NCHRP Project 20-07 / Task 400

Effect of Elevation on Rolling Thin Film Oven Aging of Asphalt Binder

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Lots of Help

- Dave Anderson
- Jim Rosenberger
- Gayle King
- John Malusky
- Shauna Teclemariam
- Volunteer Labs
- Binder Suppliers

Outline

- Review Objectives
- Review Approach
- Review Findings of Statistical Analysis
- Effect of Conditioning Time of Properties of RTFOT Residue
- Present Final Experimental Design
- Update Status

Objectives

- Confirm or refute previous studies showing an elevation effect in properties of RTFOT residue

  And if there is an effect and it is of engineering significance then….
- Improve the AASHTO T 240 procedure to minimize differences in physical properties of RTFOT residue obtained at different elevations.

Approach

- Perform statistical and engineering analysis of available data:
  - Western Cooperative Testing Group
  - AASHTO Resource Proficiency Samples
- Select method to minimize elevation effect
- Design, execute, and analyze an experiment to confirm viability of the selected method
- Prepare documentation
  - Recommended modifications to AASHTO T 240 with commentary
  - Report with data files

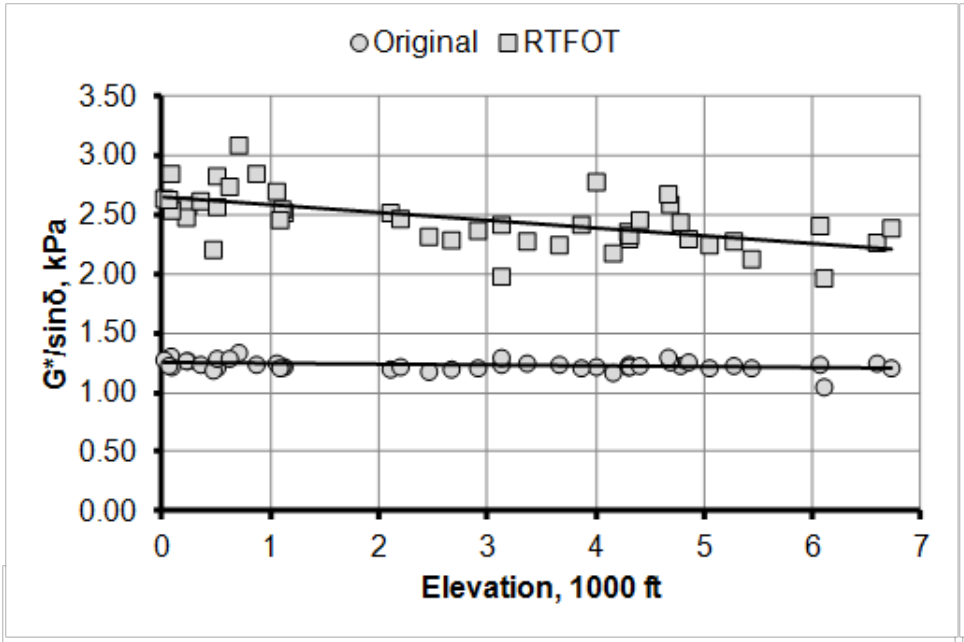
Statistical Analysis

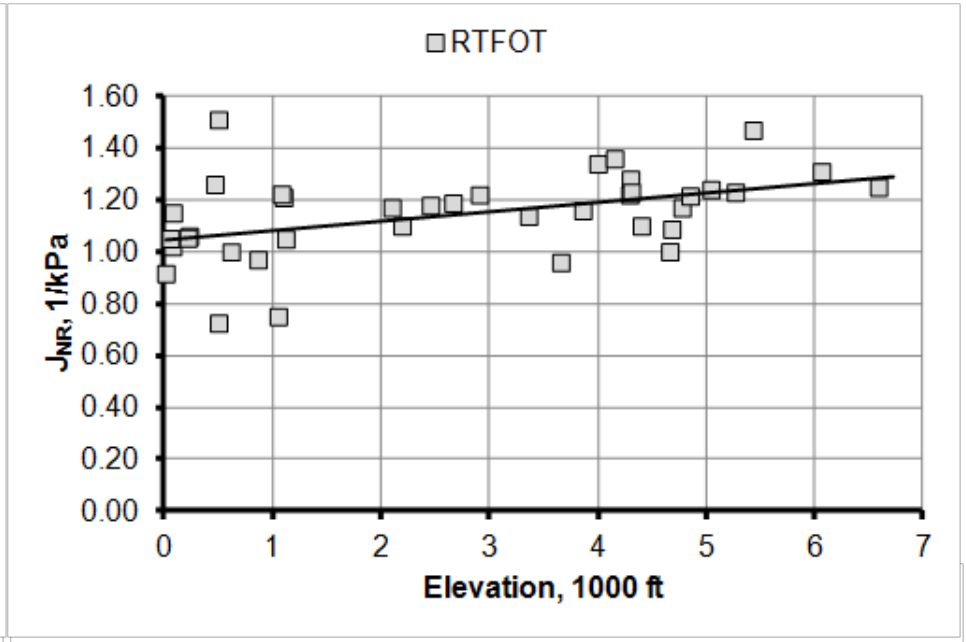
- Western Cooperative Testing Group
  - 11 binders, 1 neat, 10 modified
  - 40 labs, 1 replicate
  - 441 observations
  - 12 to 6,720 ft elevation range (uniform distribution)
- AASHTO Resource
  - 4 binders, 2 neat, 2 modified
  - 213 labs, 2 replicates
  - 1700 observations
  - 0 to 6,295 ft elevation range (68 % below 1,000 ft)

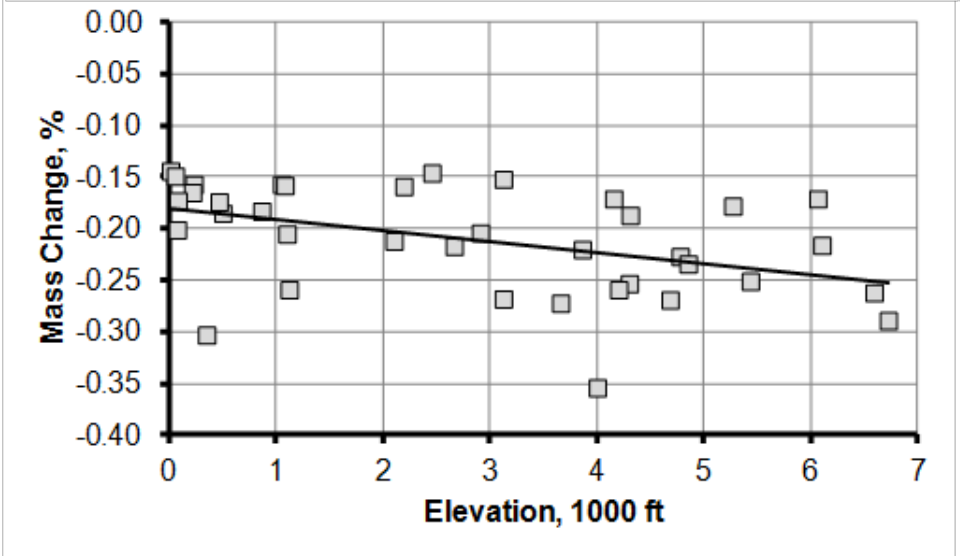
Statistical Analysis

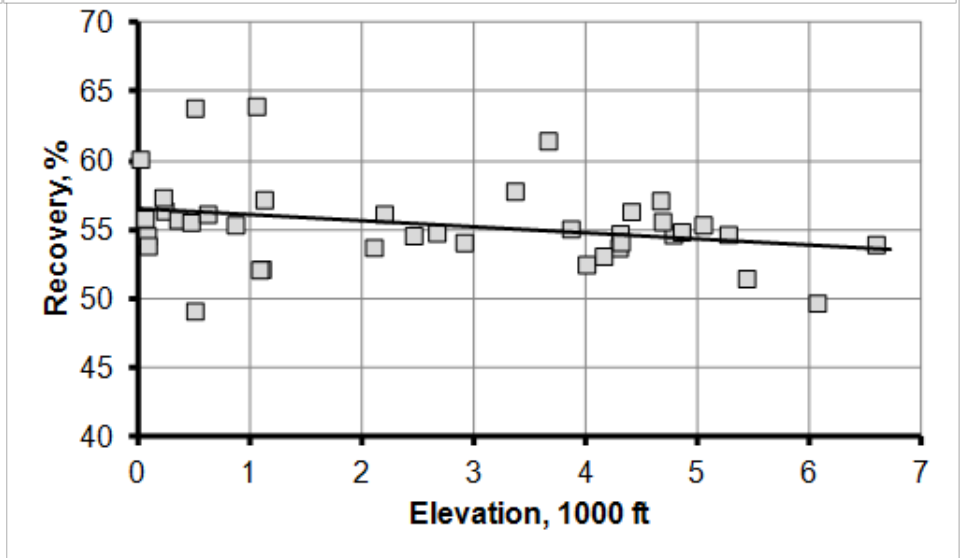
- Properties
  - Original G*/sinδ
  - RTFOT G*/sinδ
  - Aging Index
  - $J_{nr3.2}$
  - $R_{3.2}$
  - Mass Change

WCTG Binder 552

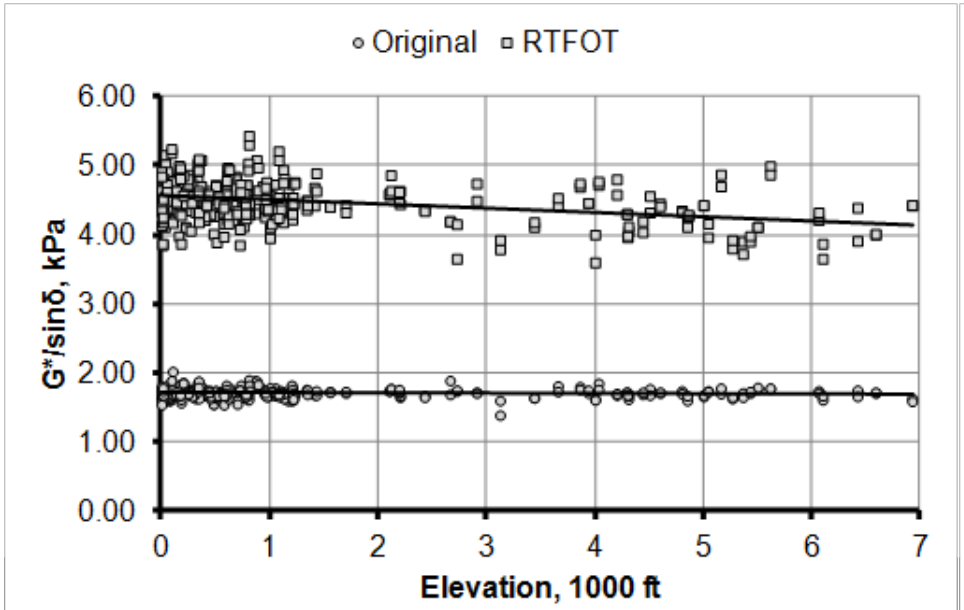


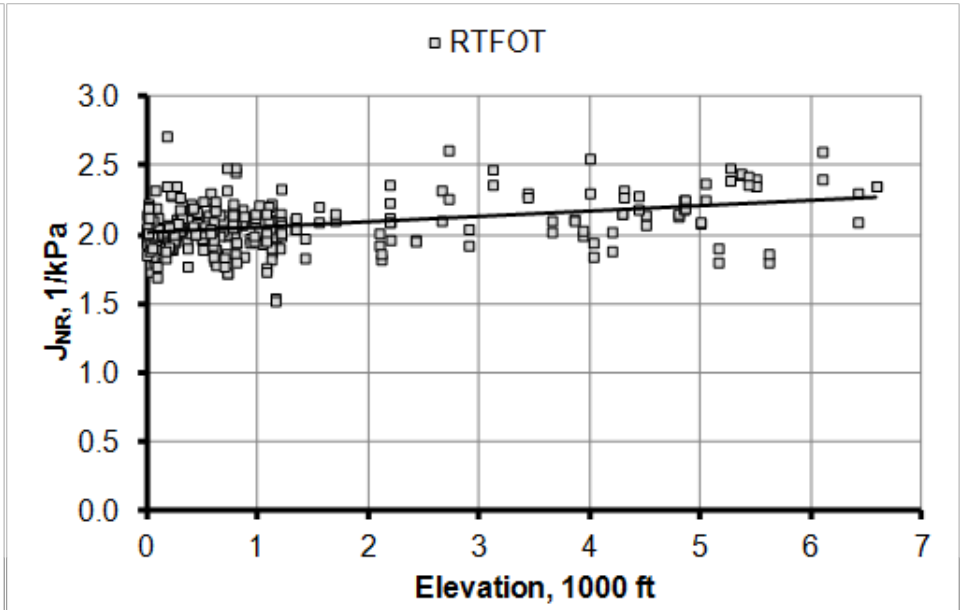


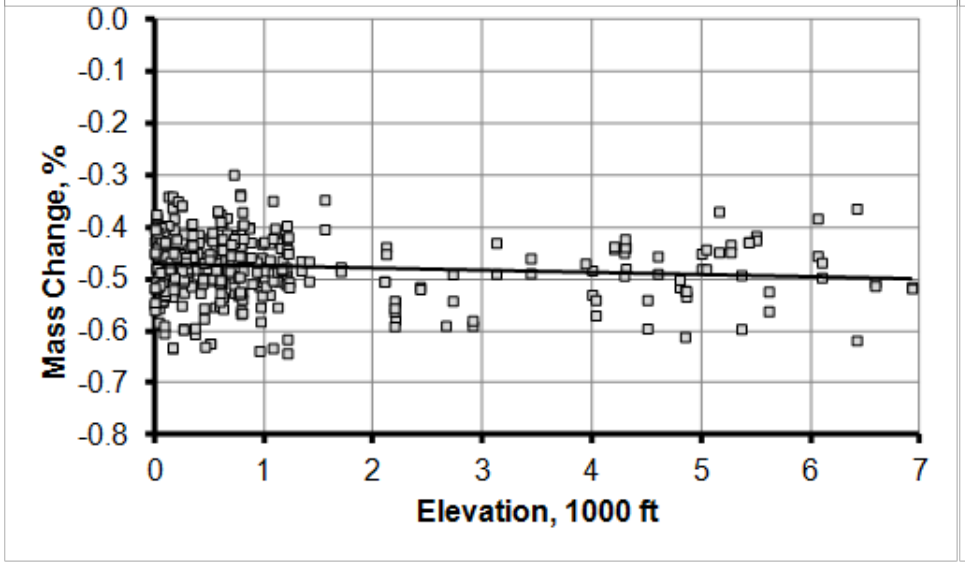


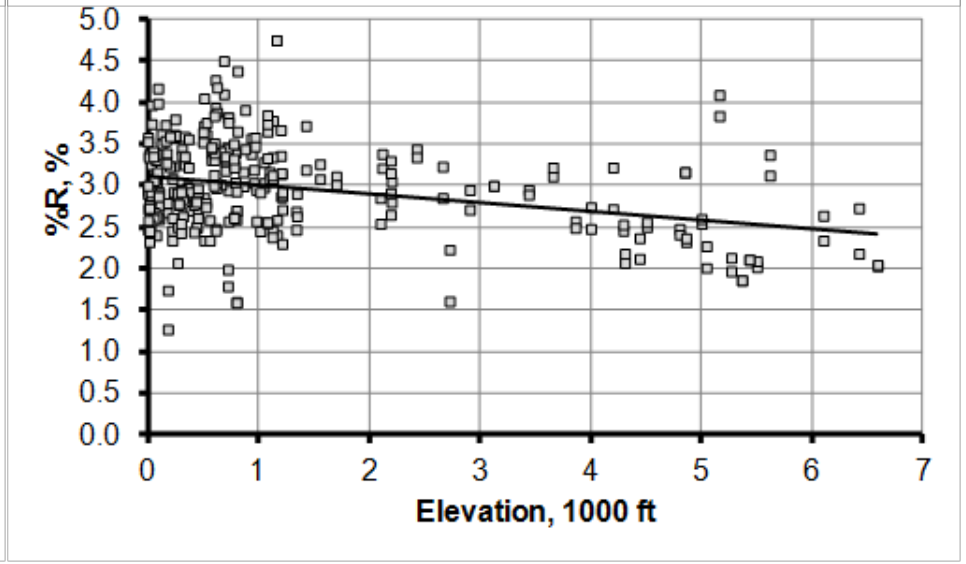


AASHTO Resource 235/236







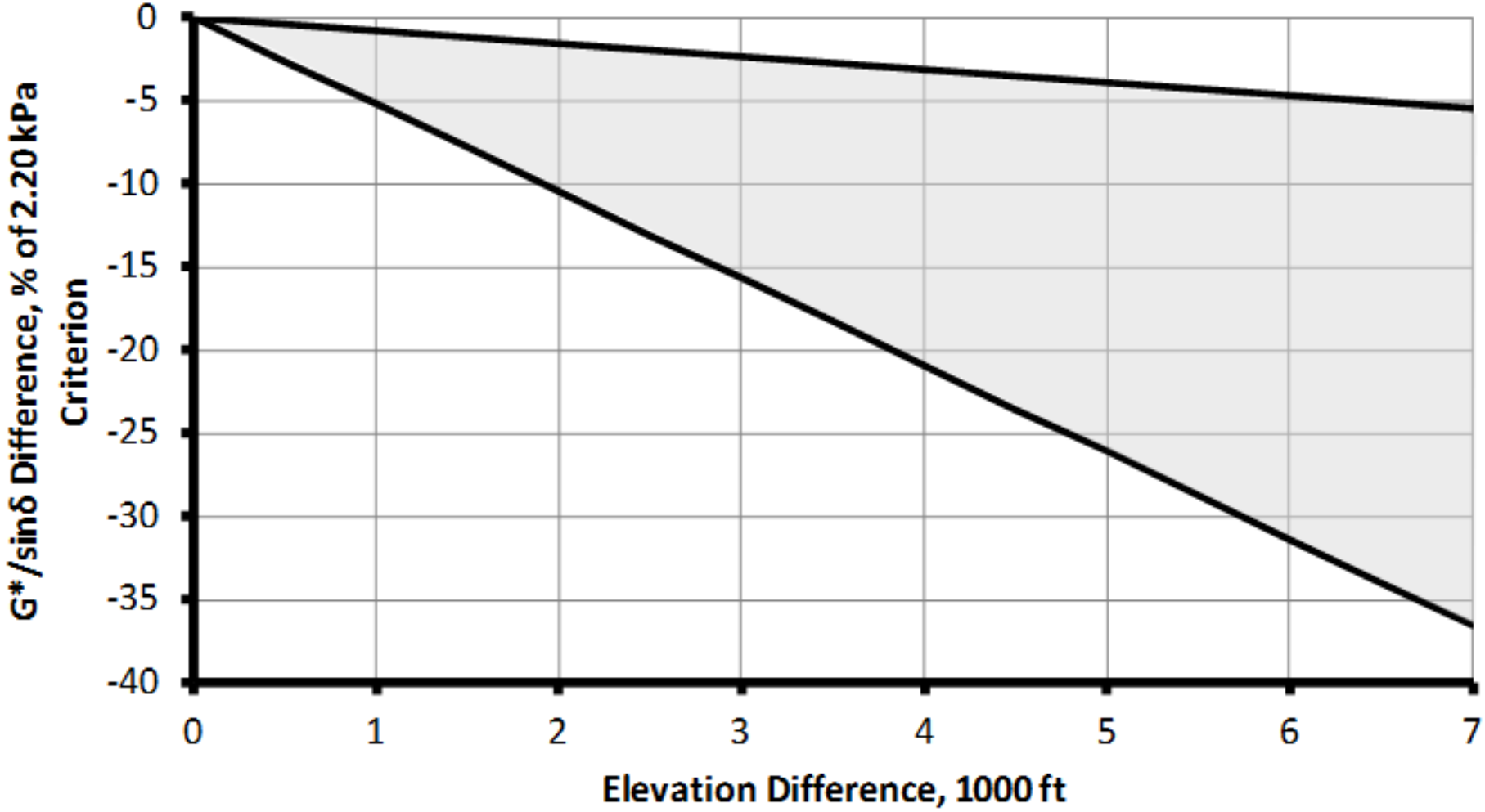


Summary of Statistically Significant Effects

Data Set	Binder	Type*	RTFOT G*/sinδ, kPa/1,000 ft	Aging Index	Mass Change, %/1,000 ft	Jnr, kPa^{-1}/1,000 ft	%R, %/ 1,000 ft
WCTG	551	P	-0.0615	-0.0354	-0.0033	0.0333	-0.059
	552	P	-0.0641	-0.0427		0.0432	-0.269
	553	P	-0.0239	-0.0146		0.0394	-0.432
	554	P	-0.0173	-0.0136		0.0677	-0.677
	555	N	-0.1149	-0.0740		0.0927	-0.119
	556	P	-0.0496	-0.0251		0.0027	0.010
	557	P	-0.0914	-0.0442		0.0204	-0.546
	560	P	-0.0477	-0.0271		0.0416	-0.415
	561	P	-0.0477	-0.0379		0.0593	-0.282
	562	P	-0.0701	-0.0609		0.0249	0.720
	563	P	-0.0448	-0.0147		0.0076	-0.413
AASHTO Resource	235/236	N	-0.0613	-0.0374	-0.0059	0.0384	-0.094
	239/240	N	-0.0806	-0.0412		0.0470	-0.032
	241/242	P	-0.0302	-0.0233		0.0002	0.519
	245/246	P	-0.0257	-0.0188		0.0236	-0.300

* N denotes neat binder, P denotes polymer modified binder

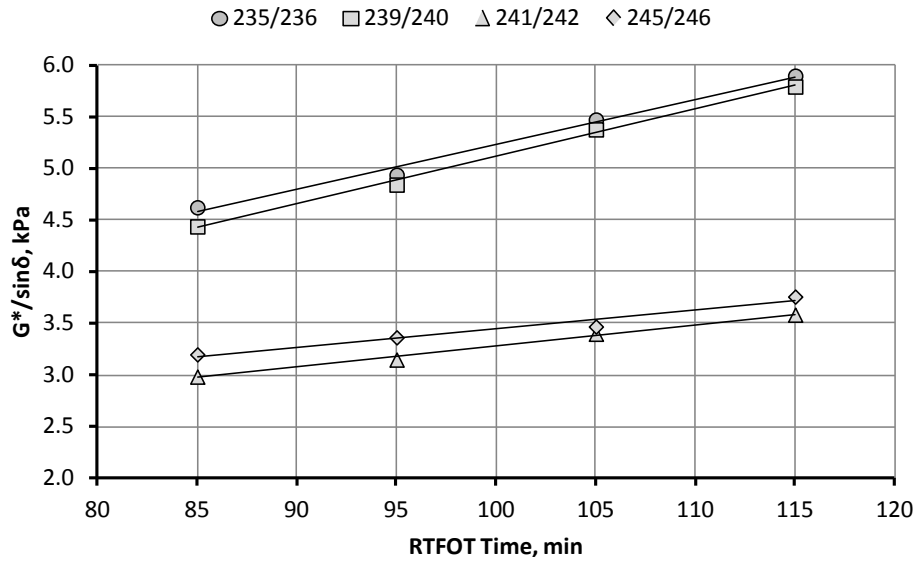
Engineering Significance of Elevation Effect: G*/sinδ

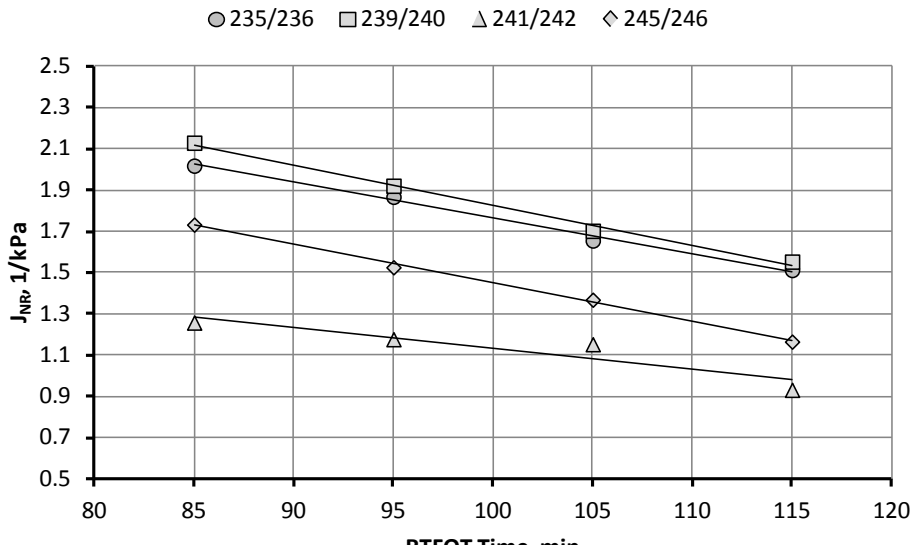


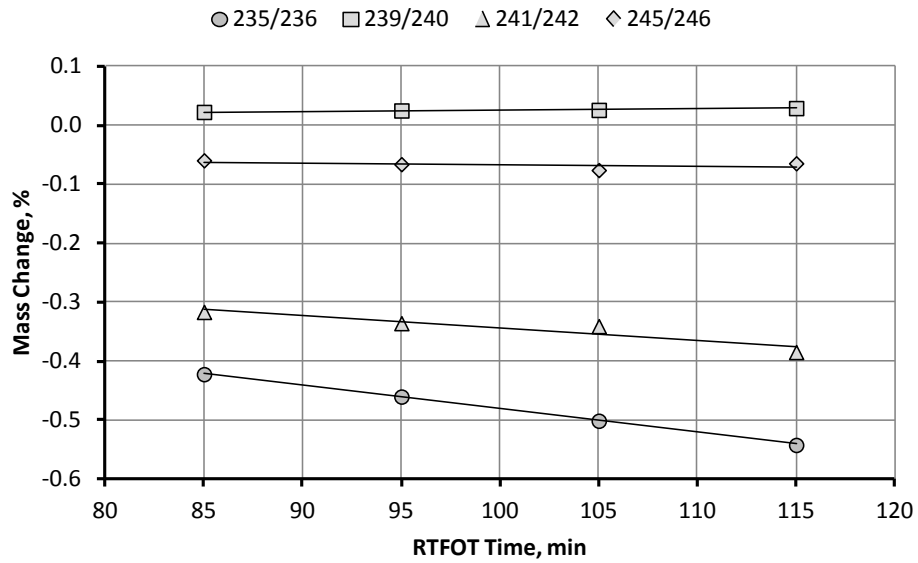
What Are the Options?

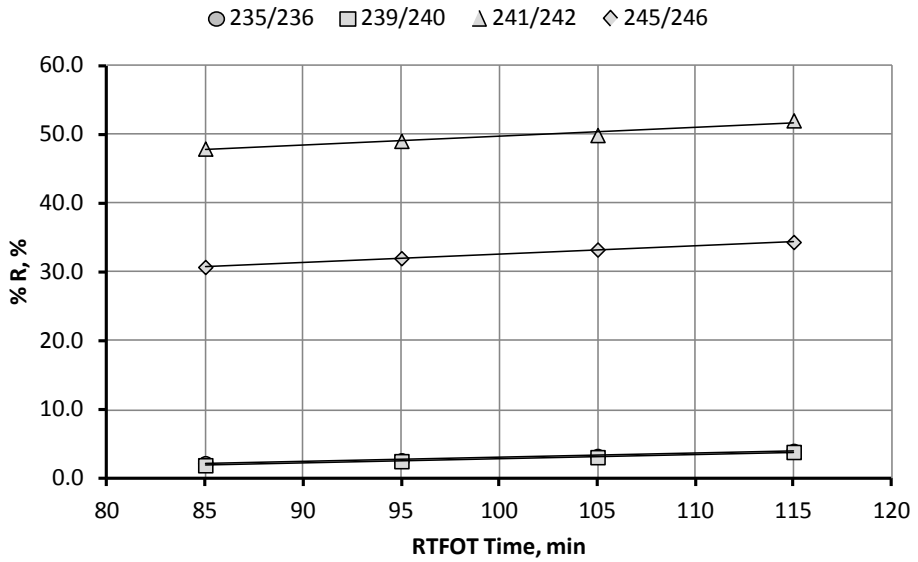
- Modify RTFOT to condition at a constant pressure
- Relate elevation effect to other measured binder properties
- Vary RTFOT temperature with elevation
- Vary RTFOT time with elevation

Effect of Conidtioning Time on RTFOT Residue Properties









Experimental Estimate of Additional RTFOT Conditioning Time

Binder	ΔG*/sinδ, kPa/min	ΔG*/sinδ, kPa/1,000 ft	Additional Conditioning Time, min/1,000 ft	ΔJ_{NR}, kPa^{-1}/min	ΔJ_{NR}, kPa^{-1}/1,000 ft	Additional Conditioning Time, min/1,000 ft
235/236	0.0468	-0.0645	1.4	-0.01728	0.0384	2.2
239/240	0.0460	-0.0806	1.8	-0.01946	0.0470	2.4
241/242	0.0217	-0.0296	1.4	-0.01002	0.0006	0.1
245/246	0.0172	-0.0257	1.5	-0.00939	0.0217	2.3

Average = 1.9 min/1000 ft

Theoretical Estimate of Additional RTFOT Conditioning Time

Carbonyl formation rate model[1]

$$r_{CA} = Ap^{\alpha}e^{\left(\frac{-E}{RT}\right)}$$

where:
r_{CA} = carbonyl formation rate
p = oxygen pressure
T = temperature
R = universal gas constant
A, α, and E are binder dependent fitting constants

[1] Liu, M.; Lunsford, K. M.; Davison, R. R.; Glover, C. J.; Bullin, J. A." The Kinetics of Carbonyl Formation in Asphalt," American Institute of Chemical Engineers Journal, Volume 42, 1996.

Theoretical Estimate of Additional RTFOT Conditioning Time

- Assume rheological properties depend on total amount of carbonyl formed

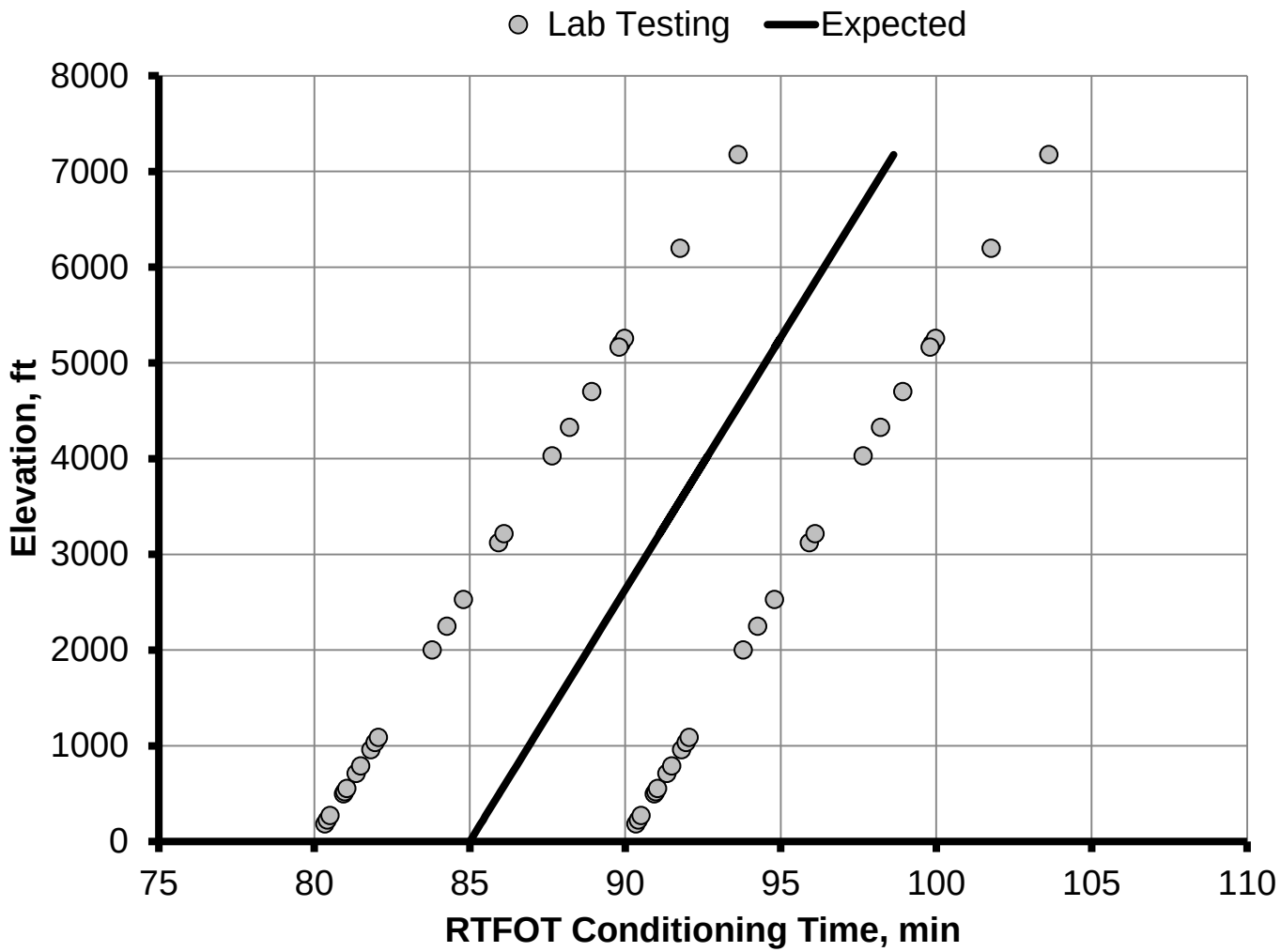
$$\left(r_{CA}\right)_0 t_0 = \left(r_{CA}\right)_h t_h$$

$$t_h = t_0 \left(\frac{p_0}{p_h}\right)^{\alpha}$$

Theoretical Estimate of Additional RTFOT Conditioning Time

Elevation ft	Equivalent RTFOT Conditioning Time, min								
	α = 0.25	α = 0.30	α = 0.35	α = 0.40	α = 0.45	α = 0.50	α = 0.55	α = 0.60	Exp
0	85	85	85	85	85	85	85	85	85
1000	86	86	86	86	87	87	87	87	87
2000	87	87	87	88	88	89	89	89	89
3000	88	88	89	89	90	90	91	92	91
4000	89	89	90	91	92	92	93	94	93
5000	89	90	91	92	93	94	95	96	95
6000	90	92	93	94	95	96	97	99	96
7000	91	93	94	96	97	98	100	101	98

Experiment Design



Experimental Design

- 24 Labs
  - 181 ft to 7124 ft
- 8 Binders

Binder	Type
PG 64-22	Neat
PG 76-22	Polymer
PG 58-28	Neat
PG 64-28	Neat
PG 76-28	Polymer
PG 52-34	Neat
PG 58-34	Polymer
PG 64-34	Polymer

Experimental Design

- Each lab will condition each binder at two times based on elevation
  - 2 bottles for mass change at lab
  - 2 bottles returned to AAT for rheological testing
  - 8 RTFOT runs per laboratory
- Analysis
  - T 240 mass change
  - T 315 G*/sinδ
  - T 350 $J_{nr3.2}$, and $R_{3.2}$

Status

- Binders have been received
- Containers have been received
- Currently breaking down binders for shipment
- Expect an e-mail from me to verify shipping address and laboratory elevation
- Expect to ship binders in October