MARC MODIFIED ASPHALT RESEARCH CENTER

E2b Design System for HMA Containing a High Percentage of RAP

Testing and Analysis Update

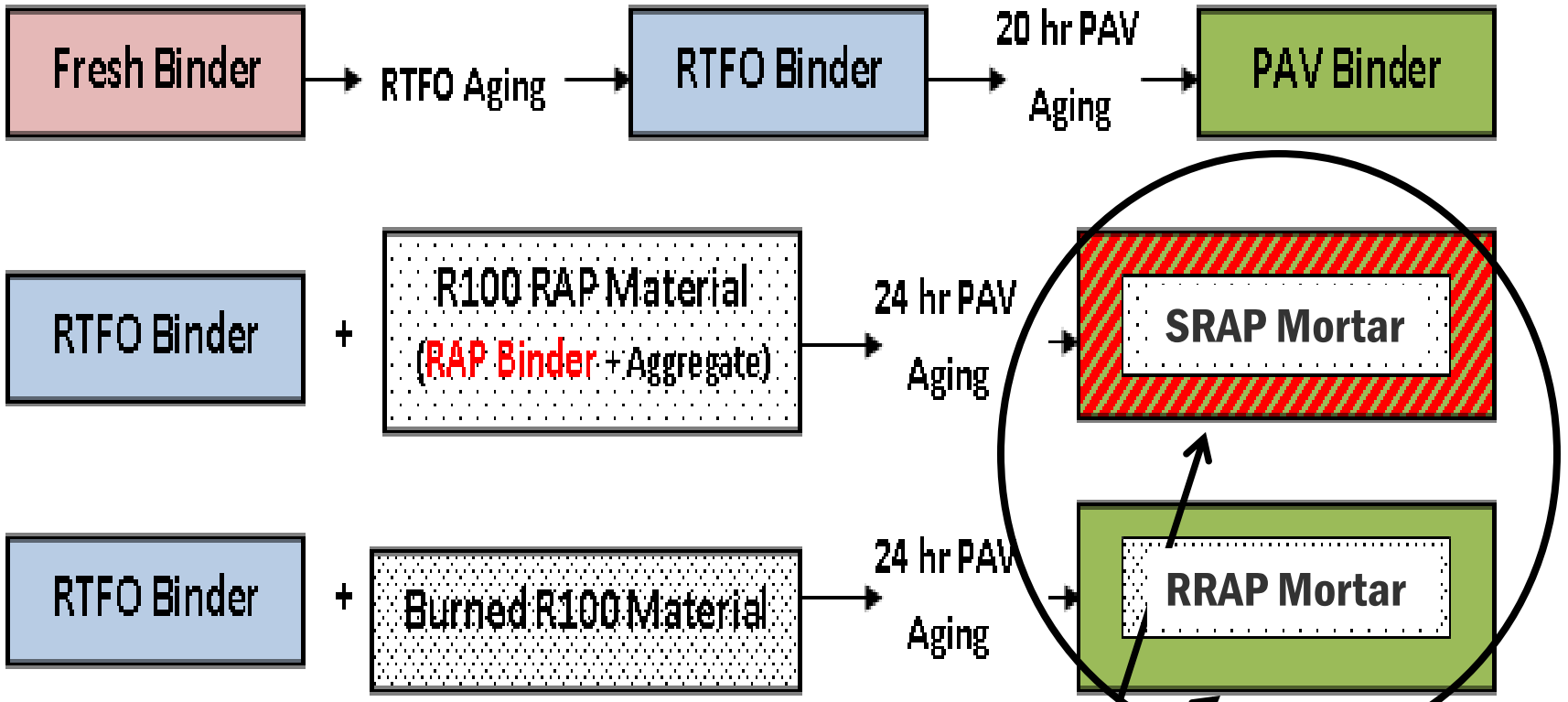
RAP ETG

Auburn, Alabama May 19, 2010

Research Hypothesis

- If the following two mortars are prepared (*identical gradation* and *identical total asphalt content)*,
  - RAP (aged Binder + Aggregate) + Fresh Binder
  - RAP Aggregate (No binder) + Fresh Binder
- then any difference in properties can be attributed to the RAP Binder only.

Samples Preparation



Only difference is RAP binder.

Procedure Output

- Output is PG of blended binder (PG zz-ww):
  - If *A%* Fresh Binder is mixed with **B% RAP binder** in a mix, then the resulting PG grade of the blended binder will be ***PG zz-ww***.
  - Based on concepts of blending charts

A % Fresh Binder: PG 58-28	+	B % RAP Binder PG xx-yy

=

Blended Binder *PG zz-ww*

Sample Preparation

- Mix binder content determined by user
  - Increase asphalt content until ***desired workability*** is achieved. (minimize fresh binder)
  - ***Desired workability:*** to allow casting BBR beams and DSR samples.
  - Starting point recommended is 70% /30% (fresh/RAP binder)
- Spreadsheet accounts for RAP asphalt content to compute total asphalt content.

Mix Calculation

User enters pink cells

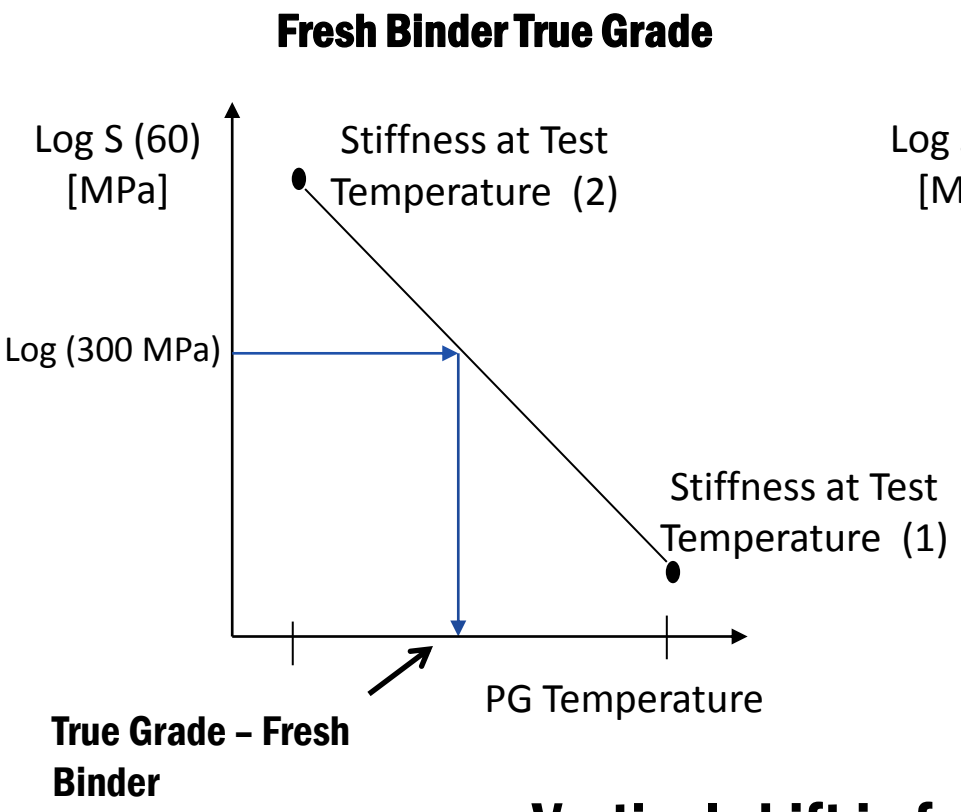
Add binder until desired workability is achieved

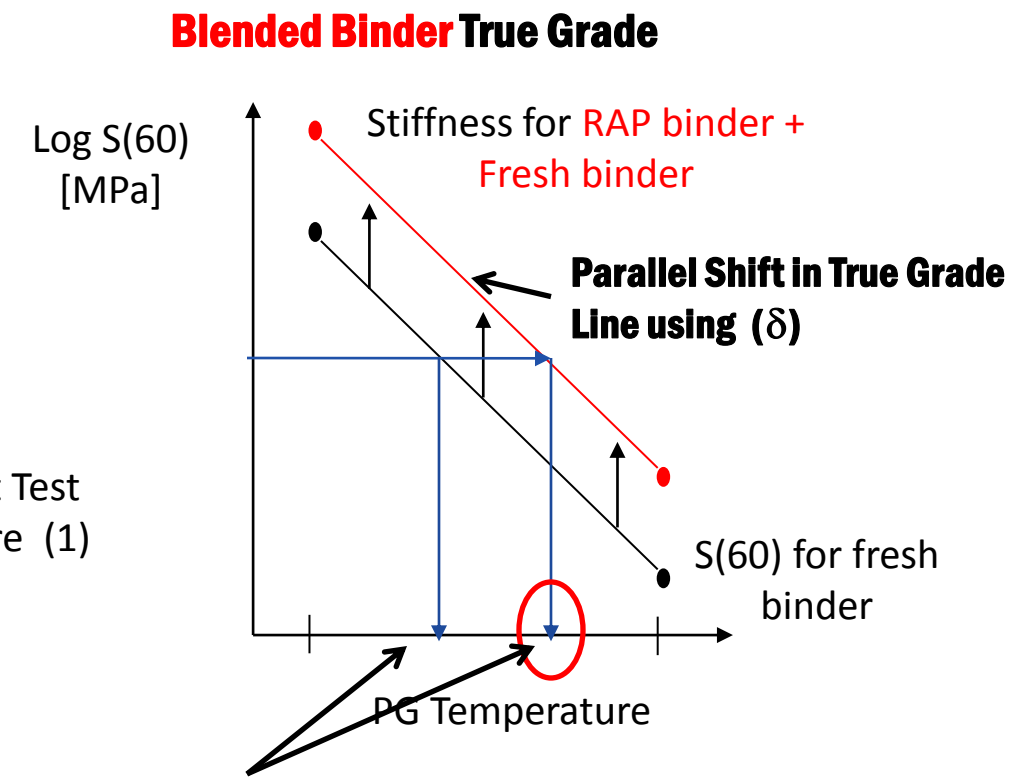
RAP Material Properties and Mix Components				
RAP Source			R100 Binder Content [%]	
		Fresh		
Fresh Binder PG Grade:				
		Low and Intermediat		
		RTFO Aged Fresh Binder + Unbu		
RAP (R100)	RTFO Binder [g]	Total Binder Content [%]	Total Mortar [g]	Min. Total Mortar Required [g]
150.00	40.00	30.61	190.00	182.82
RTFO Aged Fresh Binder + Burned R100 RAP Aggregate (RTFO-RRAP) Mix Calculation				
Burned RAP [g]	RTFO Binder [g]	Total Binder Content [%]	Total Mortar [g]	Min. Total Mortar [g]
150.00	66.47	30.61	216.47	182.82
RTFO + PAV Aged Binder			Mortar / PAV Pan [g]	162.82
RTFO Binder Required [g]	Total PAV Binder [g]		Calculated %RAP Binder in Total Blend	31.44
50	50			

Required Testing

Low Temperature: BBR		Intermediate Temperature: DSR		High Temperature: DSR	
Binder Samples	Mortar Samples	Binder Samples	Mortar Samples	Binder Samples	Mortar Samples
	PAV Aged		PAV Aged		Fresh
PAV Binder	SRAP	PAV Binder	SRAP	Fresh	SRAP
	PAV Aged		PAV Aged		Fresh
	RRAP		RRAP		RRAP
				RTFO	RTFO
					SRAP
					RTFO
					RRAP

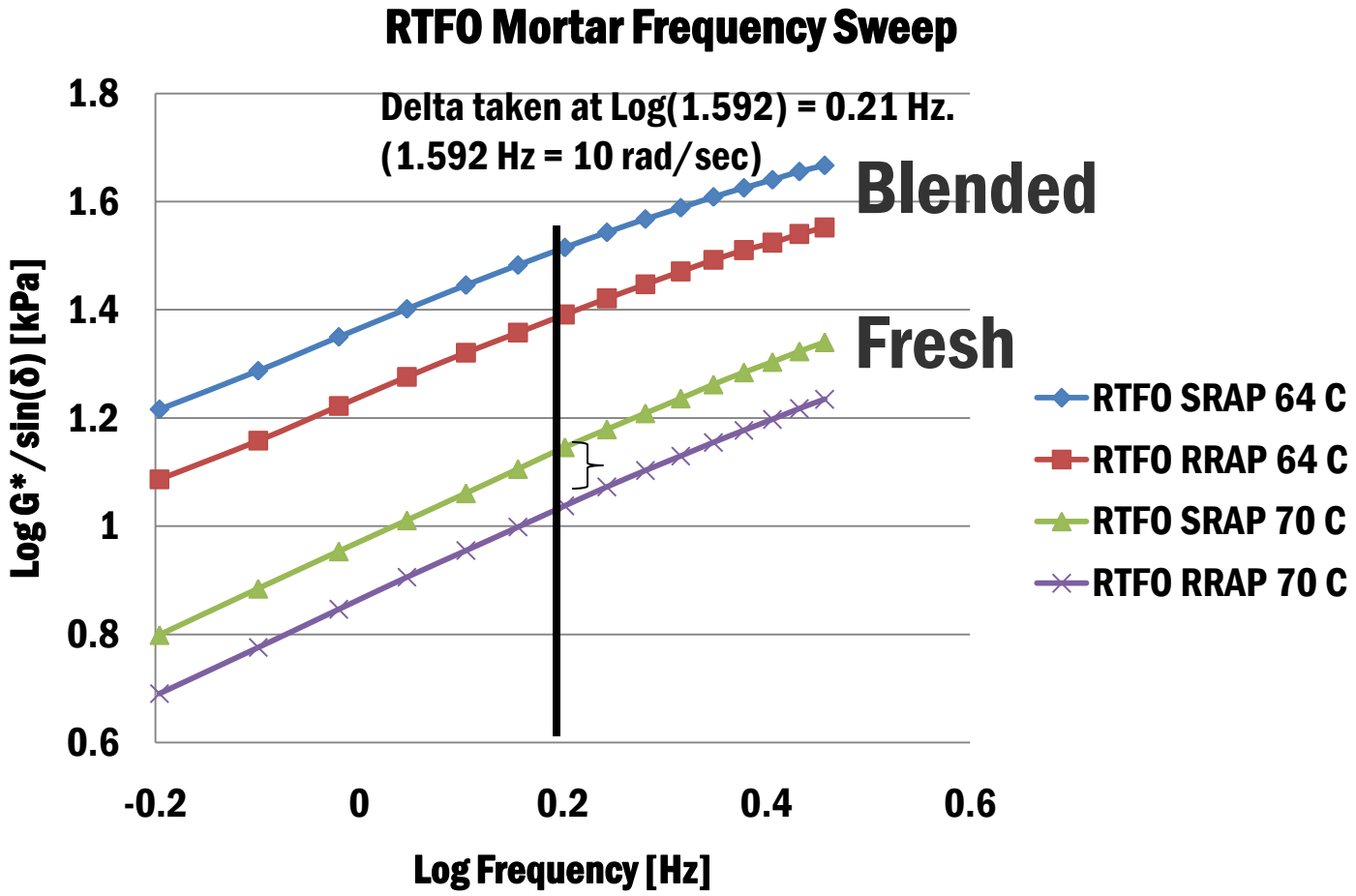
Need testing at 2 temperatures Graphically…



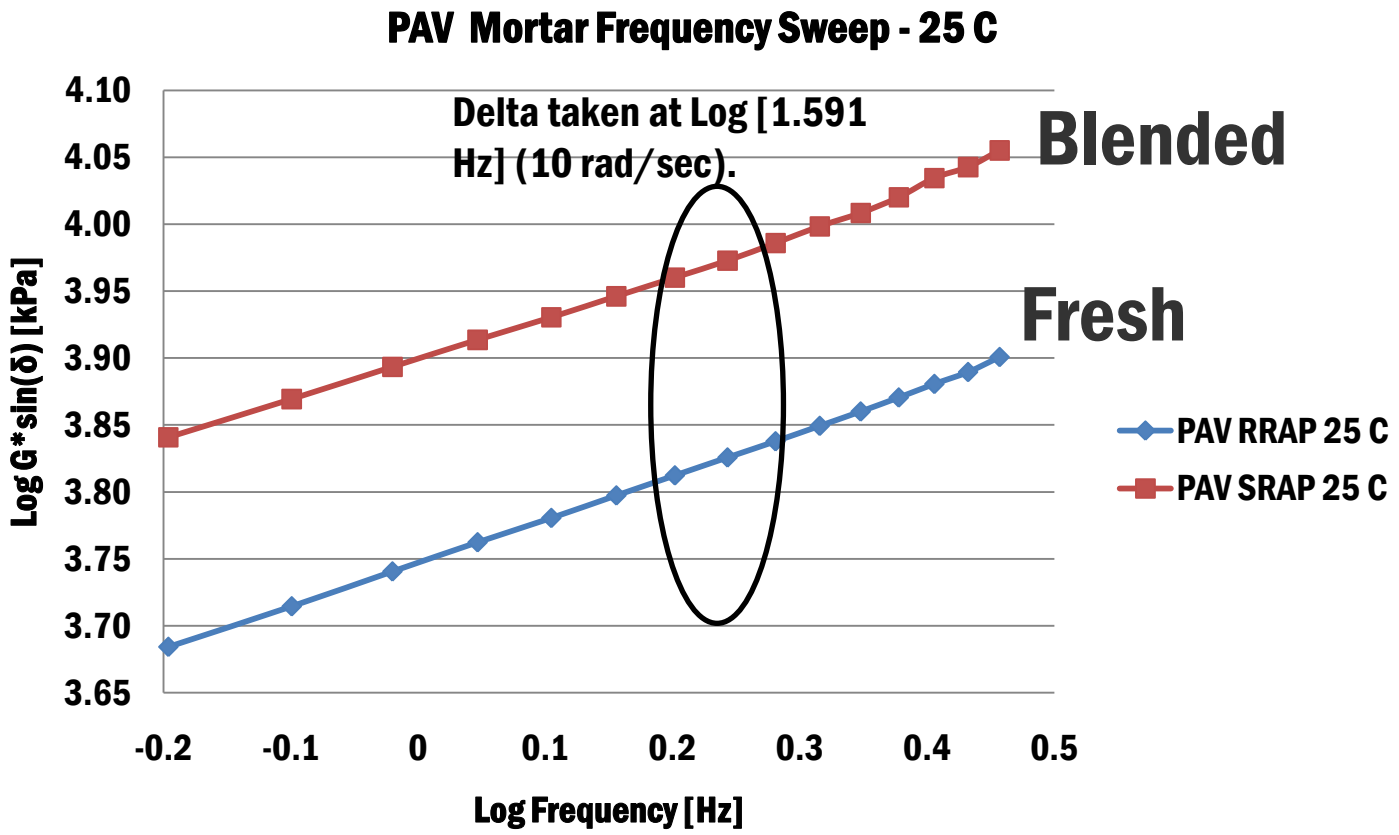


Vertical shift in fresh true grade line results in a new binder true grade (blended binder grade)

Change in G*/sind of Mortars



Shift in G*. Sin d of Mortars



Data Analysis – Enter Data S, m

BBR Test Results on PAV Aged Fresh Binder									
Test Temperature 1:				**-12**	Test Temperature 2:				**-18**
Time [sec]	**Rep. 1**	**Rep 2.**	**Average**	**% Diff.**	**Time [sec]**	**Rep. 1**	**Rep 2.**	**Average**	**% Diff.**
	S [MPa]	S [MPa]	S [MPa]	S [MPa]		S [MPa]	S [MPa]	S [MPa]	S [MPa]
60	168.0	160.0	164.0	4.88	60	291.0	288.0	289.5	1.04
	m-value	m-value	m-value	m-value		m-value	m-value	m-value	m-value
60	0.334	0.348	0.341	4.11	60	0.319	0.310	0.315	2.86
BBR Test Results on PAV Aged Fresh Binder + Burned R100 RAP Aggregate (RRAP Mortar)									
Test Temperature 1:				**-12**	Test Temperature 2:				**-18**
Time [sec]	**Rep. 1**	**Rep 2.**	**Average**	**% Diff.**	**Time [sec]**	**Rep. 1**	**Rep 2.**	**Average**	**% Diff.**
	S [MPa]	S [MPa]	S [MPa]	S [MPa]		S [MPa]	S [MPa]	S [MPa]	S [MPa]
60		681.0	681.0		60		1170.0	1170.0	
	m-value	m-value	m-value	m-value		m-value	m-value	m-value	m-value
60		0.325	0.325		60		0.274	0.274	
BBR Test Results on PAV Aged Fresh Binder + R100 RAP (SRAP Mortar)									
Test Temperature 1:				**-12**	Test Temperature 2:				**-18**
Time [sec]	Rep. 1	Rep 2.	Average	% Diff.	Time [sec]	Rep. 1	Rep 2.	Average	% Diff.
	S [MPa]	S [MPa]	S [MPa]	S [MPa]		S [MPa]	S [MPa]	S [MPa]	S [MPa]
60	1040.0	1060.0	1050.0	1.90	60	1720.0	1830.0	1775.0	6.20
	m-value	m-value	m-value	m-value		m-value	m-value	m-value	m-value
60	0.264	0.257	0.261	2.69	60	0.235	0.233	0.234	0.85

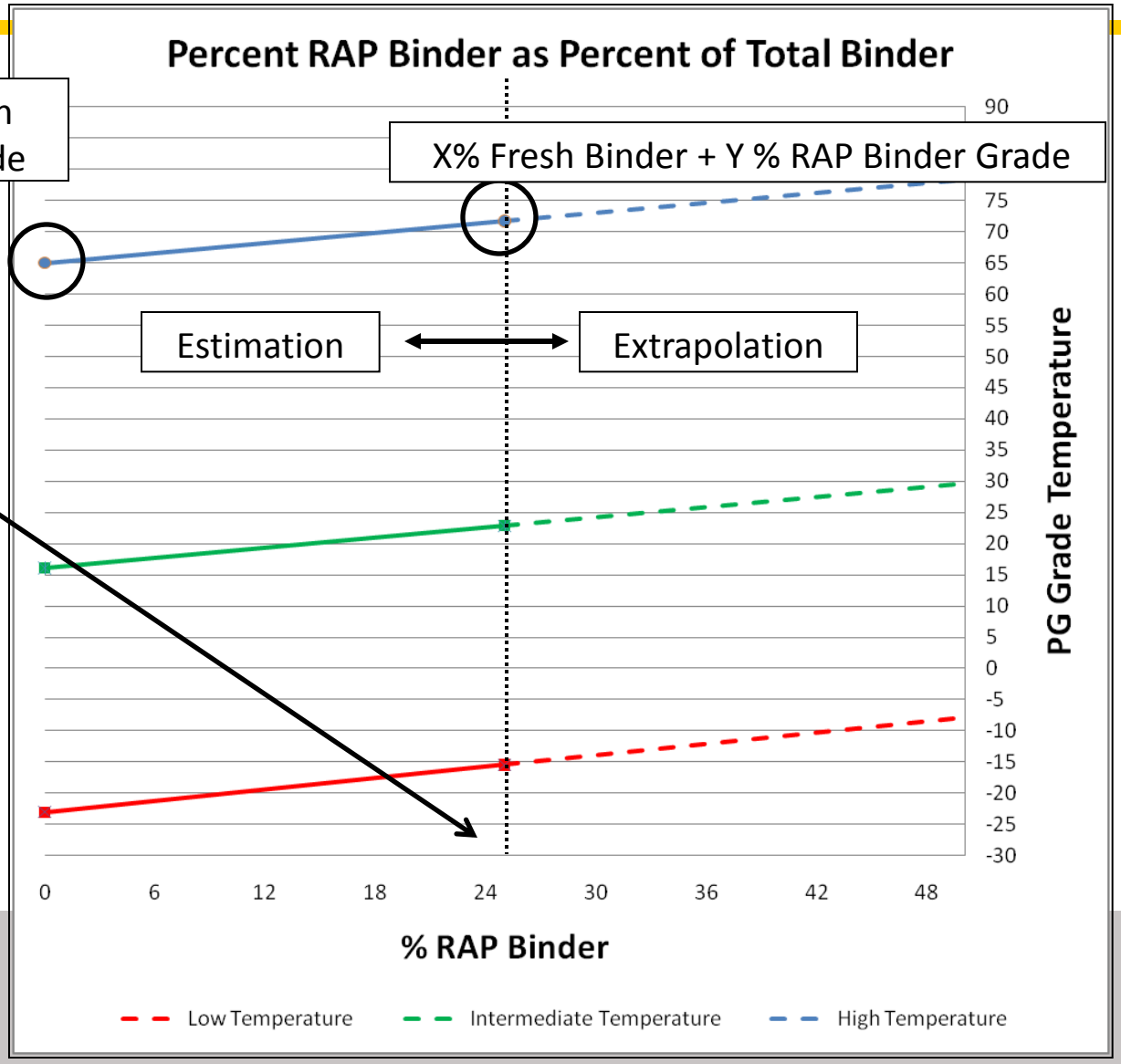
Data Entry – G*/sinδ

DSR Test Results on Fresh Binder and RTFO Aged Binder, G/sin(δ) [kPa]*									
Test Temperature 1:				64	Test Temperature 2:				70
Freq [rad/sec]	Rep. 1	Rep. 2	Average	% Diff.	Freq [rad/sec]	Rep. 1	Rep. 2	Average	% Diff.
	Fresh	Fresh	Fresh	Fresh		Fresh	Fresh	Fresh	Fresh
10	1.48	1.46	1.47	1.02	10	0.69	0.69	0.69	0.39
	RTFO	RTFO	RTFO	% Diff.		RTFO	RTFO	RTFO	% Diff.
10	4.85	4.73	4.79	2.51	10	2.36	2.40	2.38	1.81

Fresh Binder + R100 RAP and RTFO Aged Binder + R100 RAP Aggregate (Fresh and RTFO RRAP Mortar), G/sin(δ) [kPa]*									
Test Temperature 1:				64	Test Temperature 2:				70
Freq [rad/sec]	Rep. 1	Rep. 2	Average	% Diff.	Freq [rad/sec]	Rep. 1	Rep. 2	Average	% Diff.
	Fresh	Fresh	Fresh	Fresh		Fresh	Fresh	Fresh	Fresh
10	8.00	8.15	8.07	1.92	10	3.74	3.82	3.78	1.93
	RTFO	RTFO	RTFO	RTFO		RTFO	RTFO	RTFO	% Diff.
10	26.33	25.28	25.81	4.07	10	10.42	10.00	10.21	4.15

Fresh Binder + R100 RAP and RTFO Aged Binder + R100 RAP (Fresh and RTFO SRAP Mortar), G/sin(δ) [kPa]*									
Test Temperature 1:				64	Test Temperature 2:				70
Freq [rad/sec]	Rep. 1	Rep. 2	Average	% Diff.	Freq [rad/sec]	Rep. 1	Rep. 2	Average	% Diff.
	Fresh	Fresh	Fresh	Fresh		Fresh	Fresh	Fresh	Fresh
10	11.72	11.73	11.73	0.09	10	5.36	5.25	5.31	2.21
	RTFO	RTFO	RTFO	% Diff.		RTFO	RTFO	RTFO	% Diff.
10	33.16	33.78	33.47	1.85	10	14.93	14.61	14.77	2.20

Data Analysis



Example of Effect of RAP Binder on PG Grade

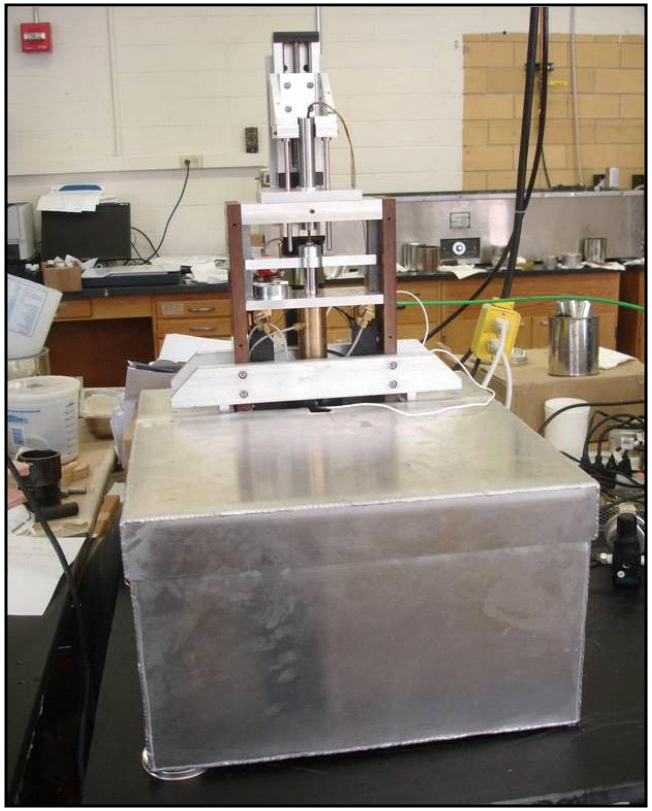
	Binder True Grade					
	Fresh Binder PG 64-22	25% Reno RAP	40% Reno RAP	**Fresh Binder PG 58-28**	25% Wisconsin RAP	40% Wisconsin RAP
Low Temperature	**-23.1**	-15.5	-10.9	**-30.5**	-26.3	-23.7
Intermediate Temperature	**17.0**	22.0	26.0	**21.8**	26.7	29.7
High Temperature	**67.0**	68.0	68.6	**61.0**	64.0	67.1
PG Grade	**64 - 22**	64 - 10	64 - 10	**58 - 28**	64 - 22	64 - 22

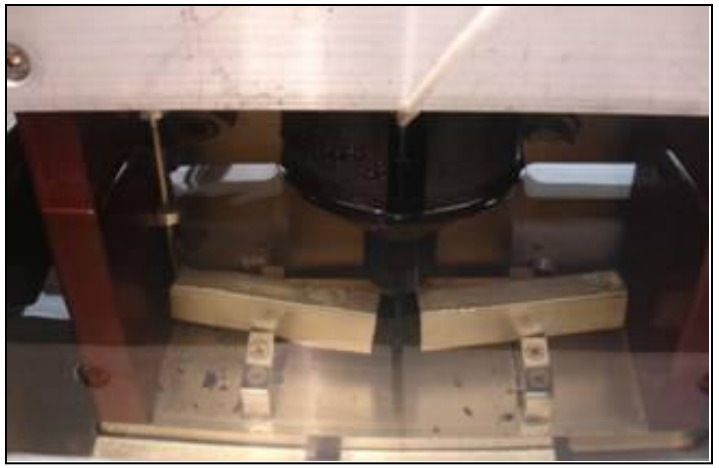
	Binder True Grade					
	Fresh Binder PG 64-22	25% Indiana RAP	40% Indiana RAP	**Fresh Binder PG 58-28**	25% Indiana RAP	40% Indiana RAP
Low Temperature	**-22.1**	-17.4	-15.3	**-28.6**	-19.9	-14.6
Intermediate Temperature						
High Temperature						
Low Temperature PG Grade	**-22**	-16	-10	**-28**	-16	-10

Challenges and Further Study

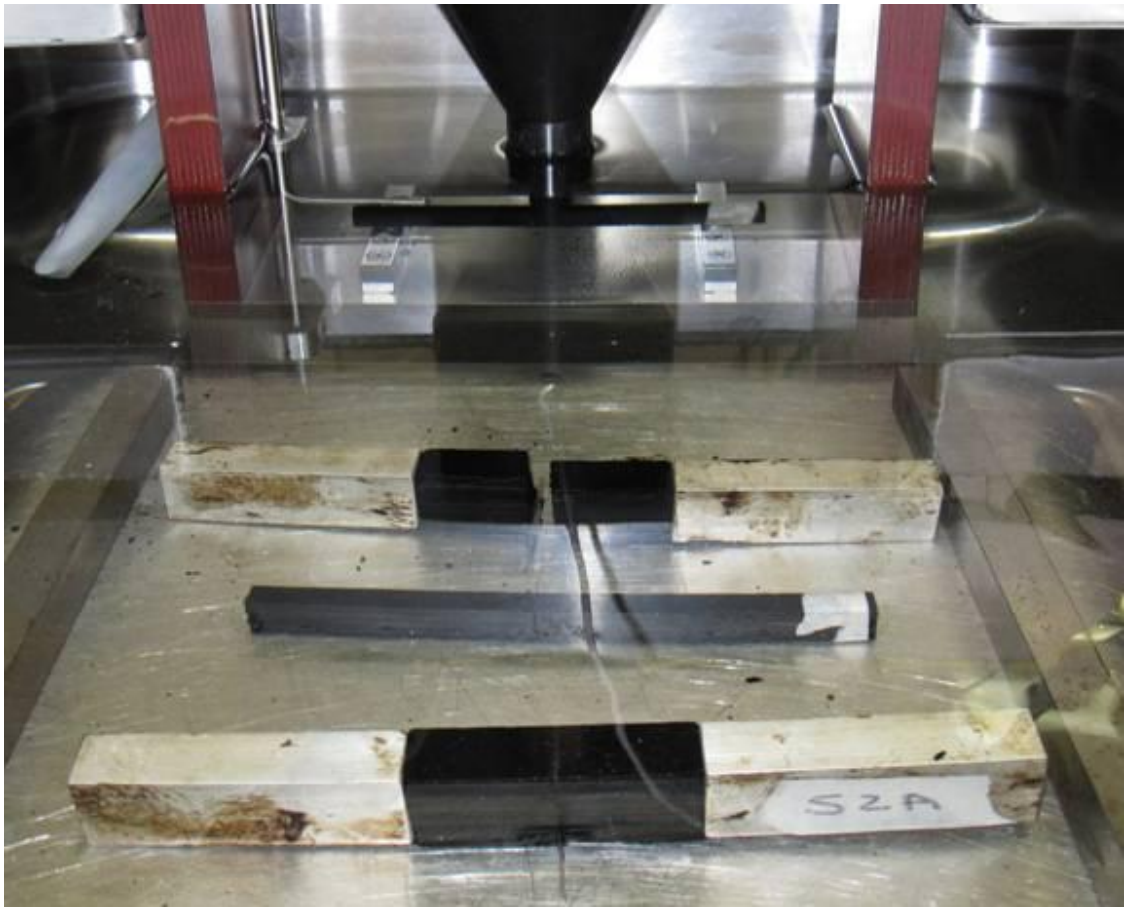
- Verification and Variability
  - Verify different combinations
  - Source Variability
- Investigating R100 Material
  - Effect of ignition oven
  - Fractionating or crushing
- Effect on Low Temp Fracture

Single-Edge Notched Beam (SENB)





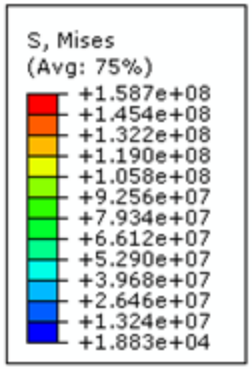
Previous and New Geometry

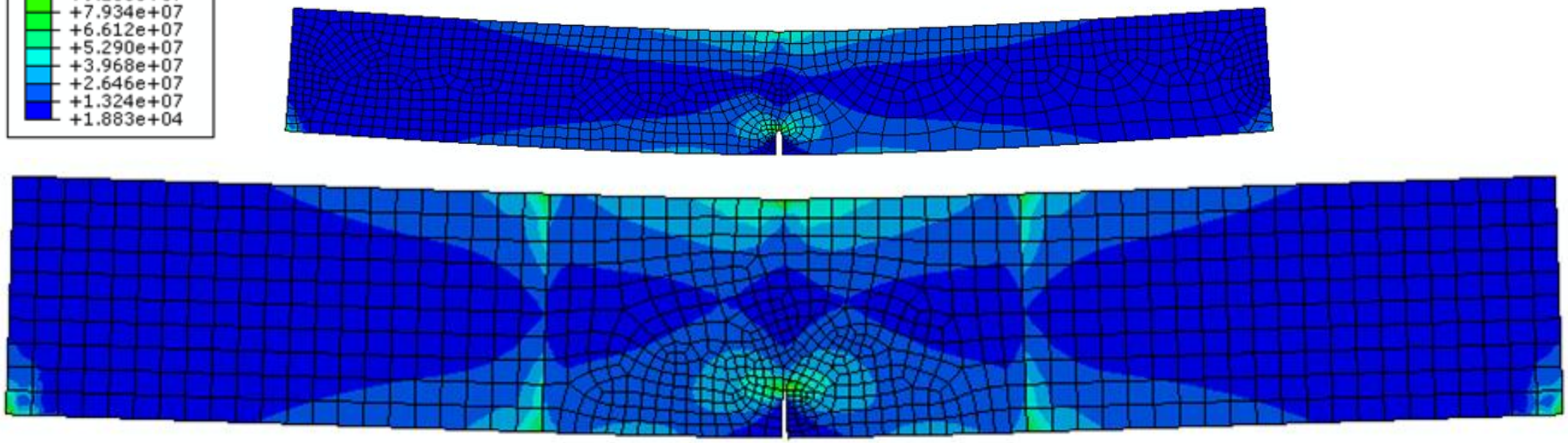


New Proposed Sample Geometry

New BBR Geometry:

- No discontinuity of stresses
- Plane sections remain plane after bending





SENB: Asphalt modified with rubber