ARC
Asphalt Research Consortium

Estimating Low Temperature PG-Grade of Binders in RAP without Extraction

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Outline

- Relevance
- Testing Procedure
- Analysis Spreadsheet
- Next steps

Research Needs

2007 Survey - Cecil Jones

- Modulus of RAP Mixes
- Fatigue Concerns
- ***Final Effective Binder Grade***
- Performance of High RAP Mixes
- ***Need to Bump Binder Grade***
- How to Better Control RAP - Fractionating

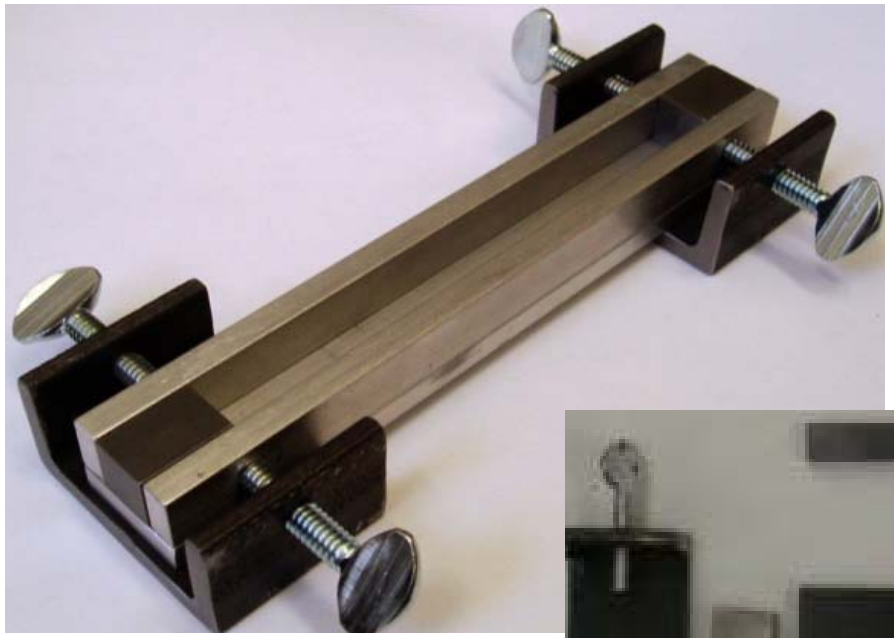
Concept of Testing

- Replace extraction and testing with testing RAP mortar
  - Mortar: Voidless mix of selected gradation of RAP with binder
- Estimate PG of binder in RAP from mortar testing
- High Temp PG
- Intermediate Temp PG
- Low Temp PG
  - Most critical
  - Start with BBR

Challenges / Solutions

- BBR is not designed for testing mortars
  - Not enough load to cause enough deflection
  - Cannot exceed load –cell limits
  - Mold is too narrow for casting mortars
- Solutions
  - Change mold – Done
  - Increase temp of testing and use models – Done
  - Re-design BBR allow higher load and measure fracture – 70 % done

Mold Modification

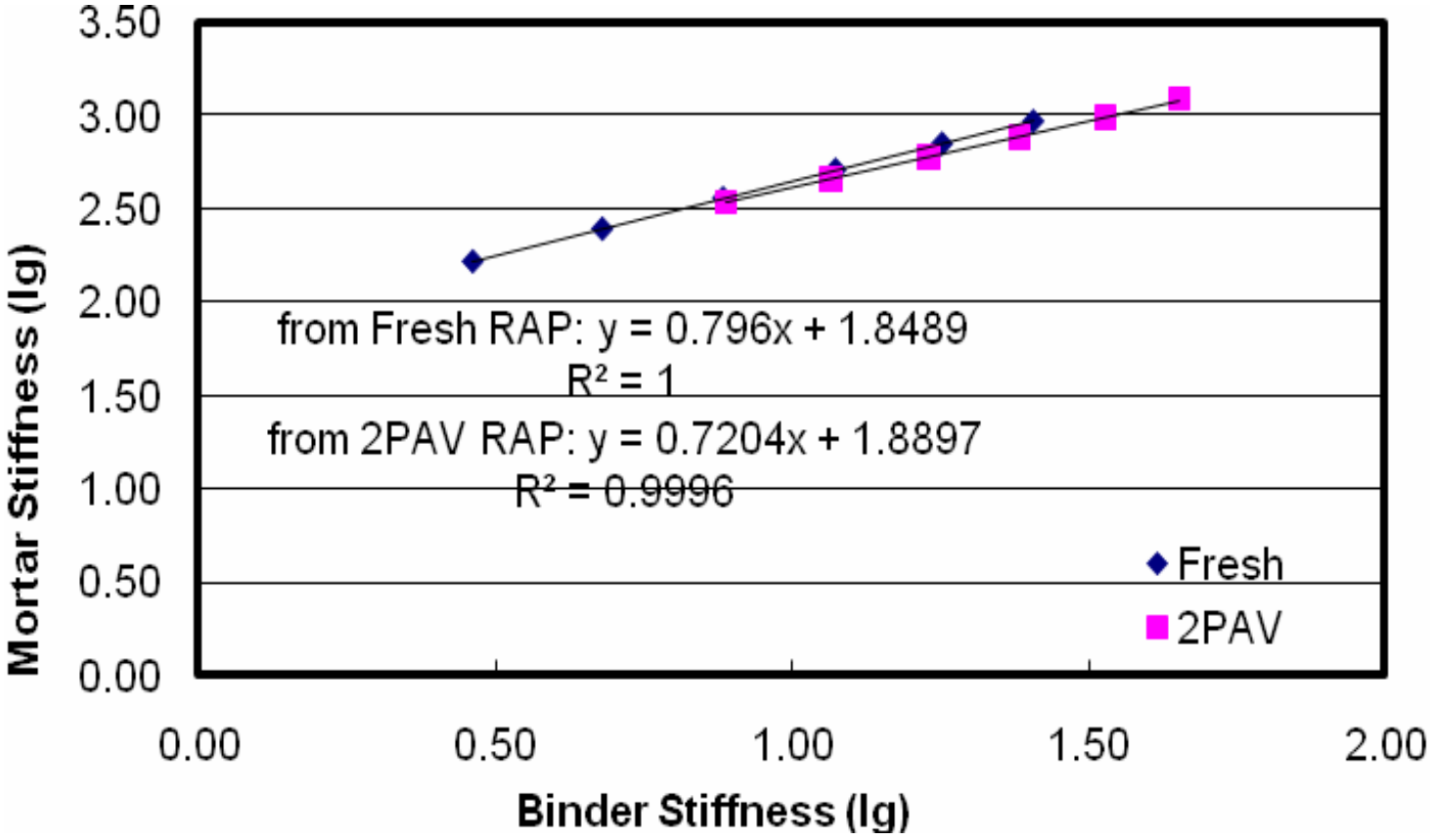


1. Wider Sample
   12.5 x 10.0 mm
2. Teflon coated
3. Stronger end holders

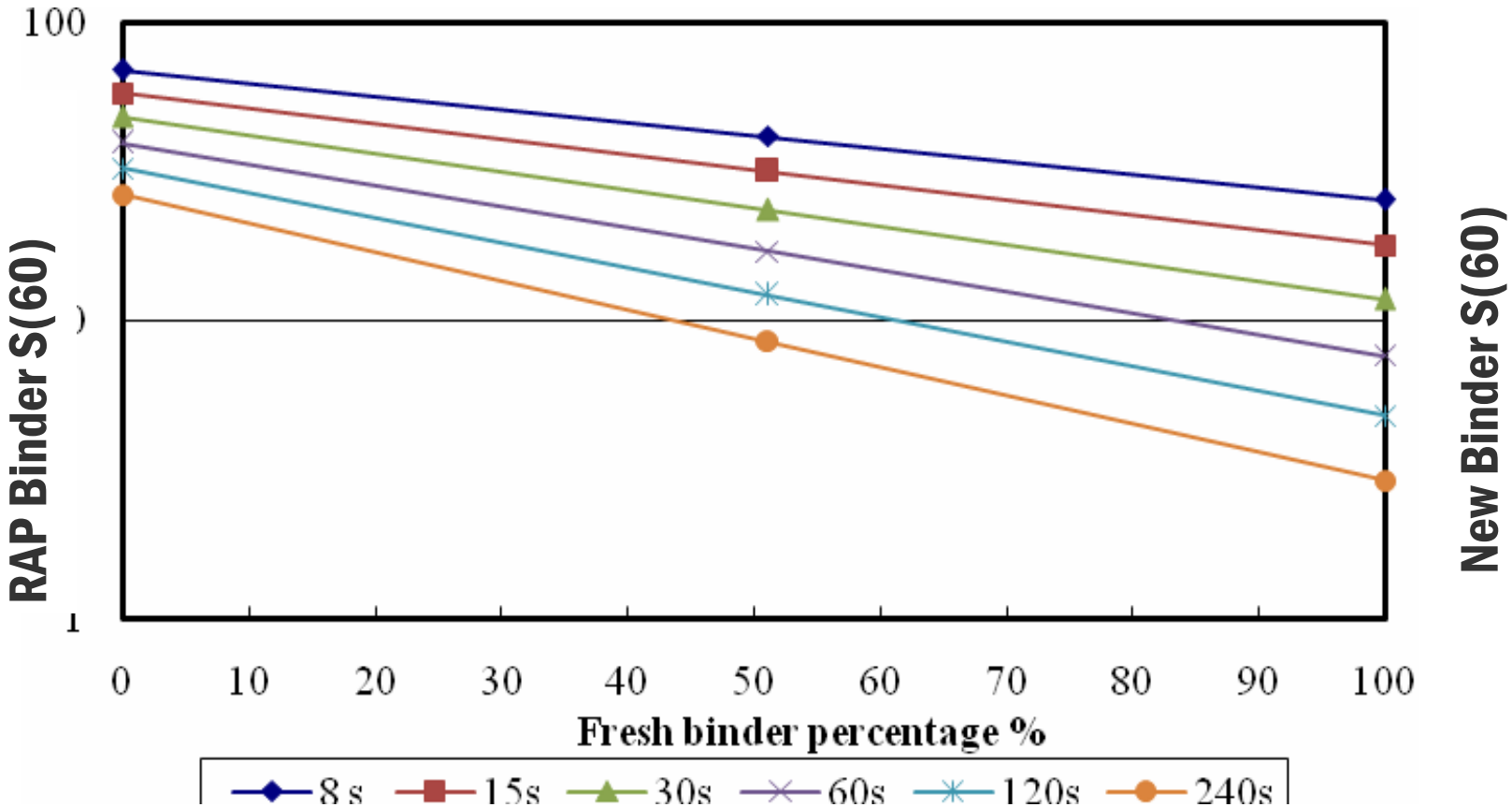
New Terminology

- ***RAP:*** **Reclaimed asphalt pavement**
  - ***Selective RAP (SRAP):*** RAP passing # 8 sieve retained on single sieve or different sieves combined according to fixed gradation
  - ***PAV RAP (PRAP):*** consists of the aggregates extracted from SRAP mixed with PAV binder
- ***Binders (B):***
  - ***PAV binder (PB):*** binder subjected to aged process of RTFO+PAV
  - ***SRAP binder (SB):*** aged binder in SRAP;
  - ***Blended binder (BB):*** SRAP binder blended with fresh or PAV binder
- ***Mortar (M):*** **RAP material mixed with binder**
  - ***PAV mortar (PM):*** RAP aggregates mixed with PAV binder by weight percentage;
  - ***SRAP mortar (SM):*** SRAP mixed with PAV binder by weight percentage;

First Approach: Test Mortars, Correlate to Binder



First Approach: Use Blending Chart to Estimate RAP Binder Grade



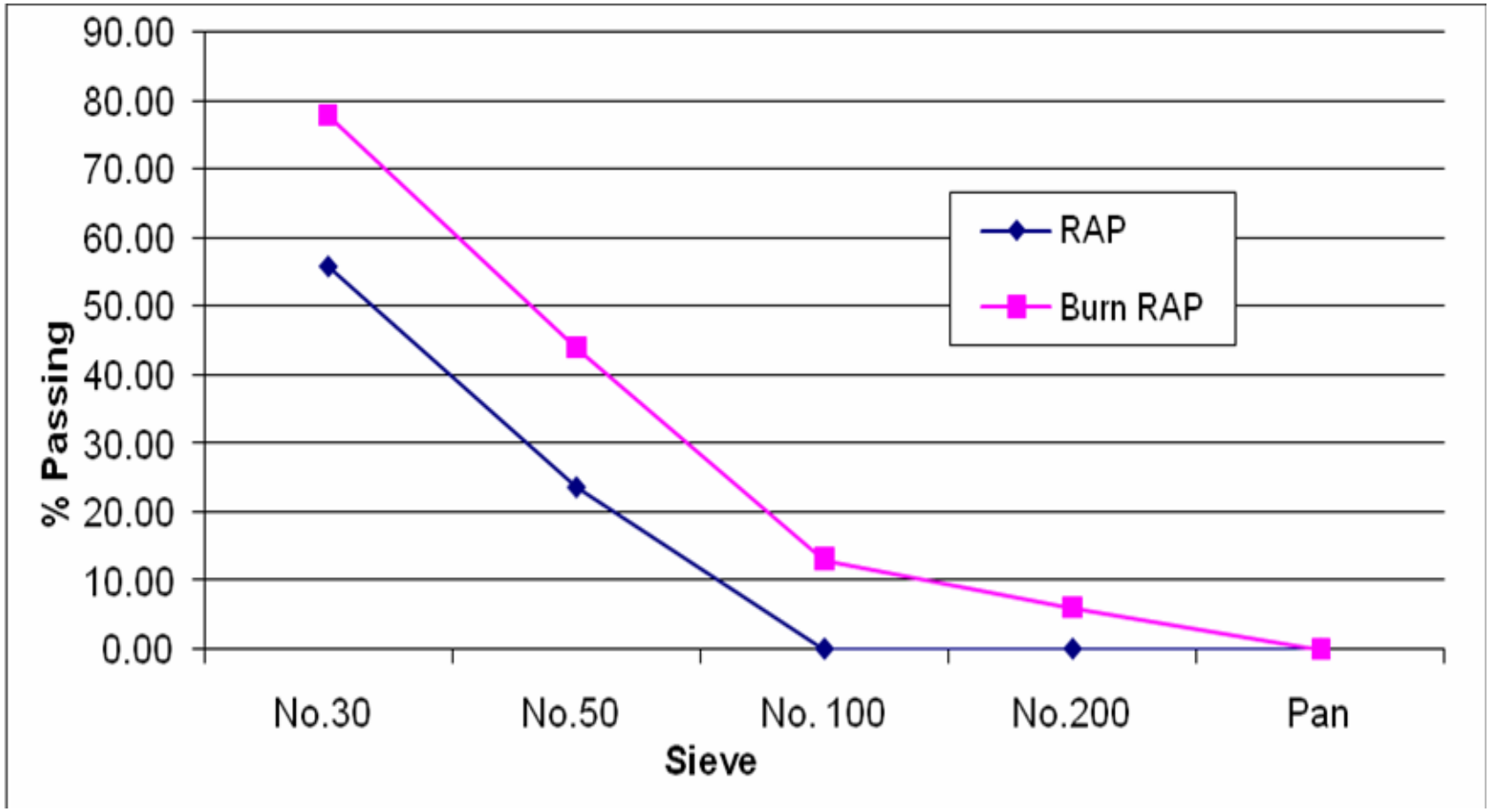
Many Problems

- Correlations vary
  - Highly temperature dependent
- RAP mortars have very high stiffness
  - hard to control molding
- Blending charts do not work for all loading times

New Approach

- Selective RAP to control molding
  - # 30, #50, #100
- Use PAV aged binder for blending
  - Can test at same temp as mortar
- Use more PAV binder to make molding easier
- New analysis procedure
  - focus on S(60), m(60).
- It appears to be working based on verification

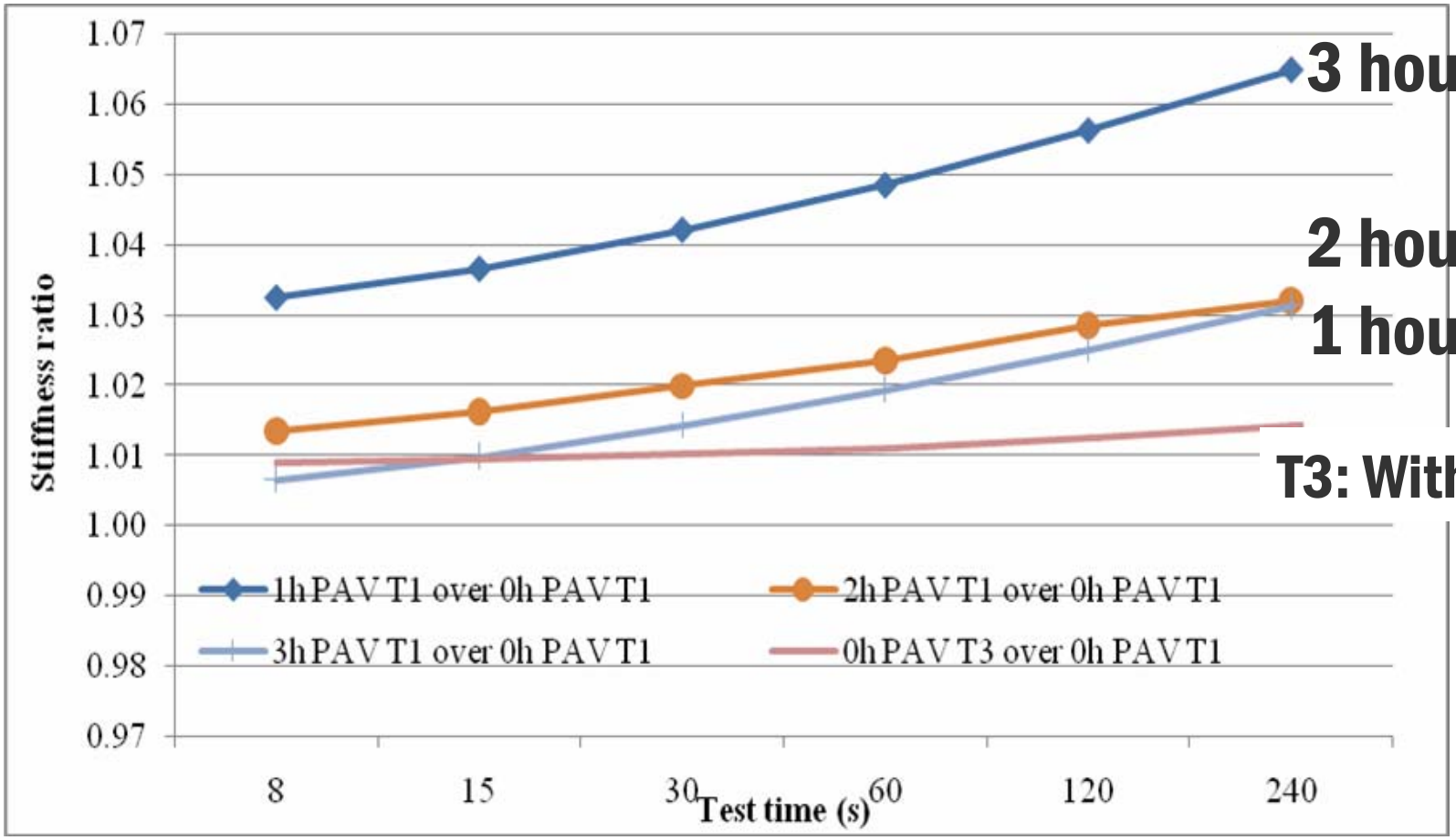
Select RAP Gradation



Blending Procedures

- **Blending procedure:**
- **Binder and was heated at 150℃ while aggregate and RAP were heated at 180℃ for 1h before mixing together to get mortar.**
- **Different mortar samples were heated for different times (1 , 2 & 3 hrs) and then left to cool down to the ambient temperature.**
  - **During the heating process, mortar was stirred every half an hour and Argon gas was used to prevent further aging of binder.**
- **All the mortar samples were heated at 150℃ for 1h and then stirred and poured into beam molds.**

Effect of Blending Time – (S-ratio)



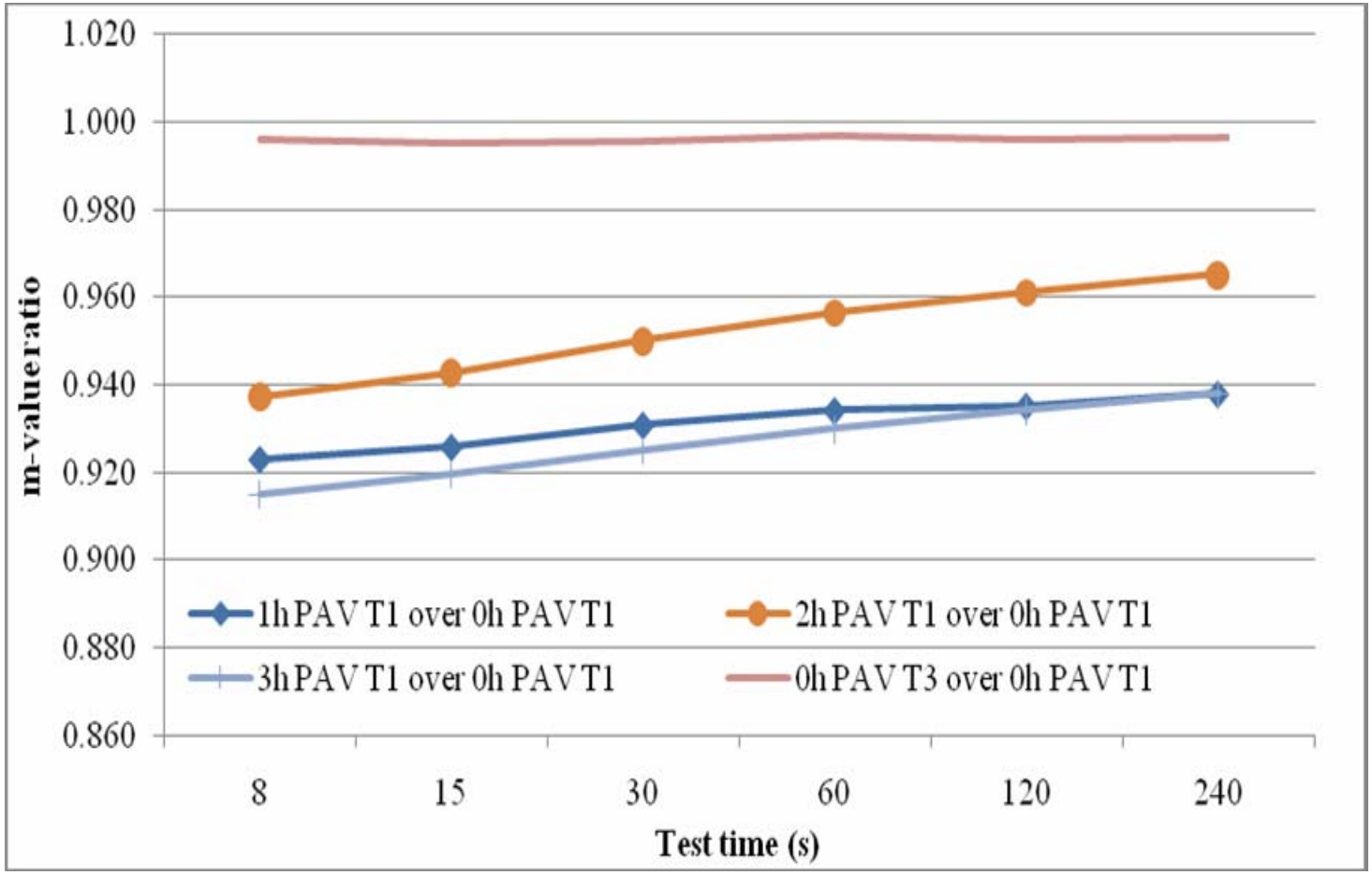
3 hours

2 hours

1 hours

T3: With fines

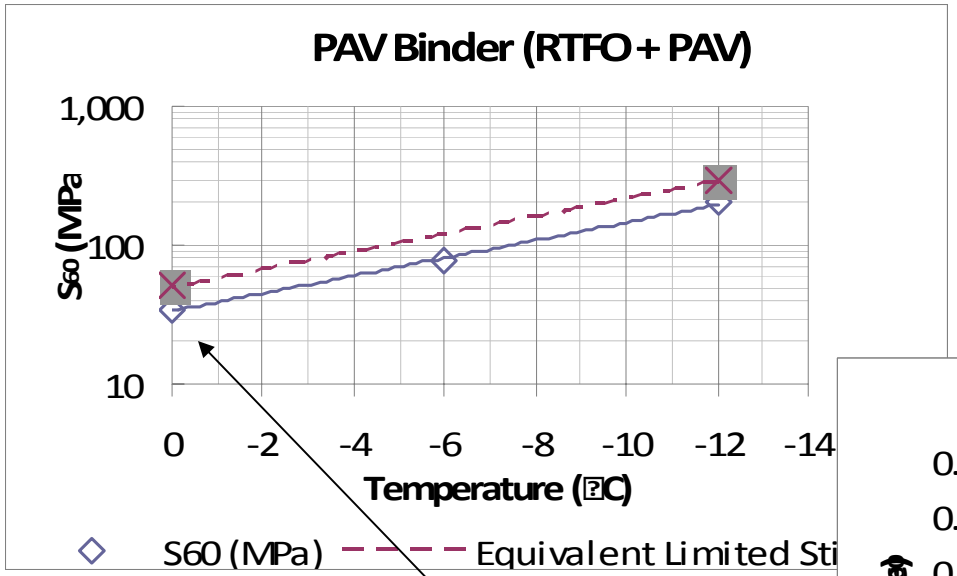
Effect of Blending Time (m-ratio)

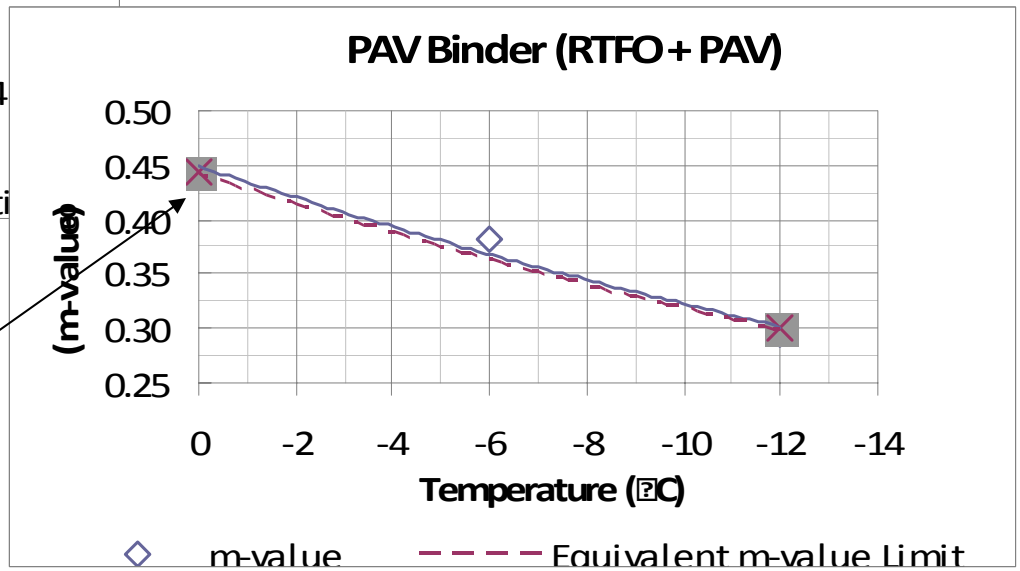


Steps – 1,2,3, 4

- Test new binder after PAV at 3 temps
  - Two around grade, plus one more temp
    - E.g. for PG xx-22, test at -6 and -12, Plus 0.0C
      - At 0.0 C, reduce load in BBR if @ -6 C S(60) <60MPa
- Burn SRAP, estimate %AC, get RAP agg.
- Mix SRAP with PAV Binder, total 25% AC
  - PRAP, test 2 specimens at 0.0 C
- Mix SRAP aggregates with 25% PAV aged AC
  - SRAP, test 2 specimens at 0.0 C

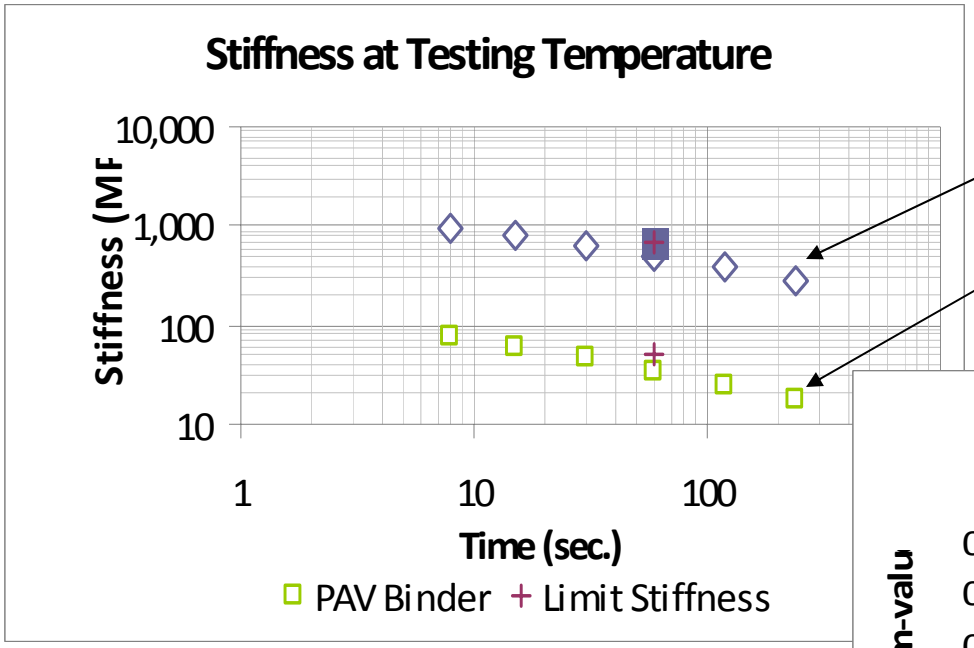
1. Estimate Equivalent Limiting Stiffness at Test Temp used for Mortars





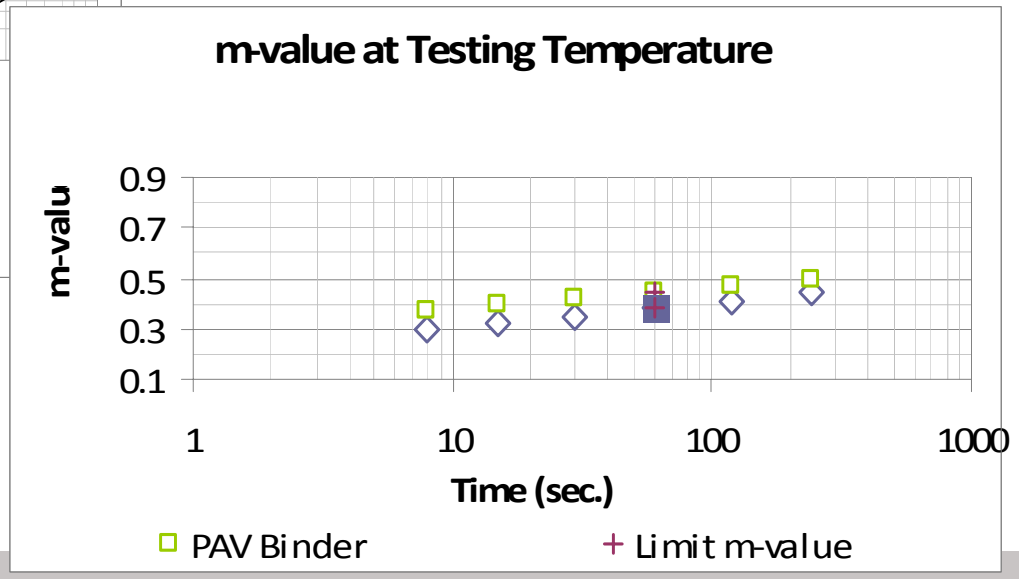
Mortars Test Temp. = 0.0 C

2. Convert binder to mortar limits (all at 0.0 C)



Mortar

Binder

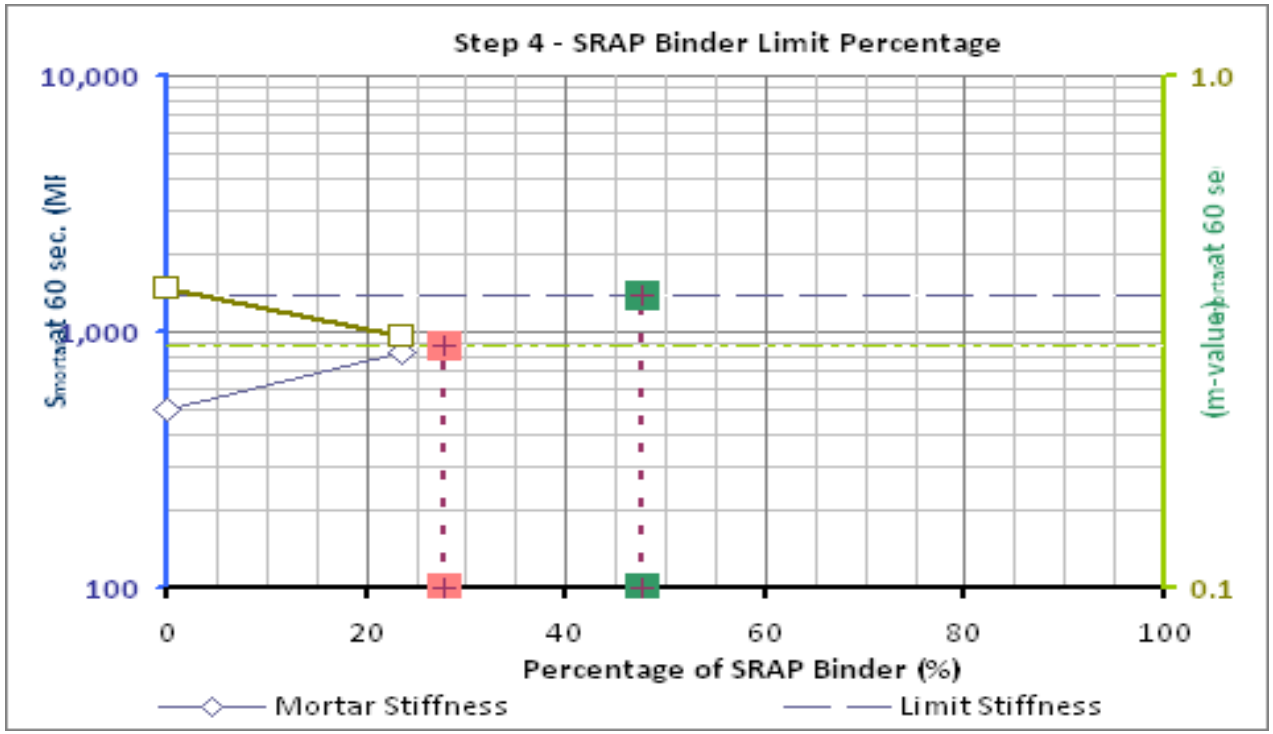


Allowable RAP Binder

Step 4 - SRAP Binder Limit Percentage

Use the PAV Mortar limit stiffness and m-value at test temp from step 3 to determine the limit % of SRAP binder.

Mortars								LIMIT PERCENT OF SRAP BINDER
Temp (°C)	Time (sec.)	PAV mortar (Pmortar)			Blended Mortar (Bmortar)			**Stiffness**
		S (MPa)	m-value	% SRAP	S (MPa)	m-value	% SRAP	
0.00	60.0	497.5	0.383	0.0	825.5	0.310	23.64	log(S) = A×log(%SRAPBinder)+B



A	B	%SRAP
9.303E-03	2.6968	**47.52**

m-value

m-value = a×(%SRAPBinder)+b

a	b	%SRAP
-3.09E-03	0.3825	**27.72**

Target binder low temp PG grade:

-16°C

Allowable %SRAPBinder

27.72

Allowable RAP Binnder

Mortars								LIMIT PERCENT OF SRAP BINDER
Temp (°C)	Time (sec.)	PAV mortar (Pmortar)			Blended Mortar (Bmortar)			**Stiffness**
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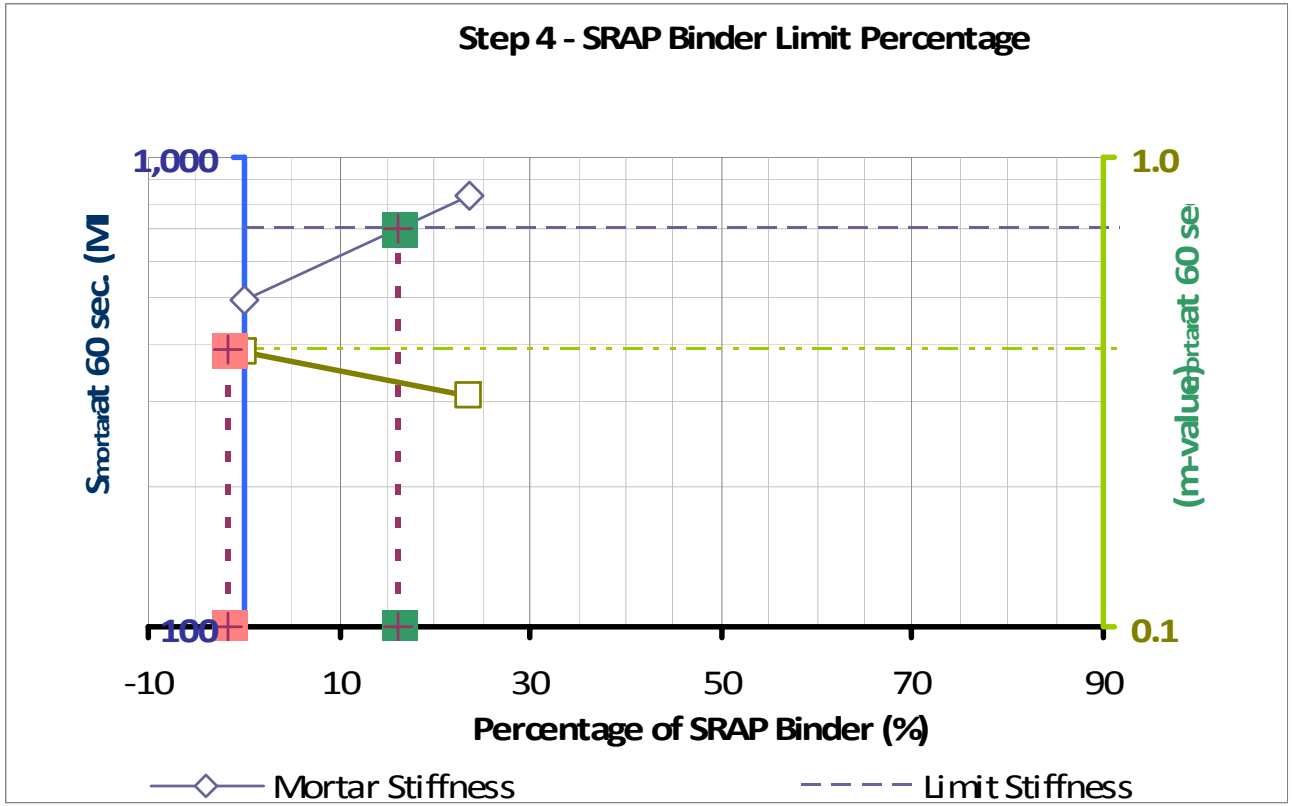


A	B	%SRAP
9.303E-03	2.6968	16.22

m-value

m-value = a×(%SRAPBinder)+b

a	b	%SRAP
-3.09E-03	0.3825	-1.60

Target binder low temp PG grade:

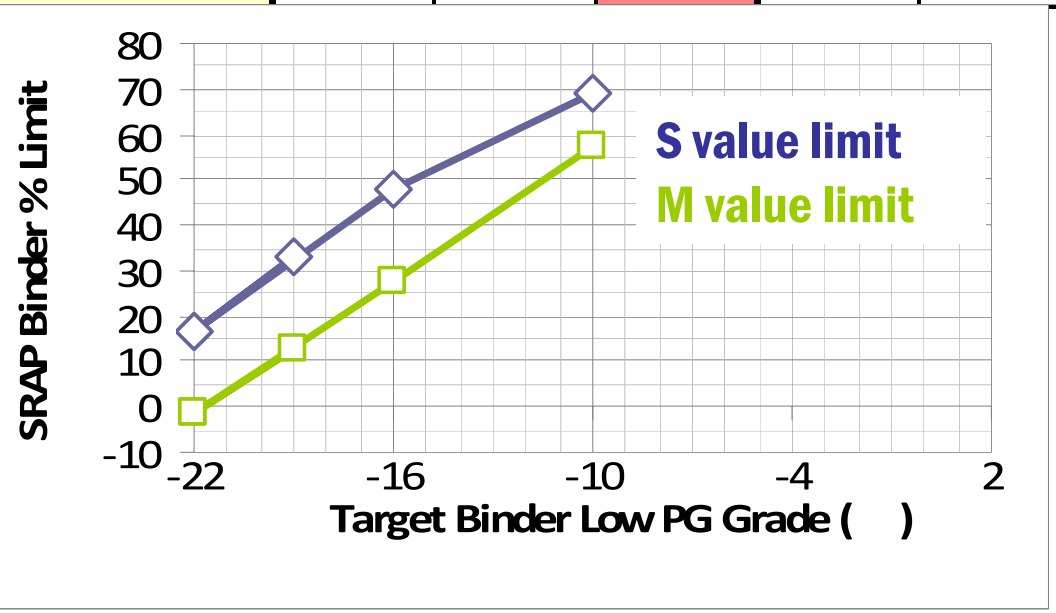
-22°C

Allowable %SRAP Binder

-1.60

Allowable RAP in New Mix

Step 5 - Target Binder Grade v.s SRAP Binder Limit Percentage										
Fresh Asphalt Binder: PG64-22				Calculation of percent RAP allowed in new HMA						
Target binder low temp PG grade (°C)	**SRAP binder % Limit**			Percent binder in new mix				5.0		
	Stiffness	m-value	Minimum*	Percent binder in RAP				5.91		
-10.0	68.9	57.0	**57.0**			**48.3**				
-16.0	47.5	27.7	**27.7**			**23.5**				
-22.0	16.2	-1.6	**-1.6**			**-1.4**				



1. Enter % AC in new mix
2. Select Target PG Grade
3. Determine max allowable RAP

Validation with artificial RAP

Time (s)	2PAV	Fresh	Blended with 51.2% of fresh			Blended with 74.9% of fresh		
			Calcul-ated	Tested	Differ (%)	Calcul-ated	Tested	Differ (%)
8	55.6	10.9	24.2	23.6	-2.2	16.4	16.1	-1.9
15	44.0	6.9	17.1	17.2	0.4	11.0	11.2	1.2
30	33.3	4.2	11.5	11.8	2.5	7.0	7.2	2.4
60	25.1	2.4	7.6	7.9	3.7	4.4	4.6	4.5
120	18.6	1.4	4.9	5.2	5.3	2.6	2.8	4.4
240	13.6	0.8	3.1	3.4	7.0	1.6	1.6	4.2

Unknowns – more work

- Effect of aging of binder RAP is not considered in this procedure
  - Will attempt aging mortars in PAV
- Temperature dependency is assumed to be same for blended and new binder
  - Can test mortar at 2 temps to verify
- Effect of RAP size blend
  - Work is underway to try several sizes

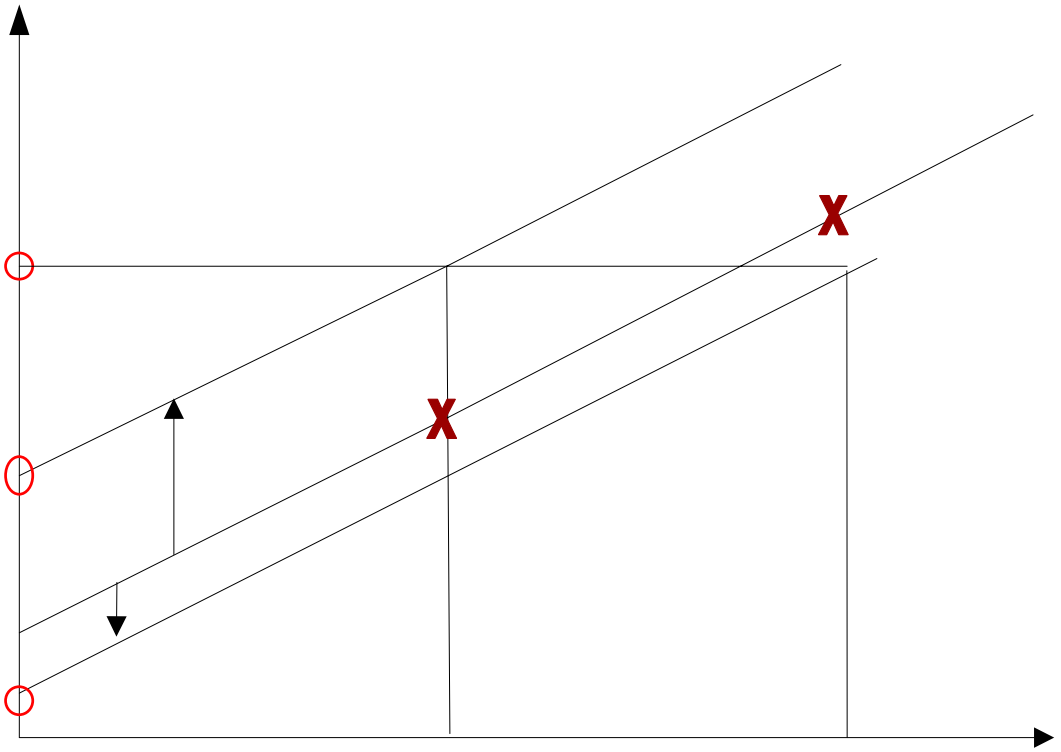
Effect on other PG properties

- High temp grade
  - Work started on # 100 - #200 RAP in DSR
  - Using parallel plate (25-mm)
- Intermediate temp
  - DSR with new geometry will be tried
  - BBR at longer times
- Fracture at low temp
  - Device is underdevelopment (New BBR).

Summary

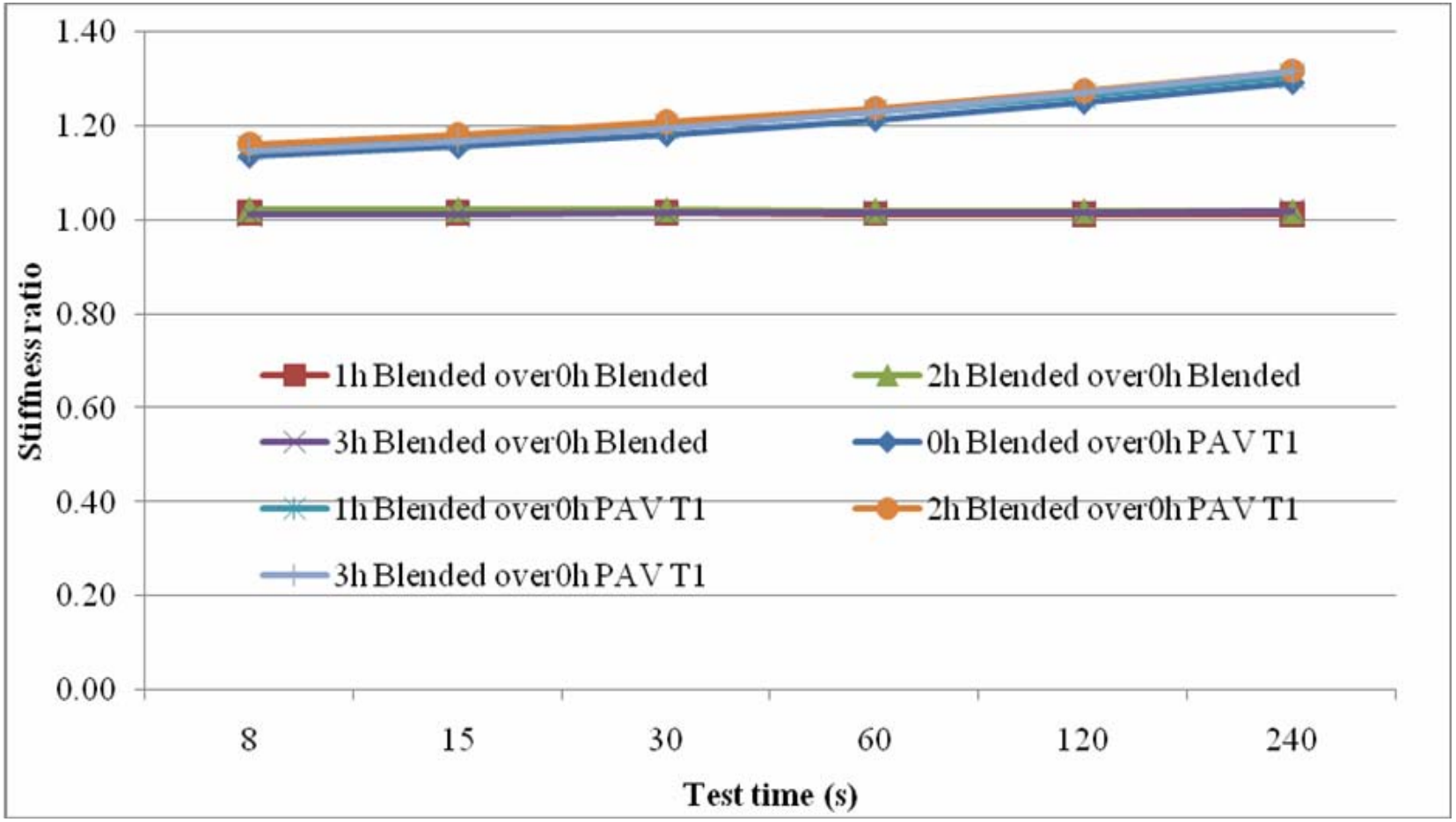
- An initial procedure has been developed
- Results appear reasonable
- A few issues to be checked
  - PAV aging of mortars
  - Temp dependency
- Future work
  - High and Intermediate Temp testing
  - Fracture

The blending concept
New binder is a PG 70-16 (TG PG70-20)



lgS(60)or m-value

Effect of blending time compared to PAV aging



Example of the problem