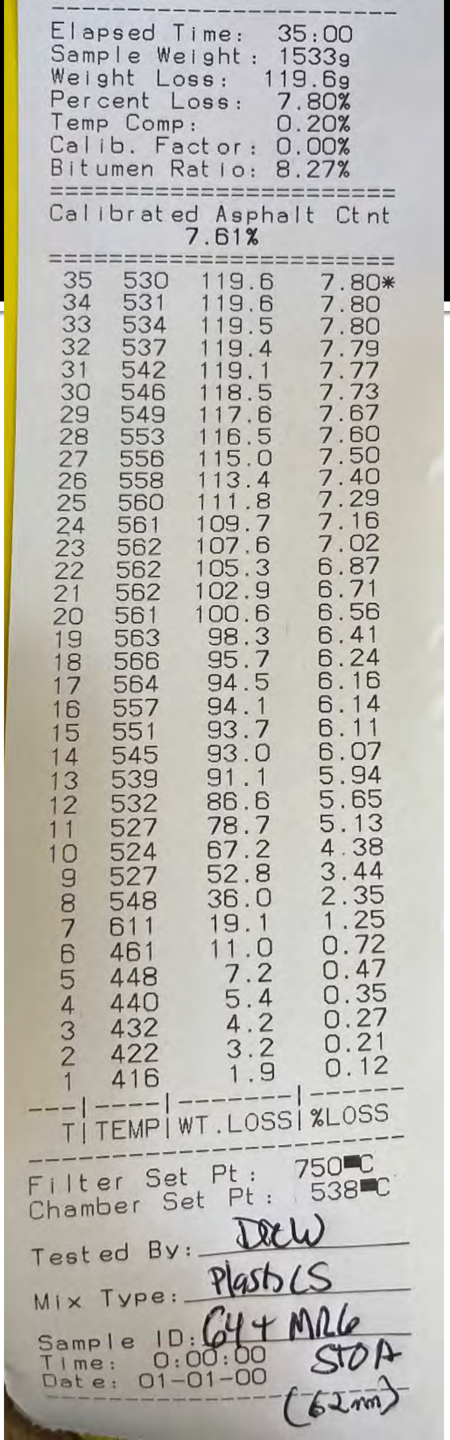


Elapsed Time: 39:00
Sample Weight: 1535g
Weight Loss: 105.7g
Percent Loss: 6.89%
Temp Comp: 0.20%
Calib. Factor: 0.00%
Bitumen Ratio: 7.20%

Calibrated Asphalt Ctnt
6.69%

T	TEMP	WT.LOSS	%LOSS
39	528	105.7	6.89*
38	529	105.7	6.89
37	530	105.6	6.88
36	531	105.4	6.87
35	532	105.2	6.85
34	534	104.9	6.83
33	537	104.5	6.81
32	541	103.9	6.77
31	545	103.1	6.72
30	549	102.1	6.65
29	552	101.0	6.58
28	555	99.7	6.50
27	557	98.2	6.40
26	559	96.4	6.28
25	560	94.5	6.16
24	561	92.4	6.02
23	561	90.2	5.88
22	561	88.0	5.73
21	561	85.9	5.60
20	565	83.9	5.47
19	567	81.2	5.29
18	563	80.4	5.24
17	556	80.0	5.21
16	552	79.6	5.19
15	547	78.8	5.13
14	542	77.2	5.03
13	536	74.1	4.83
12	530	69.4	4.52
11	526	62.7	4.08
10	523	53.9	3.51
9	524	43.4	2.83
8	537	31.6	2.06
7	599	20.1	1.31
6	462	8.6	0.56
5	442	7.3	0.48
4	432	5.6	0.36
3	423	4.3	0.28
2	411	3.1	0.20
1	401	1.7	0.11

Filter Set Pt: 750■C
Chamber Set Pt: 538■C
Tested By: WASS
Mix Type: Plastics Proj
Sample ID: 64-22 Control
Time: 0:00:00
Date: 01-01-00



Elapsed Time: 35:00
Sample Weight: 1533g
Weight Loss: 119.6g
Percent Loss: 7.80%
Temp Comp: 0.20%
Calib. Factor: 0.00%
Bitumen Ratio: 8.27%

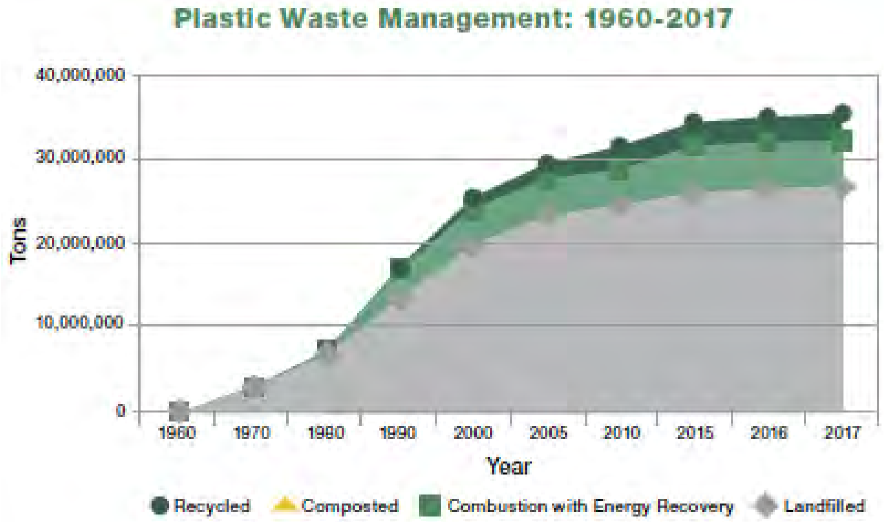
Calibrated Asphalt Ctnt
7.61%

T	TEMP	WT.LOSS	%LOSS
35	530	119.6	7.80*
34	531	119.6	7.80
33	534	119.5	7.80
32	537	119.4	7.79
31	542	119.1	7.77
30	546	118.5	7.73
29	549	117.6	7.67
28	553	116.5	7.60
27	556	115.0	7.50
26	558	113.4	7.40
25	560	111.8	7.29
24	561	109.7	7.16
23	562	107.6	7.02
22	562	105.3	6.87
21	562	102.9	6.71
20	561	100.6	6.56
19	563	98.3	6.41
18	566	95.7	6.24
17	564	94.5	6.16
16	557	94.1	6.14
15	551	93.7	6.11
14	545	93.0	6.07
13	539	91.1	5.94
12	532	86.6	5.65
11	527	78.7	5.13
10	524	67.2	4.38
9	527	52.8	3.44
8	548	36.0	2.35
7	611	19.1	1.25
6	461	11.0	0.72
5	448	7.2	0.47
4	440	5.4	0.35
3	432	4.2	0.27
2	422	3.2	0.21
1	416	1.9	0.12

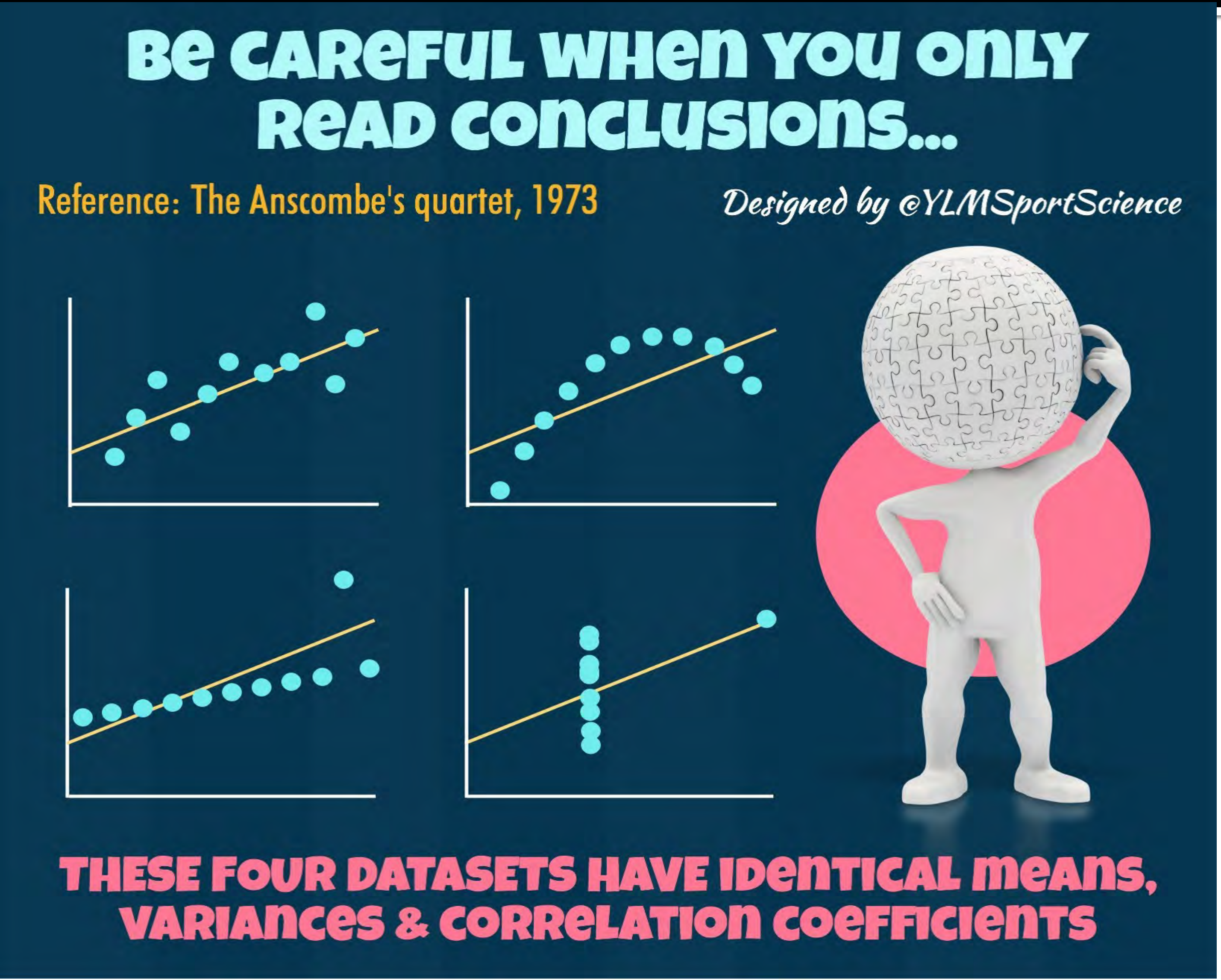
Filter Set Pt: 750■C
Chamber Set Pt: 538■C
Tested By: Drew
Mix Type: Plastics
Sample ID: 64 + MR6
Time: 0:00:00
Date: 01-01-00
STOP
(62min)

Conclusions & Future

- The type of recycled plastic will significantly impact asphalt performance
  - Wet process vs Dry process?
  - Selection of plastic type?
- Moving forward in NJ, pilot proposed
  - Running through refinery
  - Enough to supply ≈ 3,000 mix tons of HMA
    - 3% MR8 ≈ 9,000 lbs of recycled plastic (4.5 tons)
    - 4.5% MR8 ≈ 13,500 lbs of recycled plastic (6.75 tons)
    - 6% MR8 ≈ 18,000 lbs of recycled plastic (9 tons)



Thank you for your time!
Questions?



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