Review of Mass Loss Parameter for Soft PG Grades

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FHWA Asphalt Binder ETG

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Introduction

- Background
- 2017 Base Asphalt Data
- RTFO Mass Loss Studies
  - Inter-laboratory study
  - Ruggedness Study
  - Effect of RTFO temperature.
- Next Steps

Background

- NCRHP 9-36
  - Volatility is more representative of the potential for “blue smoke” than mass change.
  - Only a small amount of volatiles (~40% of mass loss) was collected during study.
  - Future work
    - Consider a separate measure for binder volatility. Numerous proposals including VCS system, vacuum were proposed.
- Simulation of Plant Aging
  - Conventional mixing/compaction temperatures are 150°C/135°C for HMA, particularly for softer grades.
  - Temperatures are getting lower due to WMA, emissions considerations, etc.

Background

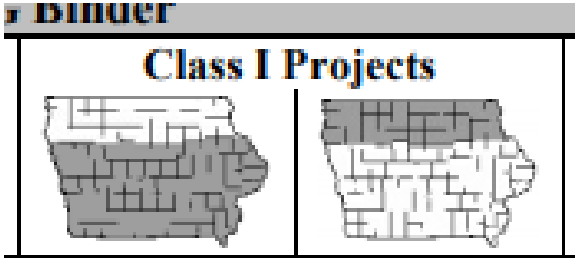
Examples of State Specifications

PG 58-34

PG 58-28

- PG 58-28 for all overlays

Iowa



PG 58-28 **PG 58-34**

Minnesota

Type of Construction	Recommended Asphalt Binder for < 3 Million ESALs (20 yr)	Recommended Asphalt Binder for 3 - 10 Million ESALs (20 yr)	Recommended Asphalt Binder for > 10 Million ESALs (20 yr)
Overlay Wearing Mixture (Top 4")[3]	PG 58S-28	PG 58S-28[1]	PG 58H-28[1]
New Construction[2] Wearing Mixture (Top 4")[3]	PG 58H-34	PG 58H-34[1]	PG 58V-34[1]
All Non-Wear Mixture (Below 4" from Surface)	PG 58S-28		

Background

AASHTO T240

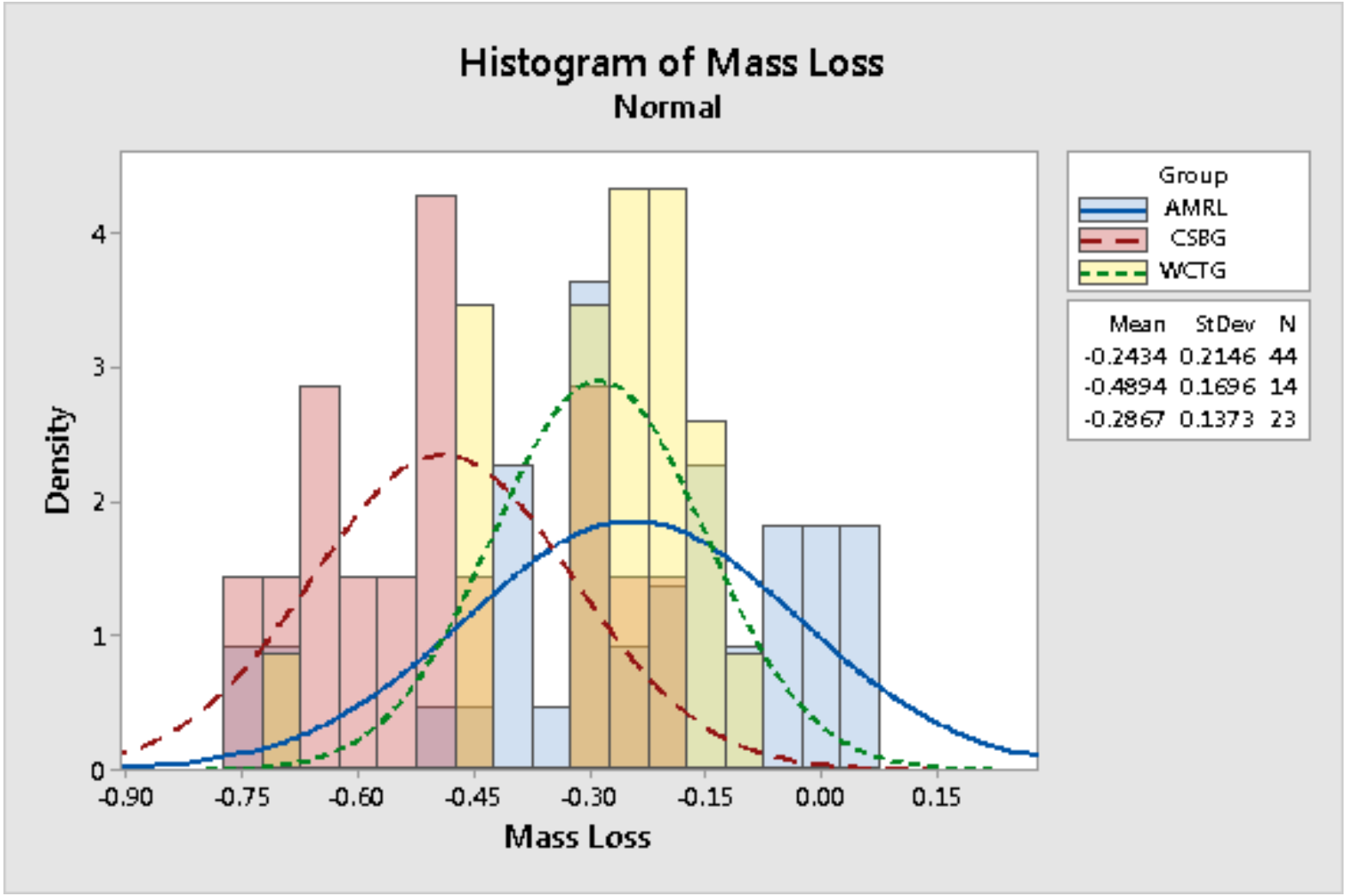
- Precision and Bias Statement

Condition	Standard Deviation (1s)	Acceptable Range of Two Test Results (d2s)
Single Operator Precision	1s = 0.0061+0.0363(X)	d2s = (0.0061+0.0363(Xavg)) x (2.83)
Multi-Lab Precision	1s = 0.00153+0.1365(X)	d2s = (0.00153+0.1365(Xavg)) x (2.83)

- P&B Statement based on mass loss values ranging from -0.05 to -0.51. Higher mass loss values use the equation to extrapolate.

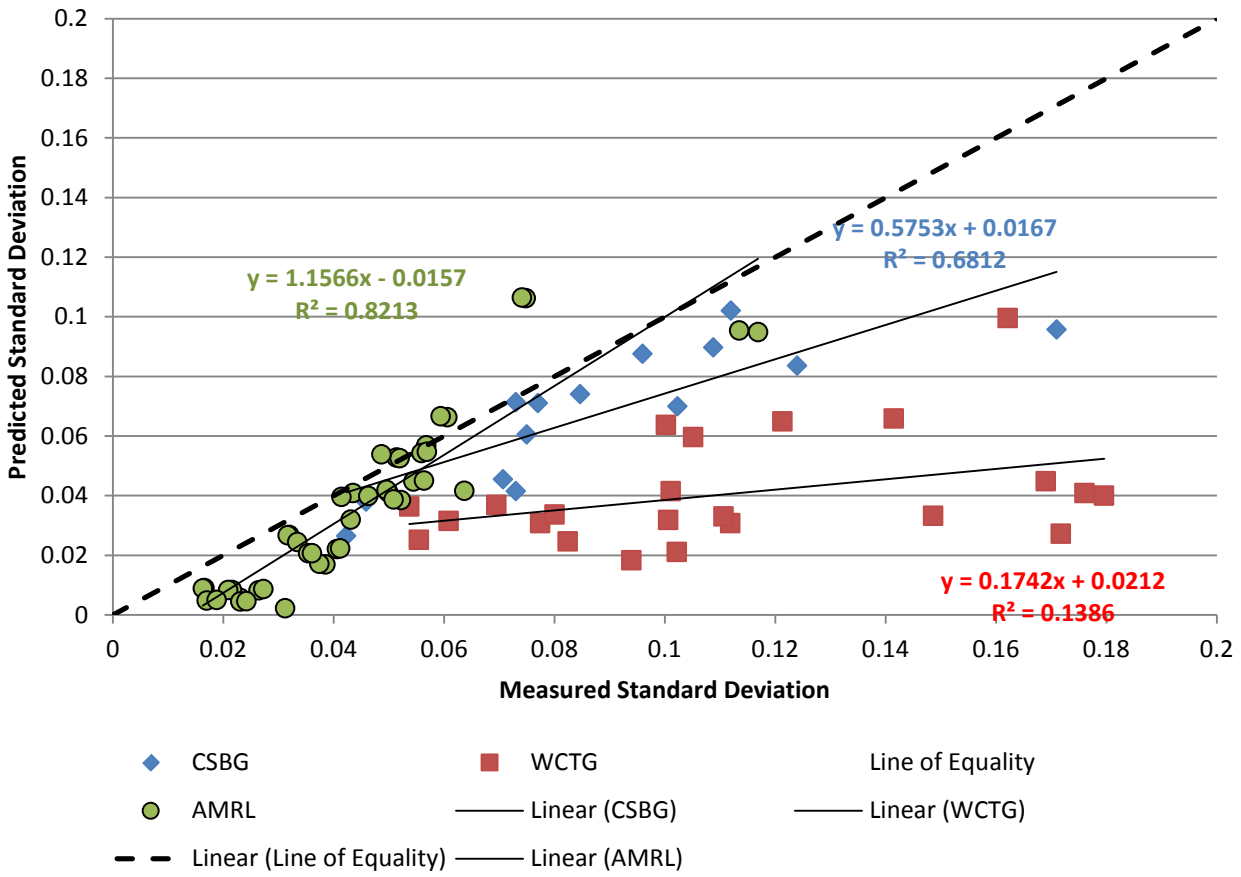
Data from Round Robin Programs

Mean Mass Loss



Data from Round Robin Programs

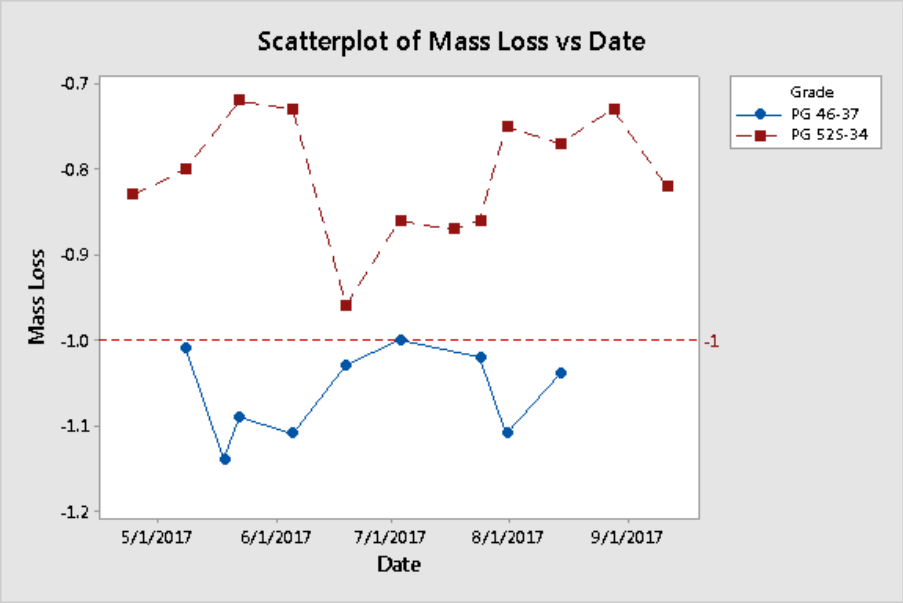
CSBG and WCTG 2013-2016

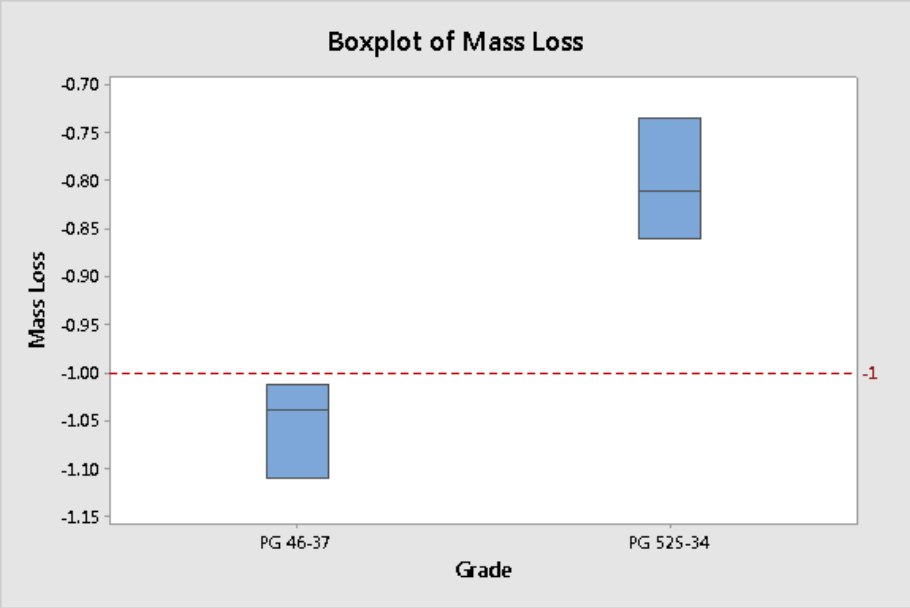


- Grades: PG 52-34, 58-34, 64-34, 64-28, 70-28, 64-22, 70-22,76-22
- Mass Loss: +0.054 to -0.719

Mass Loss Data for Supply Grades

MIA

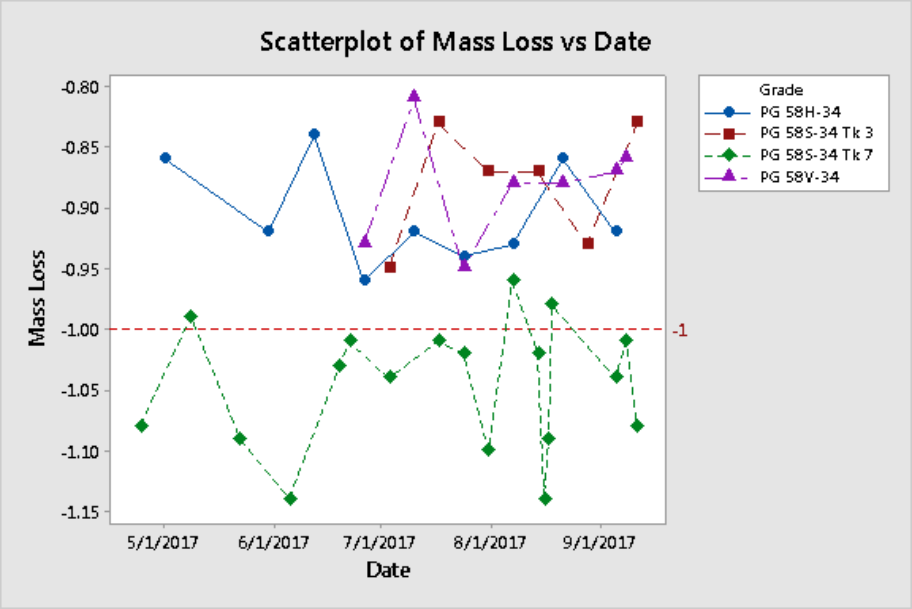


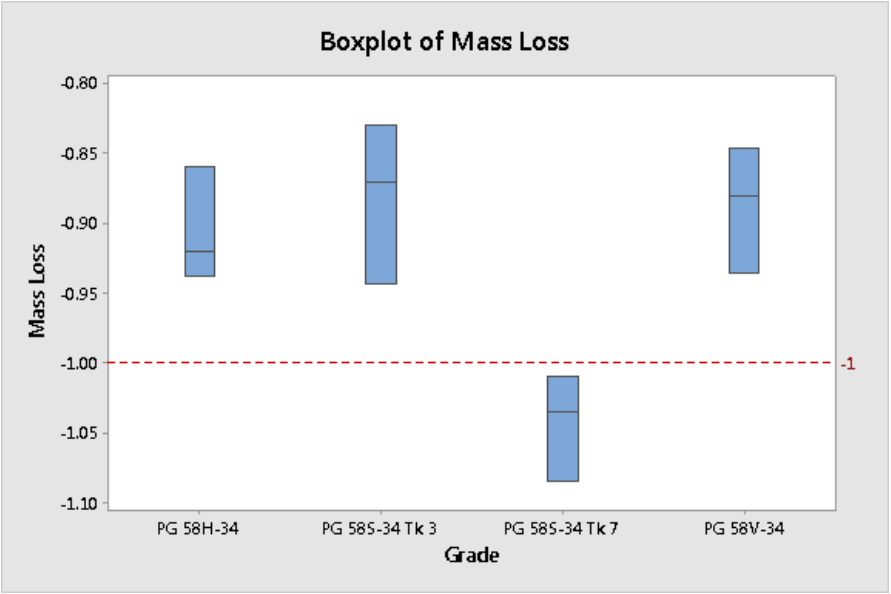


- PG 46-37 is from supplier.
- PG 52S-34 is the base binder for polymer modification. Consists of a blend of PG 58-28 and PG 46-37.
- No discernable trend with storage time.
- Box-Plot indicates that variation is the mean +/- 0.05

Mass Loss Data for Modified Grades

MIA





- PG 58S-34 contains enough polymer to make a PG 58 grade with no %R requirement. Other grades according to M332.
- Time series plots show no distinct trend with storage time.
- Mean values for in-spec grades are -0.90 +/-0.05

Discussion Points

- Corrective action has not been effective and can cause product to no longer meet PG specifications.
  - Increased storage temperatures
  - Blending with PG 58-28
- Significant increase in handling in order to ship product that meets mass loss specification.
- Asphalt is high quality in terms of durability
  - ΔTc after 20hr PAV is > -1.0°C

High Mass Loss Products

Single Operator Repeatability - MTE

Binder	Mass loss %				Avg	1s	1s Pred	d2s	d2s Pred
	A	B	C	D					
PG 46-37	-1.064	-1.078	-1.058	-1.059	-1.06	0.009	0.033	0.019	0.12
PG 58V-34	-0.861	-0.866	-0.843	-0.862	-0.86	0.01	0.025	0.0275	0.094

- Four separate quart cans were taken at the same time from the terminal. Each test replicate represents a different quart can. All have same thermal history.
- For these samples and under controlled environment standard deviation and d2s values are much better than T240.

High Mass Loss Products

Multi Lab Repeatability

Binder	Mass loss %				d2s	d2s Pred
	Saskatoon	U of C lab	MTE	Lloyd		
Pen 200/300	-1.19	-0.87	N/A	N/A	0.2689	0.4640
PG 52S-34 MIA	-0.87	-0.71	-0.82	-0.97	0.0625	0.3134

- More data is needed, conflicting results between materials/labs.
- Data sources: Can leverage existing and new round robin data.

Ruggedness Study

- Goals
  - Understand the mass loss of modified and unmodified products.
  - Quantify the effects of procedural variables.

Ruggedness Study

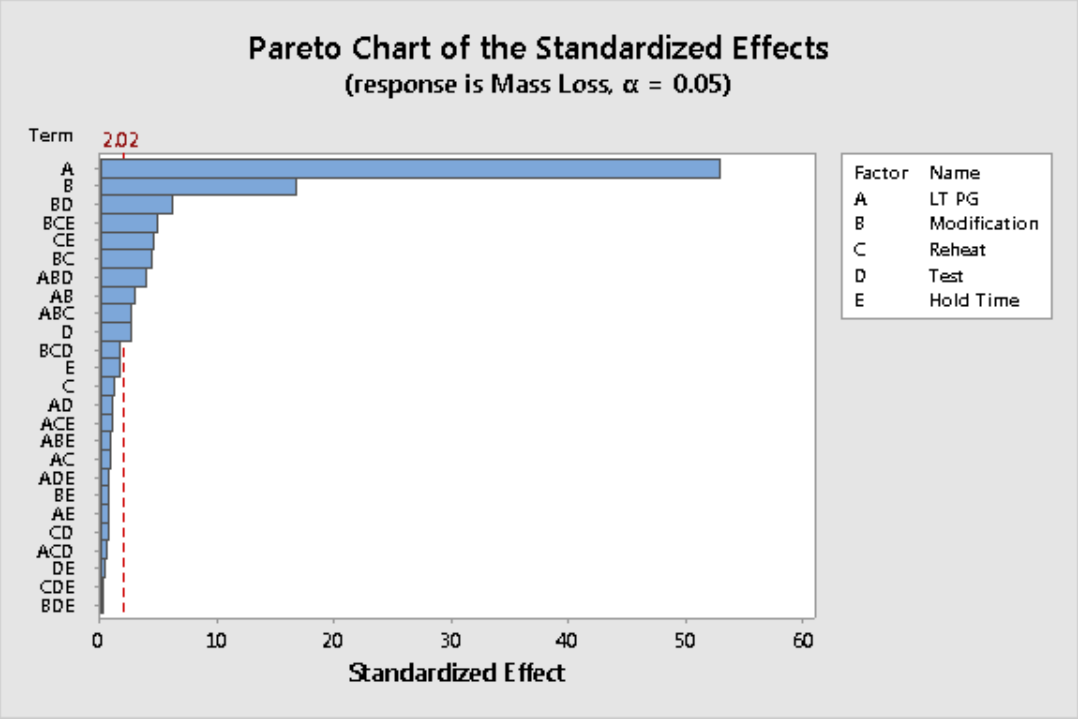
Experimental Design

Variable	Factor (+)	Factor (-)
LT PG	-28	-34
Polymer Modified	Yes	No
Re-heat	Yes	No
Hold Time After Pouring	1 hr	3 hrs
Storage Time after Sampling	Two Weeks	Test Immediately

- Each combination was replicated twice. Response is the average of two RTFO jars.
- ANOVA analysis used to identify main effects and significant interactions.
  - 95% Confidence Level
  - Up to three factor interactions included in model.

Ruggedness Study

Pareto Chart and Model Statistics



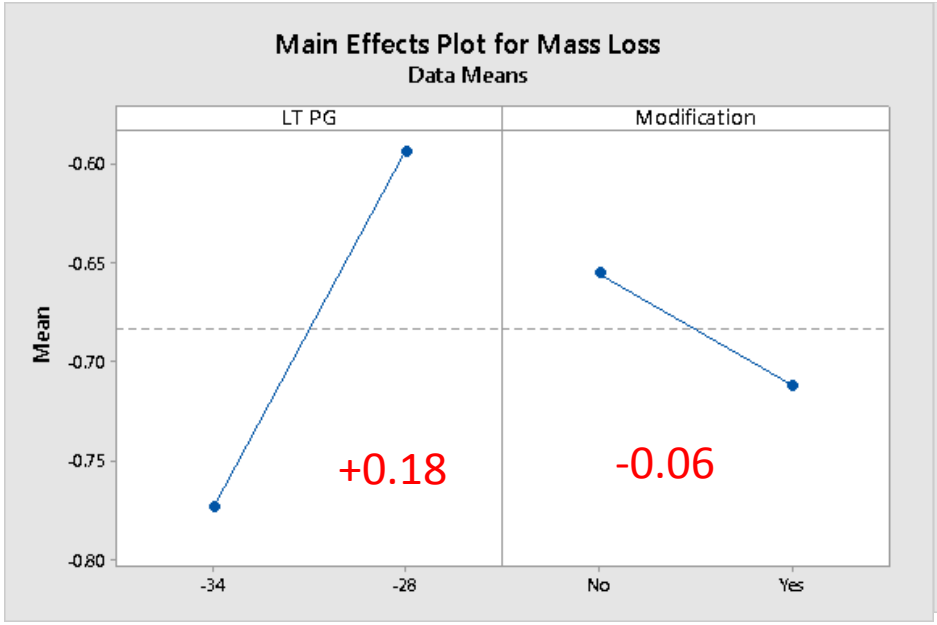
- Pareto chart plots the standardized effect of each factor.
- LT PG and Modification account for approximately 50% (38 + 12) of effects.
- Third order interactions contribute.

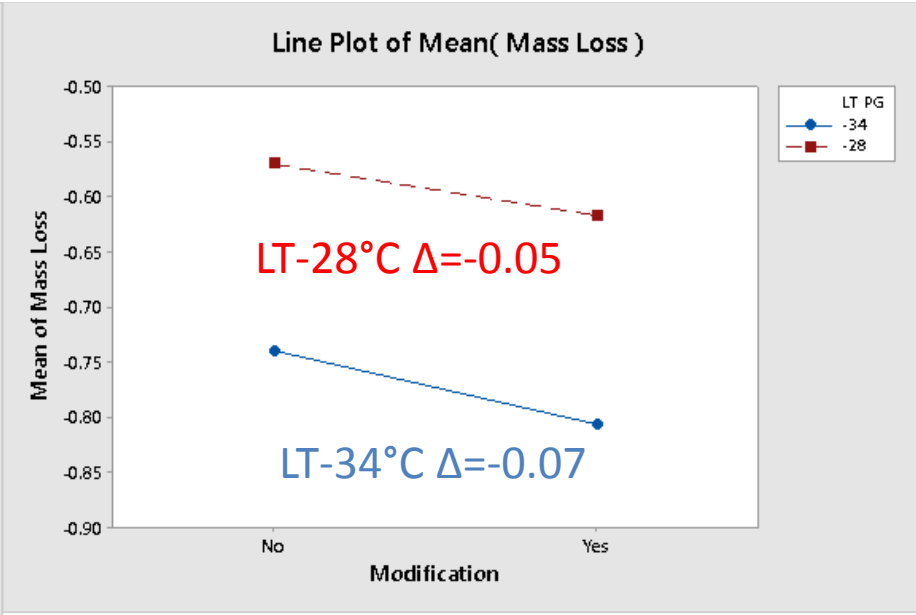
Standard Deviation	R-Sq	Adj R-Sq	Pred R-Sq
0.0136	98.4%	98.1%	96.7%

- Average standard deviation between replicates is ~0.015
- Over 95% of variation in response explained by model.

Ruggedness Study

Main Effects & Interaction Plots





- Modified asphalt formulation is Elvaloy + PPA.
- Is the PPA causing mass loss increase?

Discussion

- Low temperature PG and Modification were materials variables
  - Both were significant and had the highest effect on mass loss (based on F-value).
- The other three factors selected are process variable.
  - Investigate third order interactions to assess how these influence mass loss for a given binder (grade +modification)

Ruggedness Study

Summary Statistics

Low Temp PG = -28°C							
Modification	**N**	**Mean**	**SE Mean**	**Std. Dev**	**Min.**	**Max**	**Range**
No	16	-0.570	0.0043	0.0171	-0.595	-0.544	0.051
Yes	16	-0.617	0.0064	0.0258	-0.673	-0.578	0.095
Low Temp PG = -34°C							
No	16	-0.740	0.0068	0.0274	-0.790	-0.688	0.102
Yes	16	-0.807	0.0058	0.0234	-0.853	-0.773	0.080

- Due to factors related to sampling and testing the range in mass loss was 0.100 for most of the base asphalt/modification combinations studied.
- For -28 grades all three procedure variables had no effect on mass loss results. Only differentiating factor was modification.
- For -34 grades hold time after pouring had no effect on mass loss. Reheating had an effect on modified grades. Hold time after sampling effected both modified/unmodified. (See Appendix)

Effect of RTFO Temperature

Mass Loss – Husky Data

Temperature °C	Pen 200/300		PG 52S-34 Tk 8
	Saskatoon Lab	U of C lab	Saskatoon
163	-1.19	-0.87	-0.91
160	-0.87	-0.75	-0.72
155	-0.7	-0.61	-0.70
150	-0.71	-0.47	
145	-0.46	-0.37	

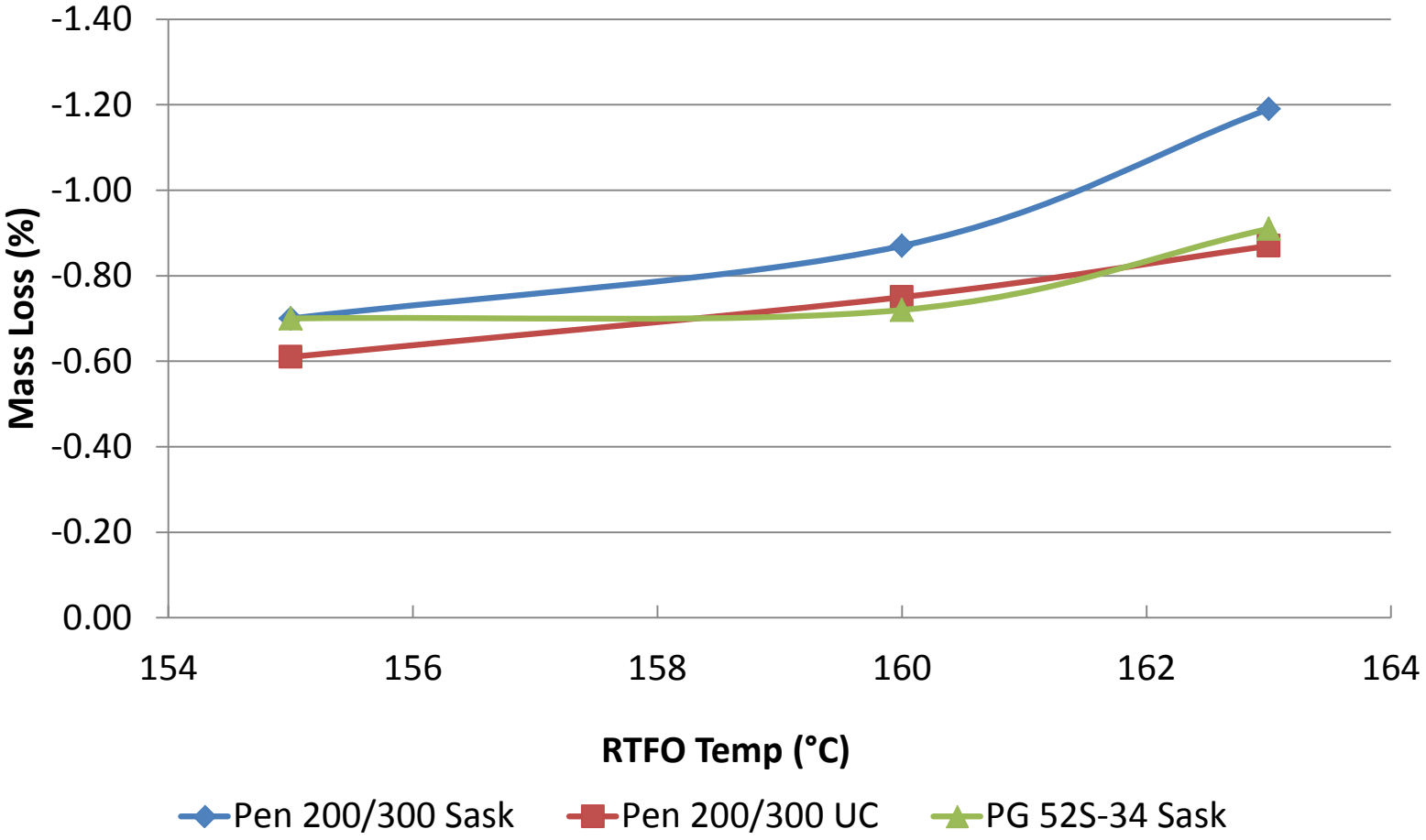
- 15% to 20% of total mass loss occurs between 160°C and 163°C. Both temperatures are still well above plant mixing and compaction range.
- Is this behavior source specific?

Pen 200/300 Continuous Grade

- 163°C = PG 56.6
- 160°C = PG 55.5

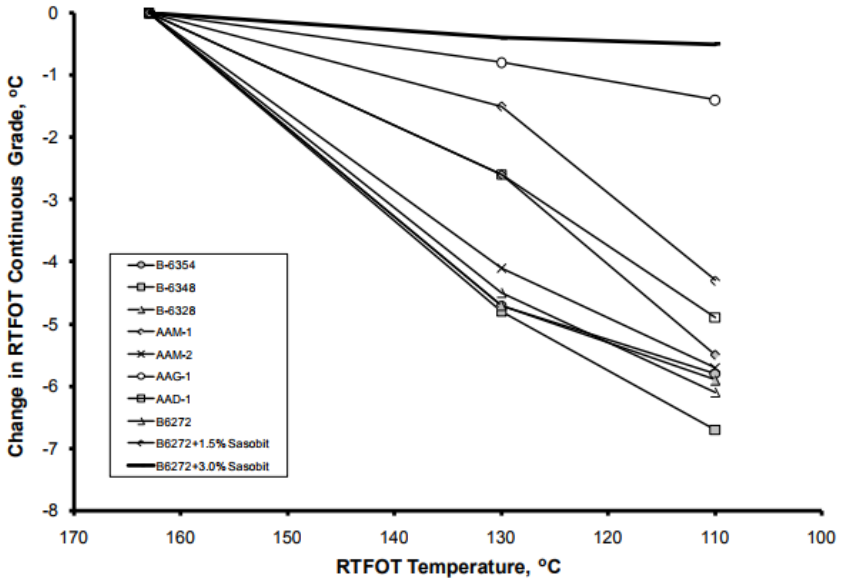
Effect of RTFO Temperature

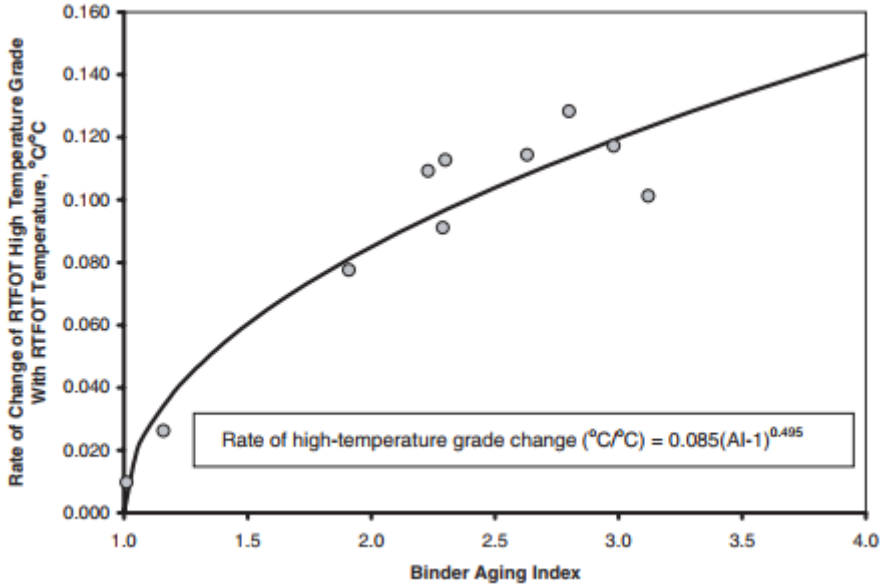
Mass Loss – Husky Data



Effect of RTFO Temperature

Continuous Grade NCHRP 9-43





- Grade change with temperature was assumed linear.
- Slope is a function of aging index.
- No mass loss data was reported.

Next Steps

1. Understand variability for high mass loss binders.
   a) PG 58H-34 and PG 58V-34 supplied to WCTG and CSBG. What is effect of PPA?
   b) Improve P&B statement.
2. Share similar slides with CSBG.
3. Other activities as recommended by ETG.
   a) Further investigation of effects of temperature and source at 160°C. More formal ruggedness study.

Discussion Points

Alternatives

1. Do nothing.
2. Wait for NCHRP 9-60 recommendations.
3. Possible Interim Changes
   - Increase mass loss limit to -1.05% for PG XX-34 grades and softer.
   - Maintain -1.00% limit and allow option to run RTFO at 160°C as an additional test.

Thank You

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Appendix – Supplemental Data

Ruggedness Study

Main Effects and Interactions

Code	Factor	F-Value	P-Value
A	**LT PG**	**2801.7**	**<0.000**
B	**Modification**	**279.9**	**<0.000**
C	Reheat	1.61	0.213
D	Hold Time after sampling (S)	6.71	0.014
E	Hold Time after pouring (P)	2.73	0.107
A*B	**LT PG x Modification**	**8.9**	**0.005**
B*C	**Modification x Reheat**	**19.0**	**<0.000**
B*D	**Modification x Hold Time (S)**	**38.8**	**<0.000**
C*E	**Reheat x Hold Time (P)**	**20.4**	**<0.000**
A*B*C	**LT PG*Modification*Reheat**	**7.2**	**0.011**
A*B*D	**LT PG*Modification*Hold Time (S)**	**14.9**	**<0.000**
B*C*E	**Modification*Reheat*Hold Time(P)**	**24.2**	**<0.000**

Ruggedness Study

Effect of Reheating

LT =-28			
Combination	**Avg**	**Grouping**	
No mod. No Reheat	-0.566	A	
No mod. Reheat	-0.573	A	
Mod. No Reheat	-0.619		B
Mod. Reheat	-0.615		B

LT =-34				
Combination	**Avg**	**Grouping**		
No mod. No Reheat	-0.725	C		
No mod. Reheat	-0.756		D	
Mod. No Reheat	-0.816			E
Mod. Reheat	-0.799			E

Effect of Hold Time After Sampling

LT =-28			
Combination	**Avg**	**Grouping**	
No mod. Cert	-0.580	A	
No mod. Retest	-0.560	A	
Mod. Cert	-0.619		B
Mod. Retest	-0.615		B

LT =-34					
Combination	**Avg**	**Grouping**			
No mod. Cert	-0.760		D		
No mod. Retest	-0.720	C			
Mod. Cert	-0.793			E	
Mod. Retest	-0.822				F

Effect of Hold Time after Testing

LT =-28			
Combination	**Avg**	**Grouping**	
No mod. 1 hr.	-0.575	A	
No mod. 3 hrs.	-0.566	A	
Mod. 1 hr.	-0.616		B
Mod. 3 hrs.	-0.618		B

LT =-34			
Combination	**Avg**	**Grouping**	
No mod. 1 hr.	-0.744	C	
No mod. 3 hrs.	-0.736	C	
Mod. 1 hr.	-0.812		D
Mod. 3 hrs.	-0.803		D