Update: PAV Degassing

FHWA Asphalt Binder ETG

Fall River, Massachusetts

September 12-13, 2016

Acknowledgements

Mike Anderson, the Asphalt Institute

Satish Belagutti, FHWA

Tina Conticelli, NMDOT

Amir Golalipour, FHWA

Andrew Hanz, MTE Services

Maria Knake, AASHTO Resources

Robert Kluttz, Kraton Polymers

Jim Mahoney, CAP Lab, CT

Bruce Morgenstern, WDOT,

Gerry Reinke, MTE Services

Ed Trujillo, Colorado DOT

Question Addressed by Task Group

- Is vacuum degassing necessary prior to conducting rheological measurements with the BBR or DSR
  - ✓ The requirements for degassing is not an issue with ultimate property measurements
- Requirements vary with ASTM and ASHTO
  - ✓ Recent proposal was to eliminate vacuum degassing based on historical studies
  - ✓ Many reject proposal- especially West Coast agencies at high altitudes
- Multi-laboratory study was established to address question

Historical - Degassing Procedure

- Added post SHRP when direct tension test was adopted
  - ✓ Small bubbles were a source of flaws that reduced tensile strength
  - ✓ Time was recently increased from 10 to 15 minutes
  - ✓ Vacuum level – temperature – time chosen somewhat arbitrarily
- Degassing protocol has not been subjected to ruggedness testing
  - ✓ Anecdotal data show vacuum alters properties of binder

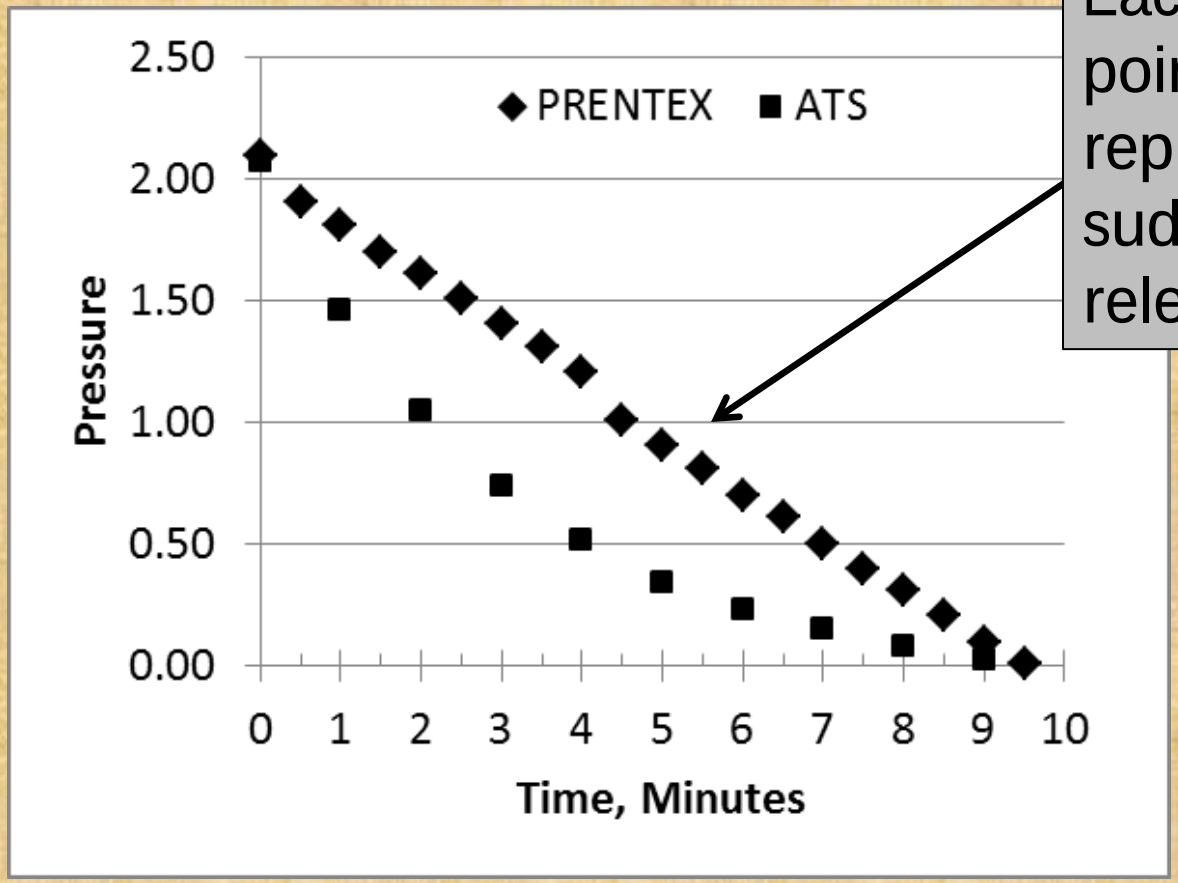
ETG Degassing Experiment - Status

- Laboratory work is complete
- Initial data analysis is complete
  - ✓ Sufficient to give recommendation for test methods
  - ✓ Additional data mining possible
- Initial draft report completed
  - ✓ Need to add data analysis
- Focus of today's presentation
  - ✓ Review experimental work
  - ✓ Describe ancillary work
  - ✓ Discuss recommendations for updating test method

Linearity of Pressure Release Rate

- Reviewed as possible cause of excessive bubbles
- Pressure vs. release rate obtained from several labs
  - ✓ Prentex releases linearly in series of small bursts
  - ✓ ATS releases non-linearly - 50% in first 90 seconds
  - ✓ Neither of the above meet original intent of test method
- Above verified by data from several laboratories
- Conclusion: Need to include continuous-linear release rate with nonlinear or short bursts
  - ✓ Release rate and uniformity of release rate may need to be addressed in test method

Pressure Release Rate – Typical Results



Each data point represents sudden release

Experiment Design

- Four materials
  - ✓ PG 76-28 (28) (Modified) (reported as “Difficult”
  - ✓ PG 64-28 (22)
  - ✓ PG 64-22 (25)
  - ✓ PG 58-28 (19)
- Eight Laboratories
  - ✓ Selected to give different elevations and devices
- Rate of PAV pressure release
  - ✓ Device controlled and manual (linear)

Measurements

- Original (unaged) binder samples sent to each participating laboratory
- Each laboratory performed RTFOT and PAV conditioning
- RTFOT residue was blended and then PAV'd
  - ✓ Subset of laboratories added manual pressure release rate
- PAV conditioned binder was then split between degassing and no degassing condition
  - ✓ Vacuum degassing pressure was specified

Study Variables

Lab	Elevation (Feet)	Vacuum Gage Reading, P_G, in Hg[(A)]	Device Controlled PAV Pressure Release Rate		Manual (Linear) PAV Pressure Release Rate	
			Vacuum Degassed	No Degassing	Vacuum Degassed	No Degassing
1	Low (880)	23.8 ± 0.7	Yes	Yes	***No***	***No***
2	Low (270)	25.2± 0.7	Yes	Yes	Yes	Yes
3	Low (520)	25.0± 0.7	Yes	Yes	Yes	Yes
4	High (5,270)	20.2± 0.7	Yes	Yes	***No***	***No***
5	High (6,180)	18.3 ± 0.7	Yes	Yes	***Yes***	***Yes***
6	Low (540)	24.9 ± 0.7	Yes	Yes	Yes	Yes
7	Low (720)	24.8± 0.7	Yes	Yes	***No***	***No***
8	High (6,920)	18.6± 0.7	Yes	Yes	***No***	***No***

Measurements on PAV Residue

- 8 mm DSR at specification temperature closest to intermediate specification temperature
  - ✓ Limited number of labs made replicate measurements
- BBR at grading temperature
  - ✓ Replicate beams
- Intent was to analyze relative change in property when degassed and non-degassed
  - ✓ Minimized lab-lab bias
  - ✓ If difference between degassed and non-degassed measurement is <2ds% for operator error then can assume no effect from degassing

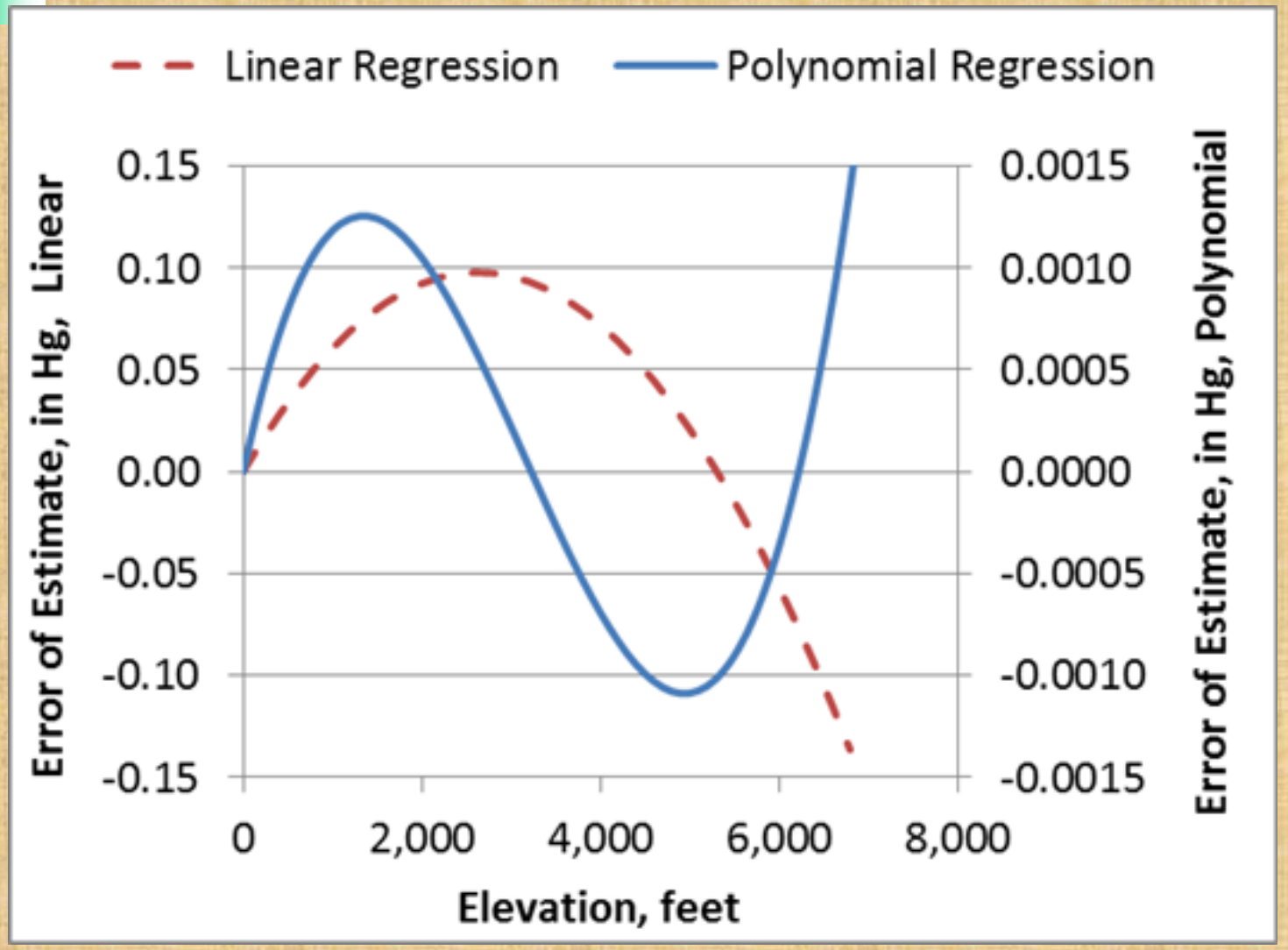
Ancillary Results – Pressure Measurements

- Measurement of residual pressure when vacuum is applied is poorly understood in many laboratories
- Recommend measurement of absolute pressure
  - ✓ Absolute pressure gage gives pressure relative to a perfect vacuum
  - ✓ No need to correct for ambient pressure
- Simplify specification to require pressure gage reading as function of laboratory elevation
  - ✓ Remove wording regarding correction, etc. in test method
  - ✓ Linear equation ok up to 6,000 ft then use polynomial

Current Instructions in Equipment Manuals Can Be Misleading!

- Instrument manuals vary with respect to adjustments for barometric pressure
- Barometric pressure not always clearly understood in field

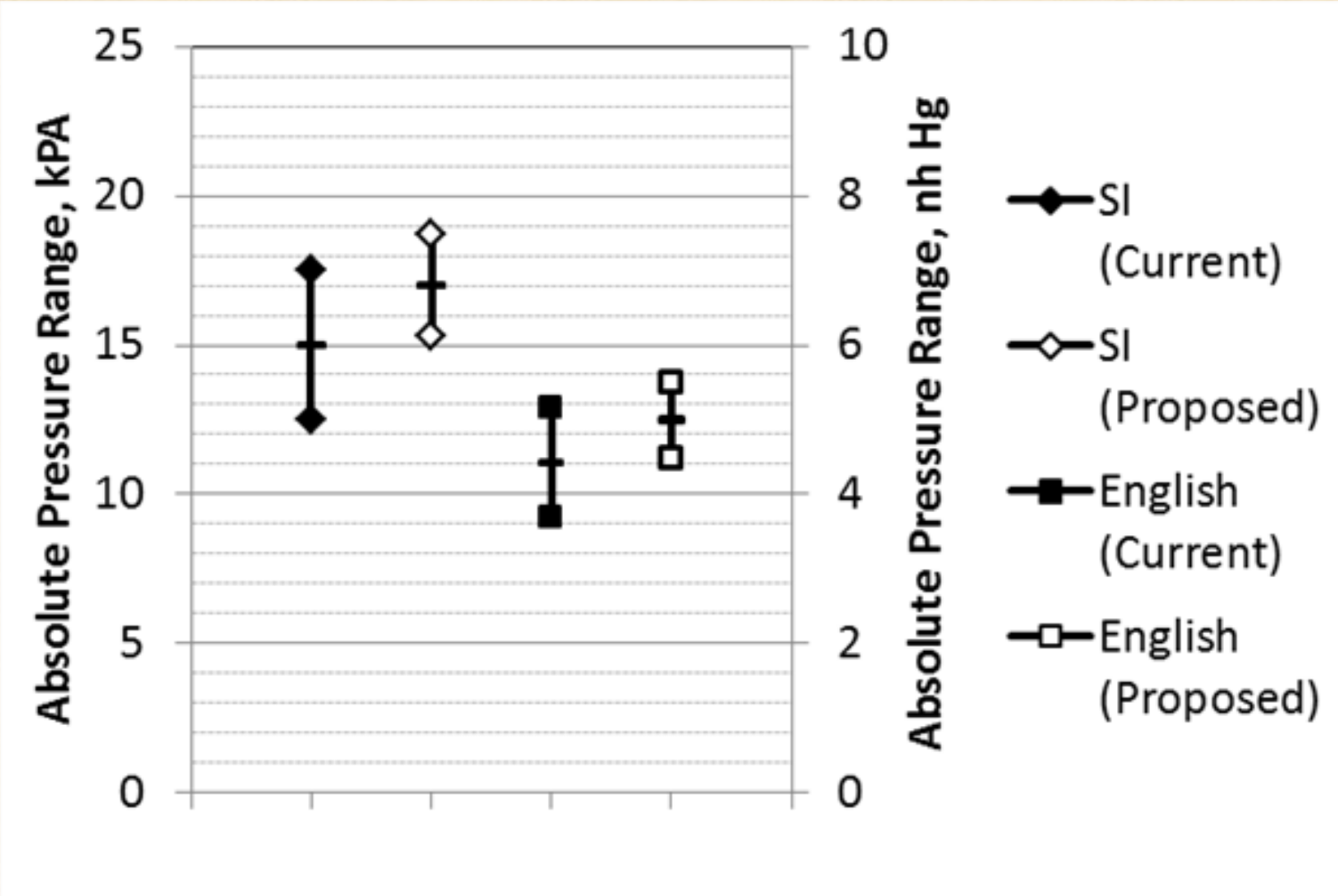
Linear vs. Polynomial Estimate of Gage Pressure vs. Elevation



Recommend Specification Wording

When using a vacuum gage to control the degassing pressure, the gauge readings given by Eq. 4 calculated using the laboratory elevation to the nearest 100 feet shall be used to control and report the vacuum during the degassing cycle. Equation 4 accounts for changes in atmospheric pressure with elevation. No additional corrections for laboratory barometric pressure, temperature, humidity, etc. shall be applied to the vacuum gage reading regardless of instructions supplied by any vendors, instrument software, or other source. The vacuum gage reading shall be reported and controlled to the nearest 0.5 in Hg (0.2 kPa).

Proposed Absolute Pressure Readings



Data Analysis

- Centered around calculating following parameter for various combinations of study variables:

For Moduli:

100% x [(Degassed – no Degassing)/Degassed

Value should be positive

For δ and m-value:

100% x [(no Degassing - no degassing)/Degassed

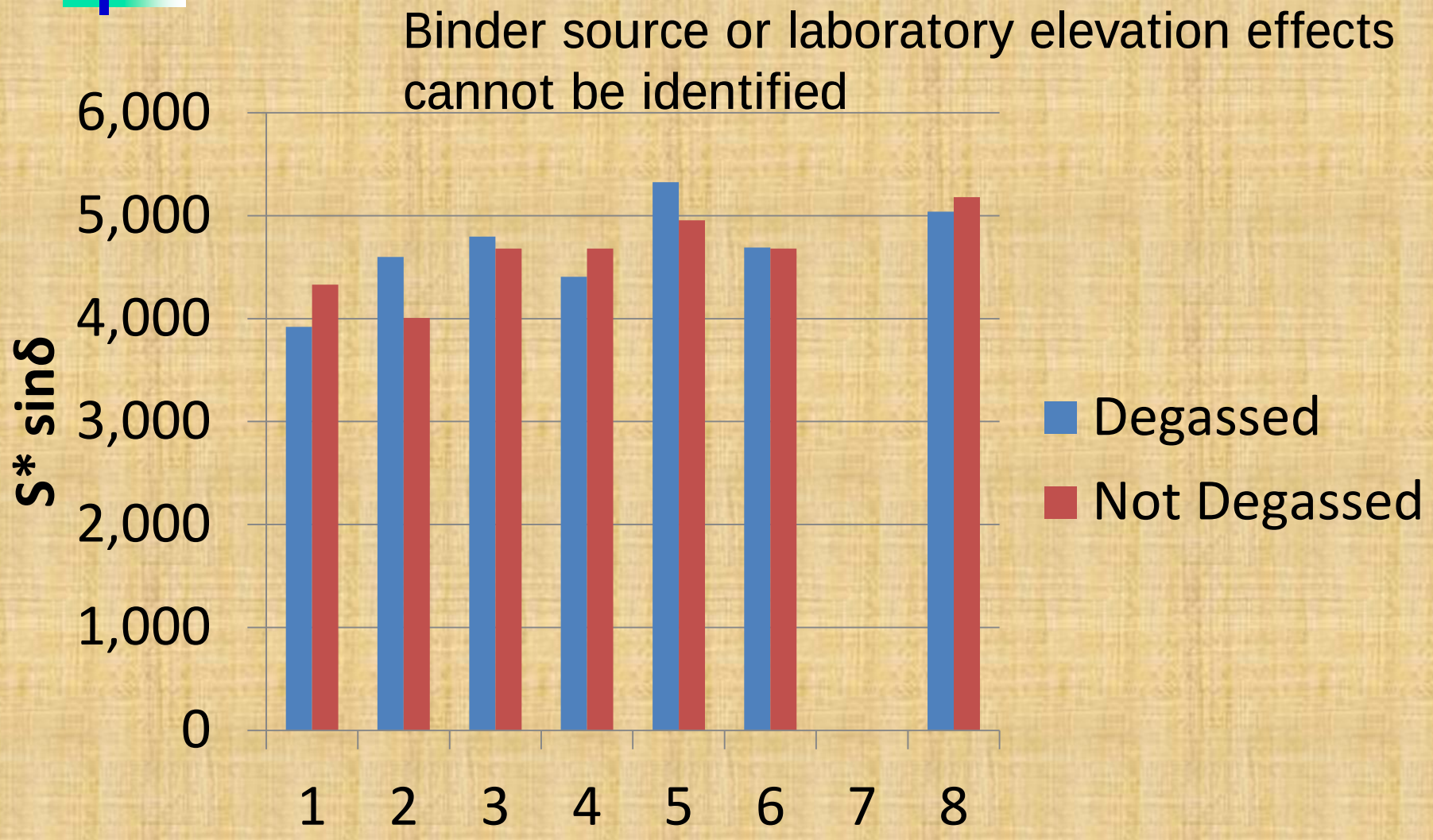
Value should be also be positive

Thus, positive value in analysis variable indicated expected effect of PAV conditioning

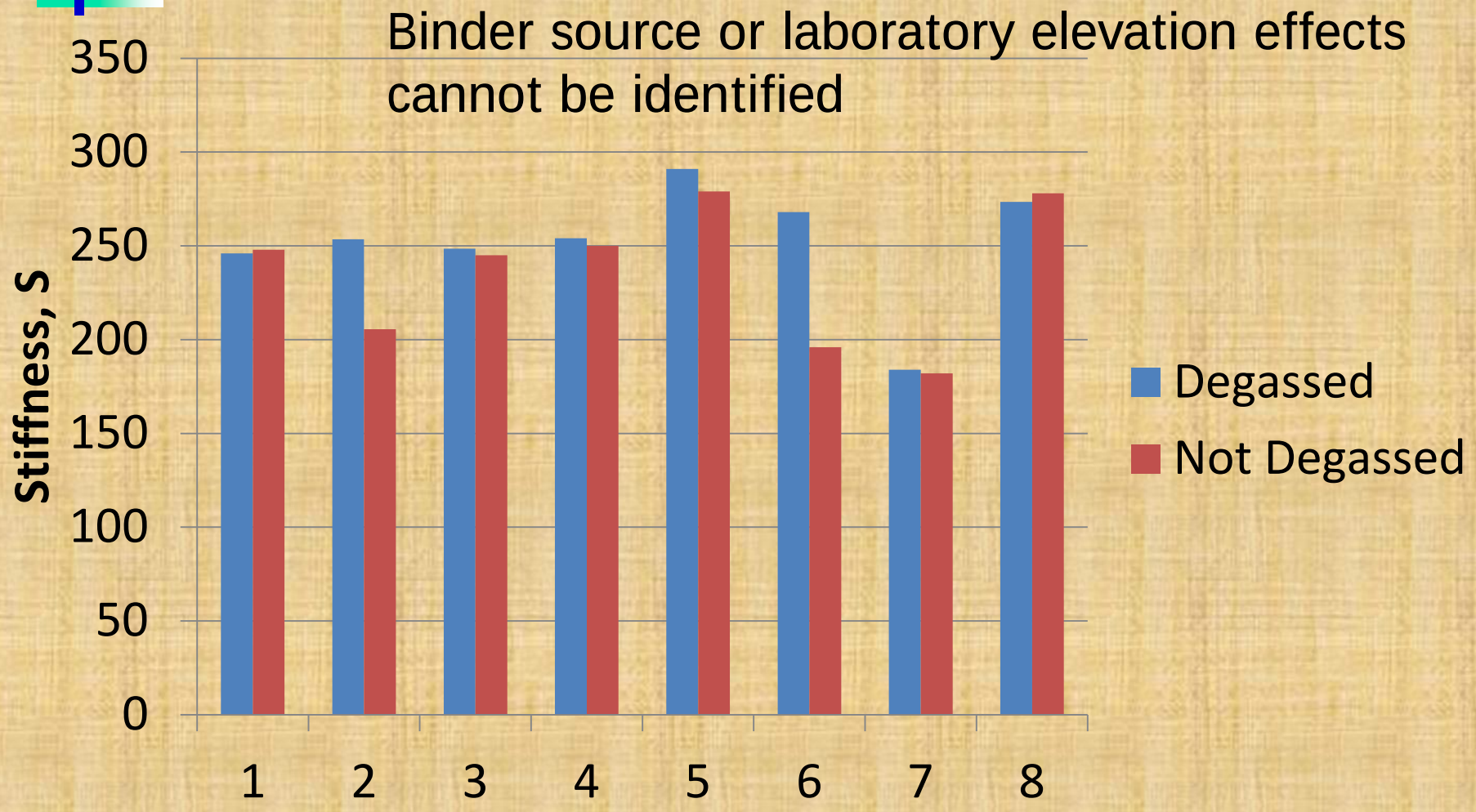
Property	Release	De-gas?	AMRL (270 ft) ATS	CAPLAB (520 ft) ATS	FHWA (540 ft) ATS	MTE (720 ft) Prentex	TAI (880 ft) Prentex	CODot (5,270 ft) Prentex	WYDOT (6,180 ft) ATS	NMDOT (6,920 ft) ATS
G* (kPa)	D	Y	5,360	6,162	6,527	5,940	7,440	6,310		6,698
		N	6,009	5,535	6,381	6,439	6,810	6,360		7,083
	M	Y	6,238	6,139	6,783					
		N	7,261	6,879	7,018					
G*sinδ (kPa)	D	Y	3,920	4,599	4,798	4,406	5,325	4,690		5,040
		N	4,330	4,007	4,680	4,682	4,956	4,680		5,180
	M	Y	4,480	4,554	4,944					
		N	5,170	5,010	5,045					
δ (Degree)	D	Y	46.0	46.3	47.1	47.0	46.9	47.1		48.8
		N	46.1	46.4	47.2	47.5	46.7	47.4		47.0
	M	Y	45.9	47.9	47.8					
		N	45.9	46.9	47.7					
S (MPa)	D	Y	246	254	249	254	291	268	184	274
		N	248	206	245	250	279	196	182	278
	M	Y	249	252	264				207	
		N	239	258	267.5				213	
m-value	D	Y	0.305	0.326	0.326	0.328	0.316	0.309	0.332	0.317
		N	0.307	0.317	0.325	0.330	0.318	0.304	0.332	0.321
	Mv	Y	0.311	0.330	0.325				0.332	
		N	0.292	0.324	0.321				0.324	

Data were tabulated By Grade - PG 58

Laboratory – Laboratory variability swamps degassing effect – PG 58-28



Same observation with stiffness – PG 58-28



Percent Change in PG 58-28 with Degassing – Device and Manual Control

Green indicated change in expected direction – apricot in “wrong direction”

58-28			AMRL 270 ft ATS	CAPLAB 520 ft ATS	FHWA 540 ft ATS	MTE 720 ft	TAI 880 ft Prentex	CoDot 5,270 ft Prentex	WYDOT 6,180 ft ATS	NMDOT 6,920 ft ATS
G*	D		-12.1	10.2	2.2	-8.4	8.5	-0.8		-5.7
(kPa)	M		-16.4	-12.1	-3.5					
G*sinδ	D		-9.5	14.8	2.5	-5.9	7.4	0.2		-2.7
(kPa)	M		-13.3	-9.1	-2.0					
δ	D		-1.9	-3.9	-0.4	-0.8	2.2	-1.3		-3.7
Degrees	M		-1.1	-2.4	-1.7					
S	D		-0.8	23.4	1.4	1.6	4.3	36.7	1.1	-1.6
MPa	M		4.2	-2.3	-1.3				-2.8	
m-value	D		-0.7	2.8	0.3	-0.6	-0.6	1.6	0.0	-1.2
	M		-1.3	-3.9	0.0				0.0	

Percent Change in PG 78-28 with Degassing – Device and Manual Control

Green indicated change in expected direction – apricot in "wrong direction"

76-28		AMRL 270 ft ATS	CAPLAB 520 ft ATS	FHWA 540 ft ATS	MTE 720 ft	TAI 880 ft Prentex	CoDot 5,270 ft Prentex	WYDOT 6,180 ft ATS	NMDOT 6,920 ft ATS
G*	D	16.2	11.6	4.9	-8.0	2.1	20.4		3.8
(kPa)	M	-0.6	14.1	-3.5					
G*sinδ	D	17.6	13.8	5.2	-6.5	-1.0	27.2		3.8
(kPa)	M	-0.3	17.1	-10.9					
δ	D	2.0	-0.7	-0.2	-1.1	4.1	-1.6		0.2
Degrees	M	-0.4	-2.9	-1.7					
S	D	8.2	4.3	10.5	11.0	4.7	0.6	-23.4	-1.9
MPa	M	1.7	34.7	-1.3				-3.6	
m-value	D	-1.5	-1.8	1.2	4.1	-1.1	3.6	0.3	-4.9
	M	0.9	-3.0	6.2				2.3	

Are degassed and non-degassed from same population – (d2s%)

Apricot indicate gassed and non-degassed differ by more than operator variability – PG 78-28

Property	Pressure Release Range: Allowabl		AMRL 270 ft ATS	B 520 ft ATS	FHWA 540 ft ATS	MTE 720 ft	TAI 880 ft Prentex	5,270 ft Prentex	6,180 ft ATS	T 6,920 ft
G*sinδ (kPa)	Devic	Allow	507	657	714	127	671	710		698
		Obser	593	614	260	62	50	1,230		190
	Manu	Allow	464	715	658					
		Obser	10	818	551					
S (MPa)	Devic	Allow	11	12	0.014	12	13	12	0.014	11
		Obser	12	7	0.004	18	8	1	0.001	3
	Manu	Allow	12	11	19				12	
		Obser	3	5	10				6	
m-value	Devic	Allow	0.010	0.010	0.010	0.010	0.010	0.009	0.010	0.010
		Obser	0.005	0.006	0.004	0.014	0.004	0.011	0.001	0.018
	Manu	Allow	0.010	0.010	0.013				0.014	
		Obser	0.002	0.010	0.004				0.010	

Are degassed and non-degassed from same population – (d2s%)

Apricot indicate gassed and non-degassed differ by more than operator variability – PG 58-28

Property	Release	Range	AMRL (270 ft) ATS	CAPLAB (520 ft) ATS	FHWA (540 ft) ATS	MTE (720 ft) Prentex	TAI (880 ft) Prentex	CODot (5,270 ft) Prentex	WYDOT (6,180 ft) ATS	NMDOT (6,920 ft) ATS
G*sinδ (kPa)	D	E	569	594	654	627	709	647		705
		O	410	592	118	276	369	10		140
	M	E	666	660	689					
		O	690	456	101					
S (MPa)	D	E	18	17	0.013	18	21	17	0.013	20
		O	2	48	0.001	4	12	72	0.000	5
	M	E	18	18	19				15	
		O	10	9	10				6	
m-value	D	E	0.009	0.009	0.009	0.010	0.009	0.009	0.010	0.009
		O	0.002	0.009	0.001	0.002	0.002	0.005	0.000	0.004
	M	E	0.009	0.009	0.013				0.013	
		O	0.019	0.006	0.004				0.008	

Observations.....

- No clear change in properties as consequence of degassing
  - ✓ Qualitative evaluation of data does nor warrant degassing
  - ✓ Until verify anecdotal information claiming vacuum stiffens binder allow degassing as optional but referee method
- Degassing may decrease test-test test variability
  - ✓ Need some more data mining to validate this claim
  - ✓ Bubbles observed in non-degassed and degassed specimens

Conclusions and Recommendations

1. Test method should be revised with specifics regarding determination of vacuum gage pressure
   - ✓ Recommendation given above
2. Specification values for gage pressure should be revised to match gages in use and to be compatible with gage readability
   - ✓ Recommendations given above
3. Some binders never stop outgassing
   - ✓ Consistent with anecdotal observations in field
   - ✓ Question degassing conditions – need another look

Now for the big question

4. Do we need to degas?
   - ✓ No definitive answer
   - ✓ May reduce repeatability
   - ✓ Marginal effect on measured variables – effect may be lost in test variability
4. Recommendation:
   - ✓ Degassing PAV residue is optional when conducting a non-destructive property such as G* or δ but is required when performing a destructive test such as the DTT
   - ✓ Degassing is required for all referee testing
   - ✓ Appropriate note must be added to each property method

What's next?

Comprehensive report detailing pressure considerations and analysis of property data

With that we should put this one to rest except for evaluation of degassing conditions – vacuum level, time, and temperature