MODIFIED ASPHALT RESEARCH CENTER

Estimating Effect of RAP and RAS on PG grade of Binders

Dan Swirtz, E. Mahmoud and H. Bahia
University of Wisconsin- Madison

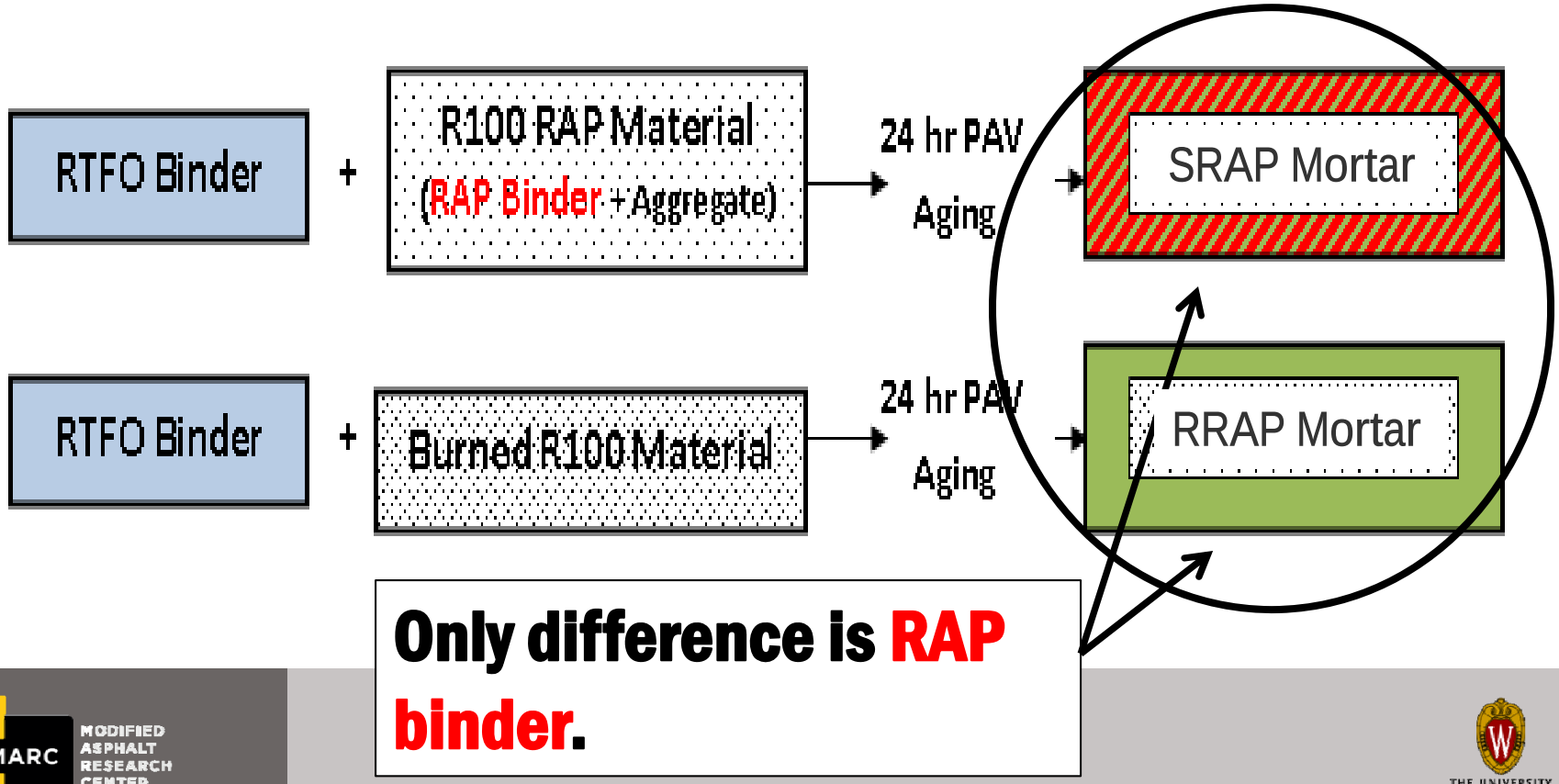
RAP ETG , Oklahoma City, October, 2010

Topics

- Testing and Analysis Procedure
  - Define Outcome: % change in grade per 1 % RAP binder
  - Finalize geometry in DSR for High Temp
- Verification Results
- Combining Shingles (RAS) and RAP
  - In collaboration with RMRC

Procedure Summary - Sample Preparation

R100: RAP passing #50 retained on #100

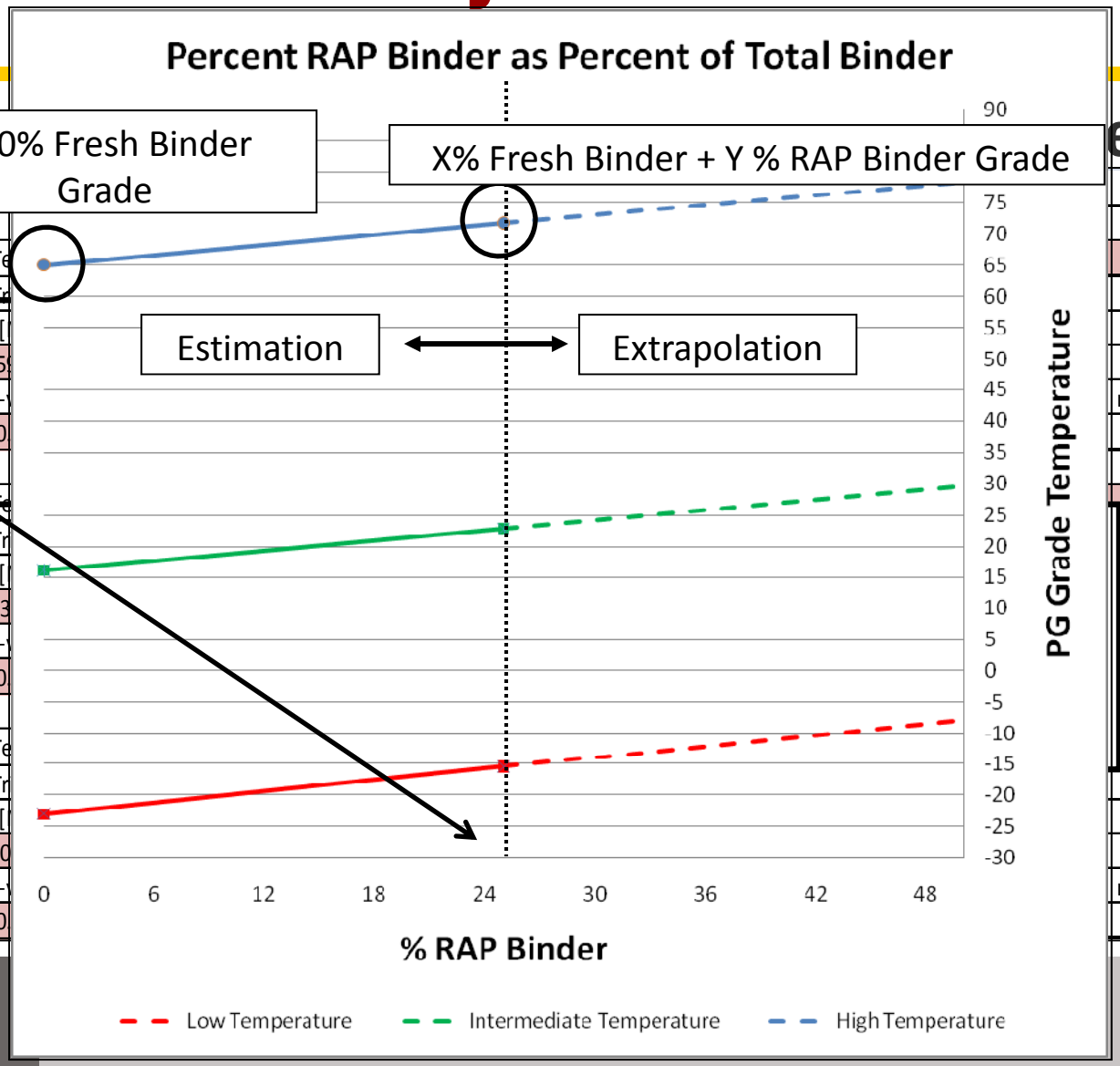


Hypothesis

- Two mortars are prepared:
  - RAM Material (Binder + Aggregate) + Fresh Binder
  - RAM Aggregate (No binder) + Fresh Binder
- If *identical gradation* and *identical total asphalt content are used*, the difference in G*, sin, m and S can be attributed to the RAM Binder only.

Spreadsheet Analysis

- Ent et



Maximum "Estimation" percentage based on RAP binder content and mixing percentages determined by user.

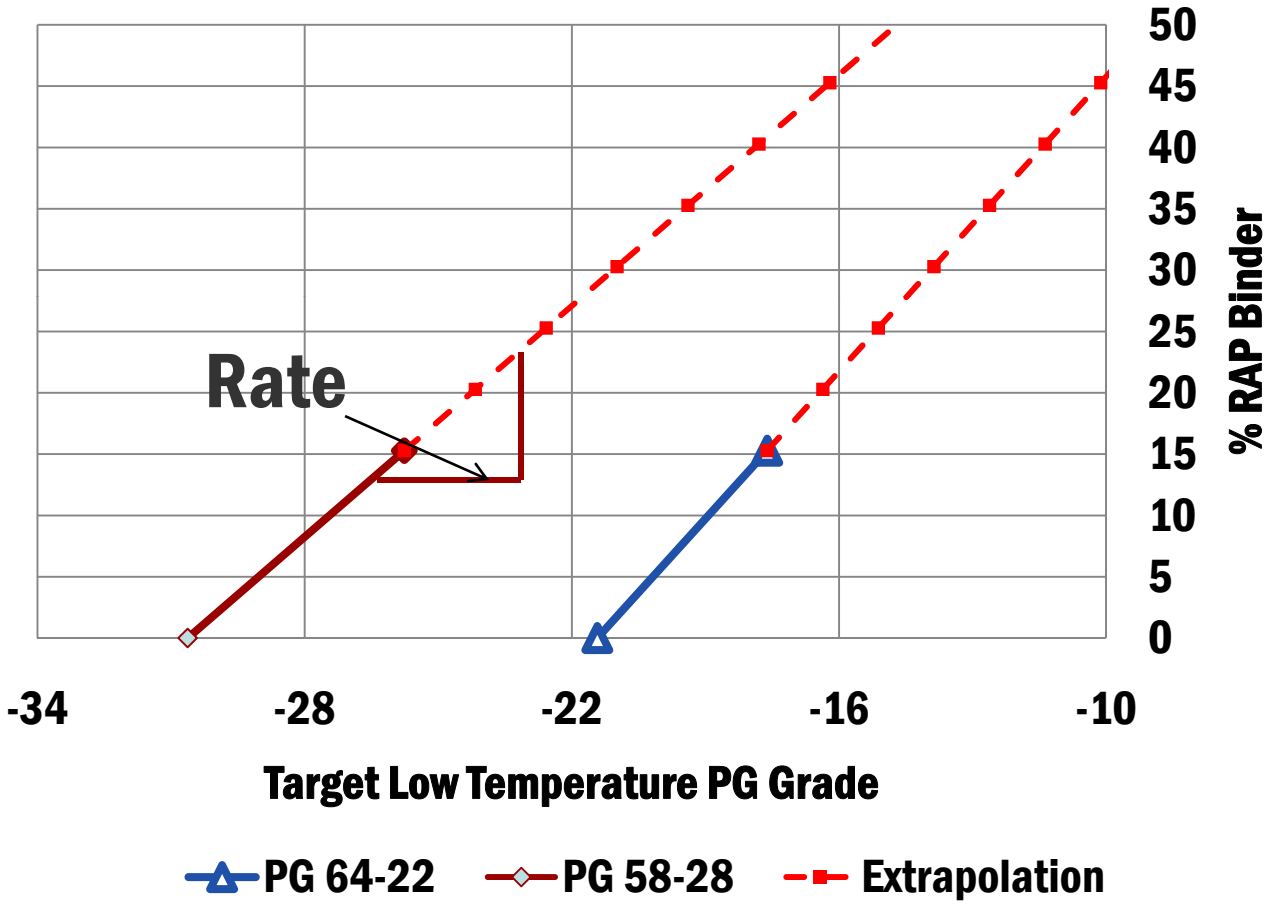
Time [sec]	Trial 1	Tr
	S [MPa]	S [
60	294.00	30
	m-value	m-
60	0.327	0
60	0.335	0

-12
COV
S [MPa]
1.21
m-value
1.48
-12
COV
S [MPa]
4.19
m-value
1.24
-12
COV
S [MPa]
0.60
m-value
0.37

MARC MODIFIED ASPHALT RESEARCH CENTER

THE UNIVERSITY of WISCONSIN MADISON

Outcome: Estimate of Rate of Change of LT Grade (*deg C / 1% RAP Binder*)



RAP Source Sensitivity Summary
Grade Change Rate

RAP Source	RAP Binder Percent [%]	Fresh Binder Grade	True Grade		Grade Change Rate (Deg C/%RAP)
			Fresh Binder	Blended Binder	
E.B.	25.17	58-28	-28.6	-17.6	0.44
		64-22	-22.0	-18.9	0.12
J.H.	19.75	58-28	-28.2	-24.0	0.21
		64-22	-19.8	-16.3	0.18
R.R.	15.00	58-28	-31.4	-22.8	0.57
		64-22	-25.4	-17.6	0.52
P.B.	15.28	58-28	-30.6	-25.8	0.31
		64-22	-21.4	-17.6	0.25

Verification Procedure

- Create and test “Artificial RAP”
  - 2 PAV aged binder + RAP aggregates
- Compare results against binder – only blends
  - e.g. 20% 2 PAV binder + 80% RTFO binder (High Temp)
- Compare True-Grade Values
  - Discrepancies could indicate
    - Invalid assumption of complete blending
    - Problems with analytical procedure

Verification Experiment

[illegible] + [illegible] 64 − 22 − [illegible]	Case I
[illegible] + [illegible] 58 − 28 [illegible]	Case II
[illegible] + [illegible] 58 − 28 [illegible]	Case III
[illegible] + [illegible] 64 − 22 − [illegible]	Case IV

Artificial RAP A_1: 40 hr PAV aged PG 64-22-a binder + R100 aggregate from Reno, Nevada mixed at a 10.5% total asphalt content.

Artificial RAP A_2: 40 hr PAV aged PG 64-22-b binder + R100 aggregate from Reno, Nevada mixed at a 10.5% total asphalt content.

Artificial RAP B: 40 hr PAV aged PG 58-28 binder + R100 aggregate from Wisconsin mixed at a 7.4% total asphalt content.

Results and Discussion

Verification

(BBR) LowTemperature Results

	Binder Replacement	Test Temp. [C]	Estimated True Grade [C]	Measured True Grade [C]	Difference [C]
Case I	15%	-6 -12	-18.87	-19.18	**0.31**
Case II	15%	-12 -18	-24.92	-27.36	**2.44**
Case III	15%	-12 -18	-25.96	-26.17	**0.21**
Case IV	25%	-6 -12	-20.43	-21.05	**0.62**

Verification

- Intermediate (DSR) Temperature Results

	Test Temp. [C]	Binder Replacement	Estimated True Grade [C]	Measured True Grade [C]	Difference [C]
Case I	25 28	15%	19.72	21.62	1.90
Case II	25 28	15%	16.59	19.01	2.42
Case III	25 28	15%	16.82	18.29	1.47
Case IV	25 28	25%	24.00	24.28	0.28

Verification High Temp

	Test Temp. [C]	Binder Replacement	Estimated True Grade [C]	Measured True Grade [C]	Difference [C]
Case I	64 70	15%	67.64	73.60	**5.96**
Case II	58 64	15%	59.77	63.45	**3.68**
Case III	58 64	15%	60.16	64.02	**3.86**
Case IV	64 70	20%	67.92	71.71	**3.80**

Selection of DSR Geometry

High Temperature Trial DSR Testing Geometries

	Plate Dia. [mm]	Gap [mm]	Strain [%]	Difference in True Grade* [deg C]
Standard Geometry	25	1	10	5.96
Trial 1	25	2	10	2.97
Trial 2	25	1	1	4.34
Trial 3	8	2	1	7.04

*Measured blended binder true grade – estimated blended binder true grade

Verification – Effect of conditioning time

Conditioning Time Analysis Summary

Standard Geometry

Conditioning Time	Measured True Grade	Estimated True Grade	Diff. [C]
None [mixing]	71.71	67.92	3.79
4 hr	71.71	67.80	3.91
24 hr	71.71	67.78	3.93

2 mm Gap Geometry

Conditioning Time	Measured True Grade	Estimated True Grade	Diff. [C]
None [mixing]	71.09	67.95	3.14
4 hr	71.09	67.81	3.28
24 hr	71.09	67.94	3.15

Effect of Total Binder Content

2 mm Gap Trial Geometry

Total A.C. [%]	RAP Binder [%] of total AC	TG From Plot	TG Estimate from Mortar Testing	Diff. [C]
36.0	20.00	71.04	67.97	3.07
50.0	11.60	69.36	67.48	1.88
60.0	7.81	68.60	67.43	1.16
70.0	5.03	68.04	67.84	0.20

Results and Discussion

Verification – High Temperature

> 3°C Discrepancy for all cases with standard geometry.

Re-tested to isolate:

- **Test Geometry (Trial at 2 mm gap setting)**
- **Conditioning time check (Complete blending)**
- **Sample Gradation (Sieve burned aggregates)**
- **Blending chemistry considerations (Change O.B.)**
- **Asphalt Content (Aggregate interlock effect)**

Results and Discussion

Verification – High Temperature

Discrepancy still exists…

Example High Temperature Verification Progression				
Original Difference in True Grade:		3.84		
Difference in True Grade after Change				
Gap Setting	Conditioning Time	Blend Chemistry	Gradation	Asphalt Content
3.12	3.12	3.72	Negligable	2.97

Note:

- Difference in True Grade always conservative: Est <Measured
- Increasing total asphalt content results in less RAM binder effects.

Comparison with Extraction and Recovery – Purdue Samples

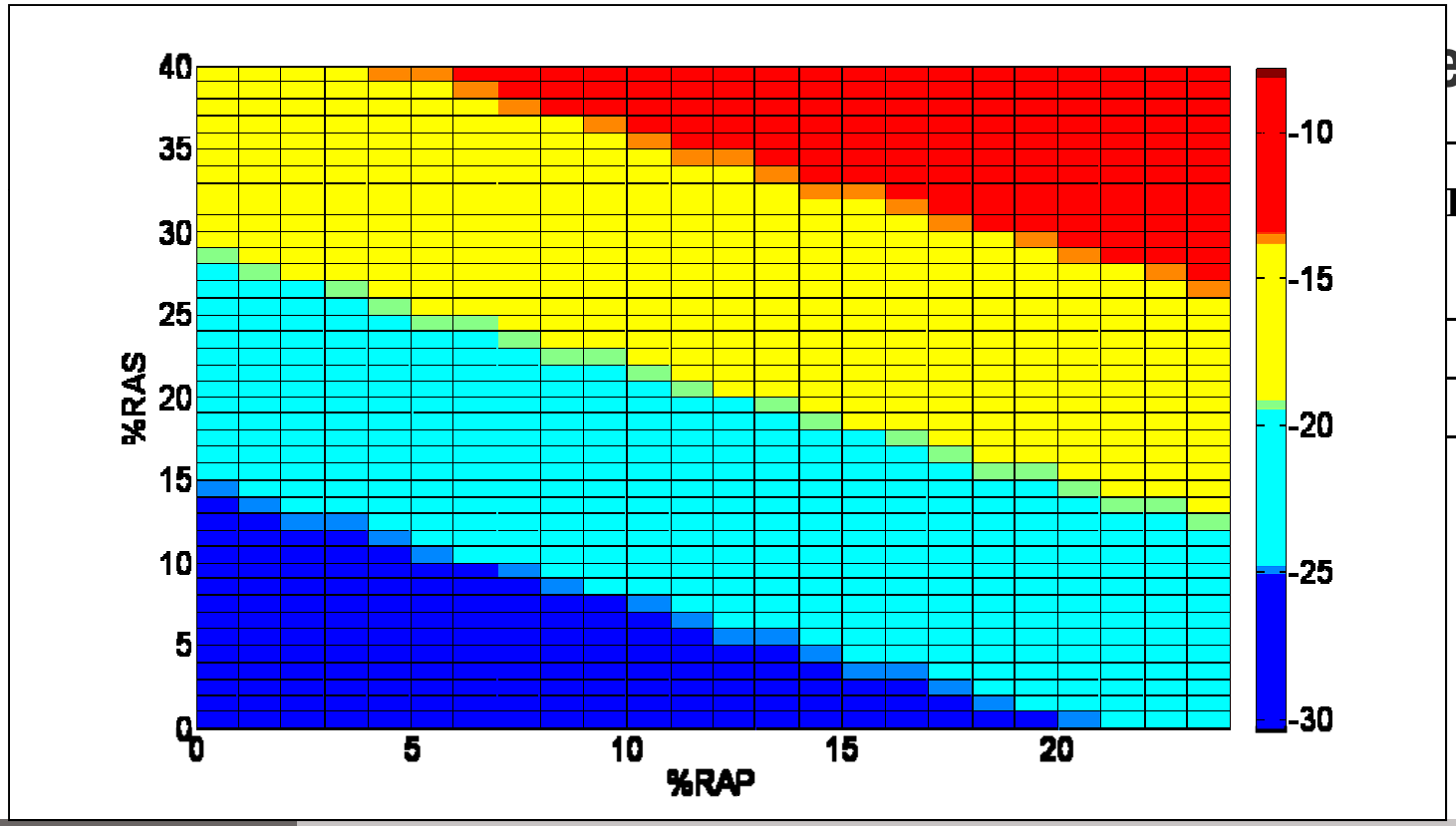
- **Comparison with mixture extraction samples:**

	% RAP in Mix	True Grade of Blended Binder		Difference
		Mortar Procedure	Mixture Extraction	
Fresh Binder Grade PG 64 - 22	0	-21.4	-20.6	**-0.8**
	15	-18.2	-20.5	**2.2**
Fresh Binder Grade PG 58 - 28	0	-30.6	-	**-**
	25	-23.9	-26.3	**2.4**

- **Notes:**
  - **When RAP present – Mortar procedure is conservative**
  - **Change in True Grade for extraction samples (PG 64-22) seem suspect (0.1 C change for 15% RAP)**

Results and Discussion

- RAP and RAS Blends



ests

Difference [C]
2.08
0.82

Results and Discussion

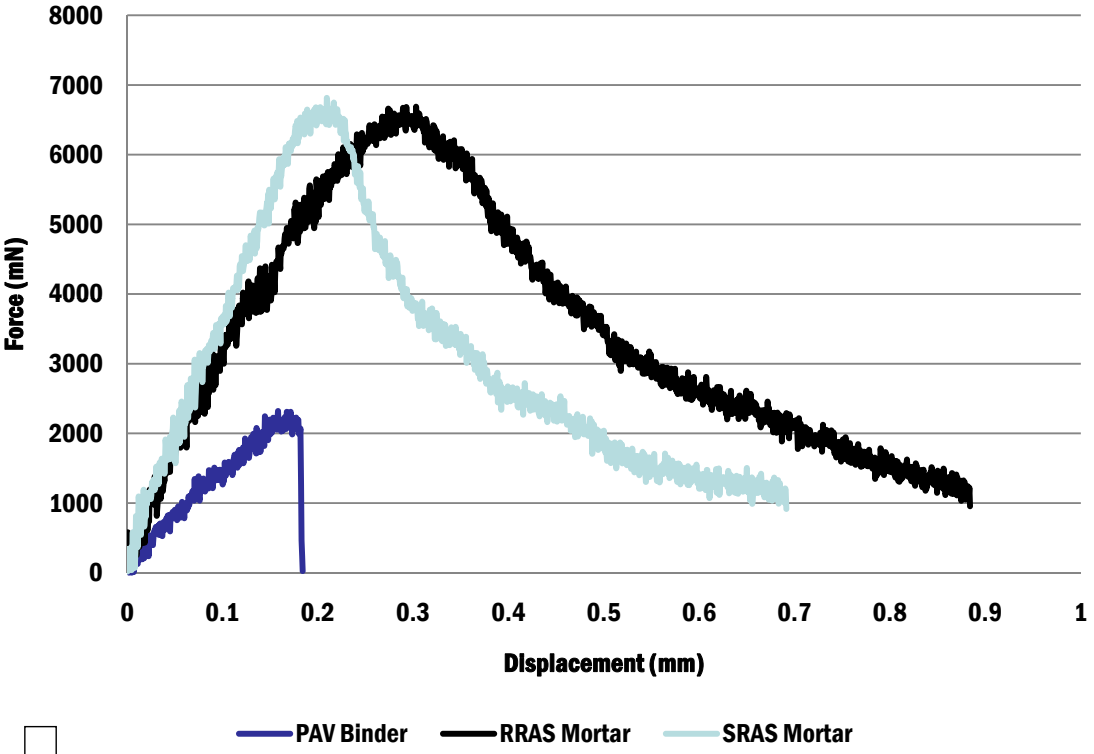
- Interim Findings
  - Procedure can be use to estimate low and intermediate properties with limited application at high temperature
  - Each RAP, RAS, and fresh binder blend is unique
    - Characterization can not be “lumped”

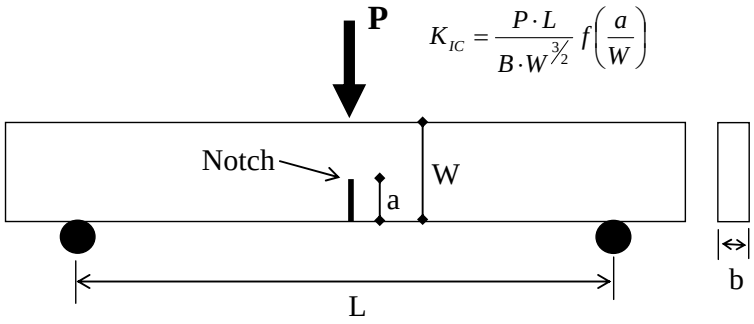
Further Study

- Low temperature Fracture Testing and Glass Transition
- Workability Concerns
- Variability (RAS)
- Verification Using Mixes

Fracture Testing – Modified BBR

BBR sample a Notch in the middle





$$K_{IC} = \frac{P \cdot L}{B \cdot W^{3/2}} f\left(\frac{a}{W}\right)$$

Effect of RAP and RAS on Fracture

RRAP: Fresh Binder , SRAP: Blended Binder

RAP/RAS	Material Tested	Max Load (mN)	Displacement at Fracture (mm)	Stress Intensity Factor (K_{IC})(kPa*$m^{0.5}$)	Fracture Energy* [mJ/mm^2]
RAP @ -6 C	PAV Binder	2488.3	0.447	27.6	658.8
	RRAP Mortar	12189.1	0.643	143.8	4279.4
	SRAP Mortar	10817.3	0.428	128.4	2469.5
RAP @ -12 C	PAV Binder	1761.3	0.371	20.2	407.4
	RRAP Mortar	7799.6	0.485	87.3	1968.7
	SRAP Mortar	8619.7	0.361	101.4	1822.1
RAS @ -18 C	PAV Binder	2320.5	0.158	26.2	189.1
	RRAP Mortar	6689.5	0.303	73.6	1049.0
	SRAP Mortar	6814.8	0.209	71.2	692.9