RAP Recycling in Indiana
Analysis of a HyRap Project, Ft. Wayne, IN

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Rejuvenation

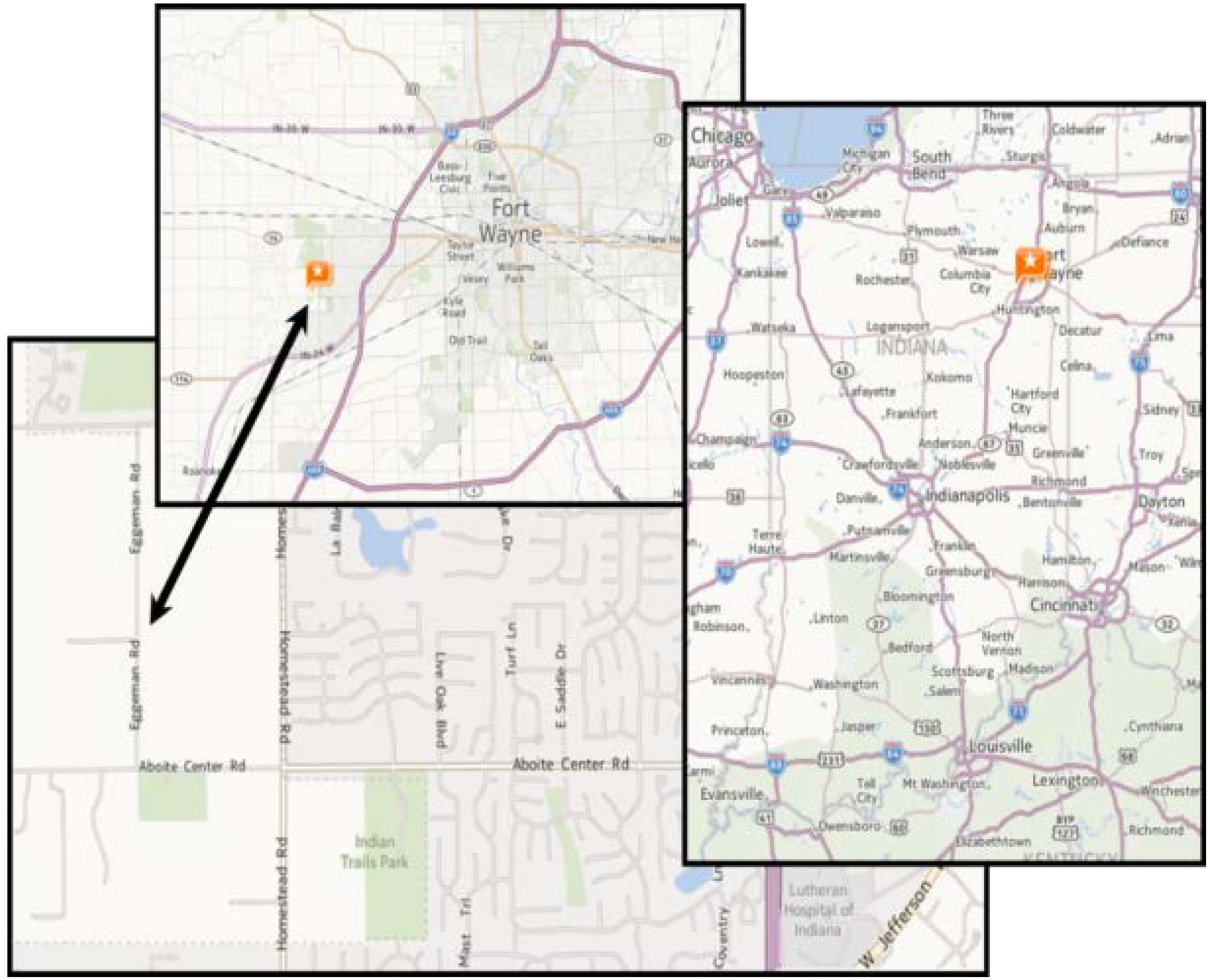
Eggeman Rd, Fort Wayne, IN

Ft. Wayne – High RAP Project

- Study
  - 5 core locations – 3 High RAP, 2 Control
  - Volumetrics
  - Gradations
  - PG comparison with other sites
  - Binder complex modulus G* comparison
  - Mixture complex modulus G* comparison
  - Mixture flexural cracking test
  - Analysis of binder and cracking potential
- Laboratory work conducted by
  - North Central Superpave Center
  - MTE

Site

- Eggeman Rd, Fort Wayne, IN 46814
- Total length of road – approx. 1 mile
- Approximately ½ of this length is high-rap materials



Core locations

0+00	South End of new pavement at intersection with Aboite Center Road		
5+50	Location #1	Northbound 4 ½ ft from Centerline	HyRap Mix
10+50	Location #2	Southbound Right Wheel Path	HyRap Mix
17+00	Location #3	Southbound Right Wheel Path	HyRap Mix
30+00	Location #4	Southbound 5 ft from Centerline	Conventional Mix
35+00	Location #5	Southbound Right Wheel Path	Conventional Mix

Location 1 – 5+50, High RAP

Lane center


Eggeman Rd. – June 19, 2014
Location 1

Location 2 – 10+50, High RAP

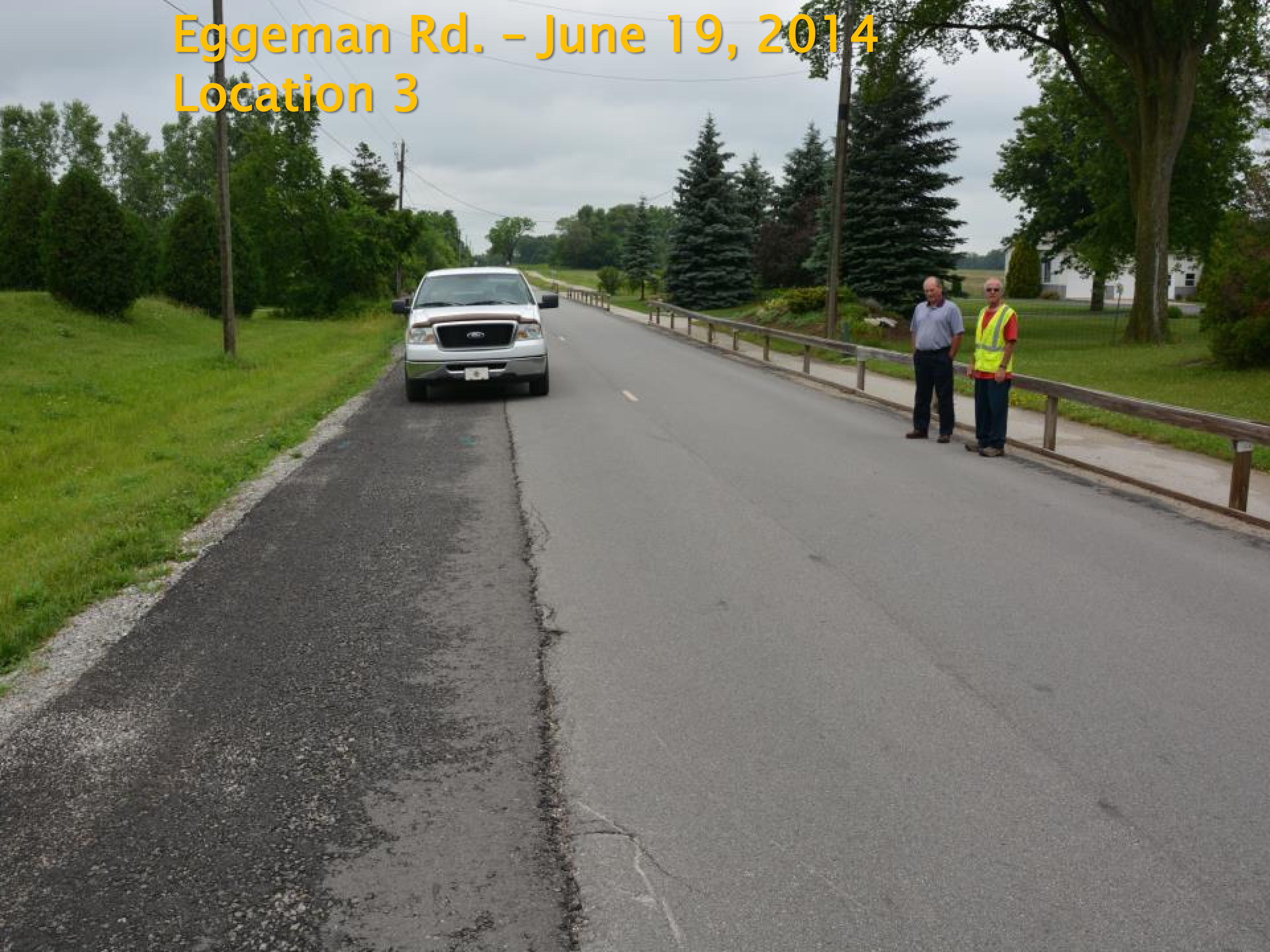
Wheel path

Eggeman Rd. – June 19, 2014
Location 2

Location 3 – 17+00, High RAP

Wheel path

Eggeman Rd. – June 19, 2014
Location 3



Location 4 – 30+00, Control

Lane center

Eggeman Rd. – June 19, 2014
Location 4

Location 5 – 35+00, Control

Wheel path

Eggeman Rd. – June 19, 2014
Location 5

Core analysis summary

ID	G_{mm}	G_{mb}	%AV	%AC	Minus 200, %	G_{se}*	G_{sb}	P_{ba}
#1	2.484 2.486	2.424 (1A) 2.415 (1E) 2.421 (1F)	2.5 2.8 2.6	6.6 6.9	7.8 7.7	2.772	2.596	2.45
#2	2.475 2.489	2.350 (2B) 2.354 (2D) 2.347 (2F)	5.3 5.2 5.4	5.6 6.2	7.3 6.9	2.722	2.605	1.65
#3	2.478 2.477	2.279 (3D) 2.278 (3E) 2.277 (3F)	8.0 8.1 8.1	5.9 6.2	7.8 8.1	2.705	2.614	1.29
#4	2.494 2.492	2.259 (4D) 2.261 (4E) 2.244 (4F)	9.4 9.3 10.0	6.1 5.7	5.2 5.1	2.739	2.596	2.01
#5	2.496 2.495	2.335 (5D) 2.338 (5E) 2.221 (5F)	6.4 6.3 6.6	5.7 5.5	5.3 5.2	2.728	2.600	1.80

**Assumed G_b = 1.023*

Gradation results

- Analysis results in compliance with gradation requirements as a 9.5mm mix
- The mix being finer than 47% on the 2.36mm sieve restricts use to Category 1 & 2 roads

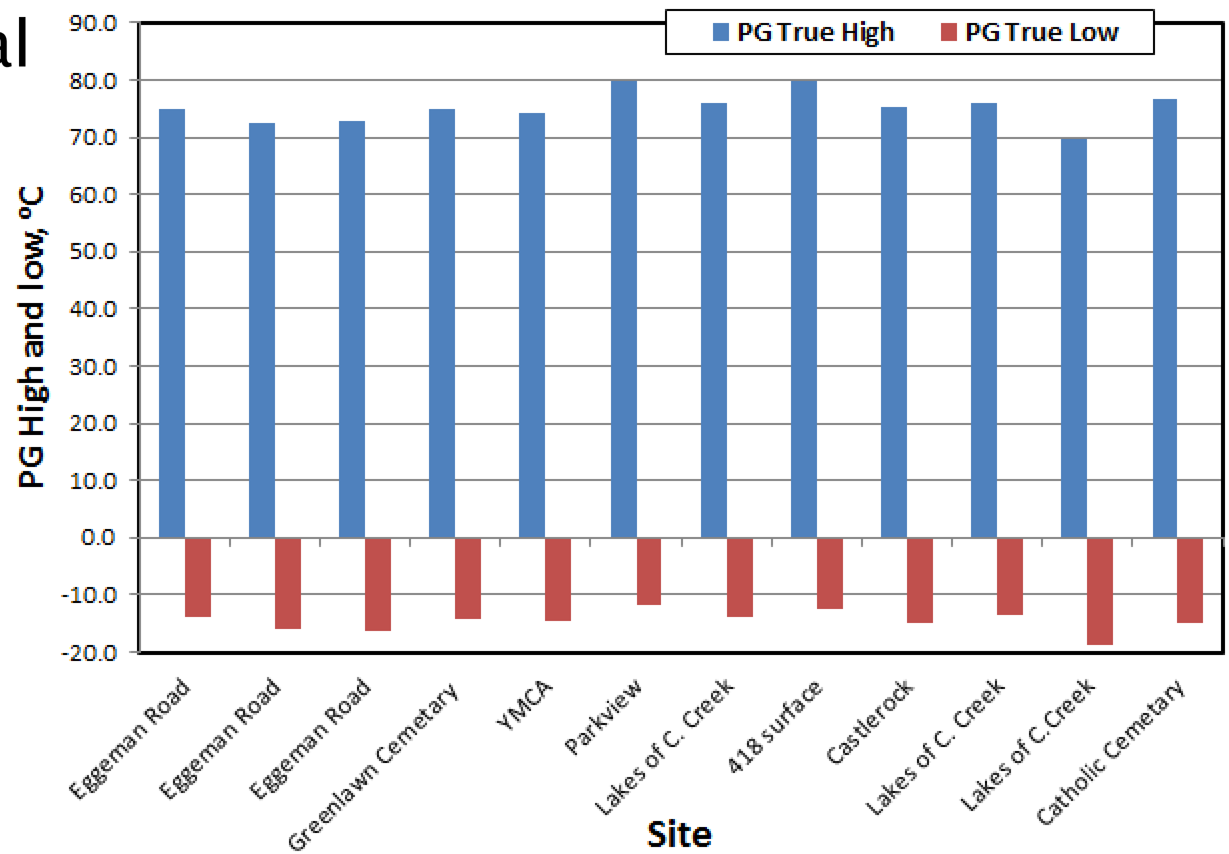
size	Cumulative Percent Passing				IN DOT Clause 401.05 (Table) – requirements for 9.5mm Mix
d, mm	#1	#2	#4	#5	
12.5	100.0	100.0	100.0	100.0	100
9.5	94.3	94.0	95.4	94.6	90-100
4.75	72.0	72.5	63.8	61.4	<90
2.36	49.0	49.3	49.3	47.2	32.0-67.0*
1.16	36.5	36.0	37.7	36.4	-
0.6	27.5	25.7	27.6	26.7	-
0.3	17.9	16.6	17.1	16.3	-
0.15	11.0	10.8	9.2	8.4	-
0.075	8.4	8.5	6.6	5.9	2-10

*The mix design gradation shall be less than or equal to the PCS control point for 9.5 mm category 3, 4 and 5 surface mixtures. The PCS control point is 47 – for a 9.5 mm mix.

ESAL CATEGORY	ESAL
1	< 300,000
2	300,000 to < 3,000,000
3	3,000,000 to < 10,000,000
4	10,000,000 to < 30,000,000
5	≥ 30,000,000

PG Comparison

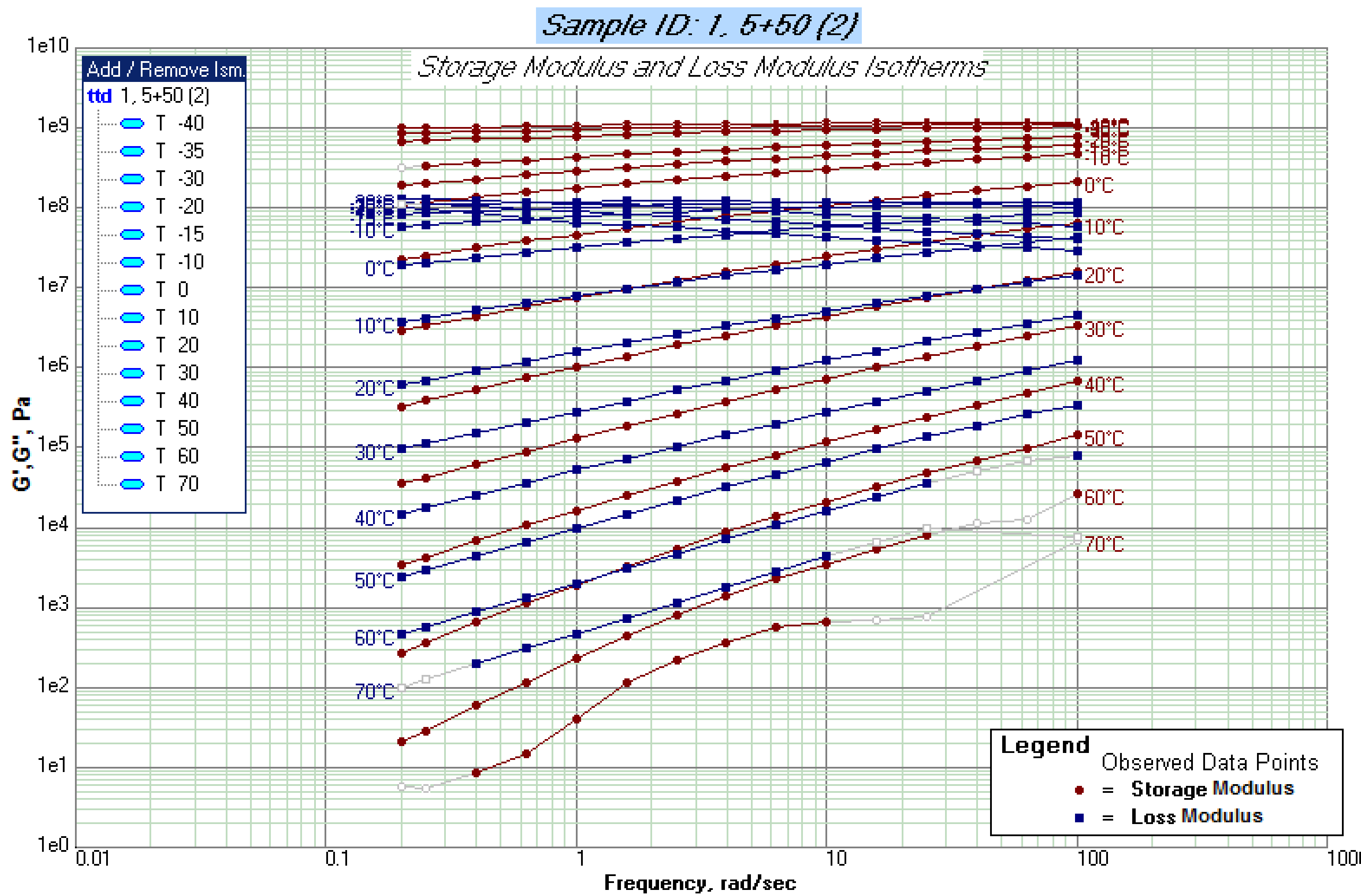
- 10 conventional sites versus 2 High RAP locations
- Similar results for all sites
- All sites constructed in similar time frame



Master curve development

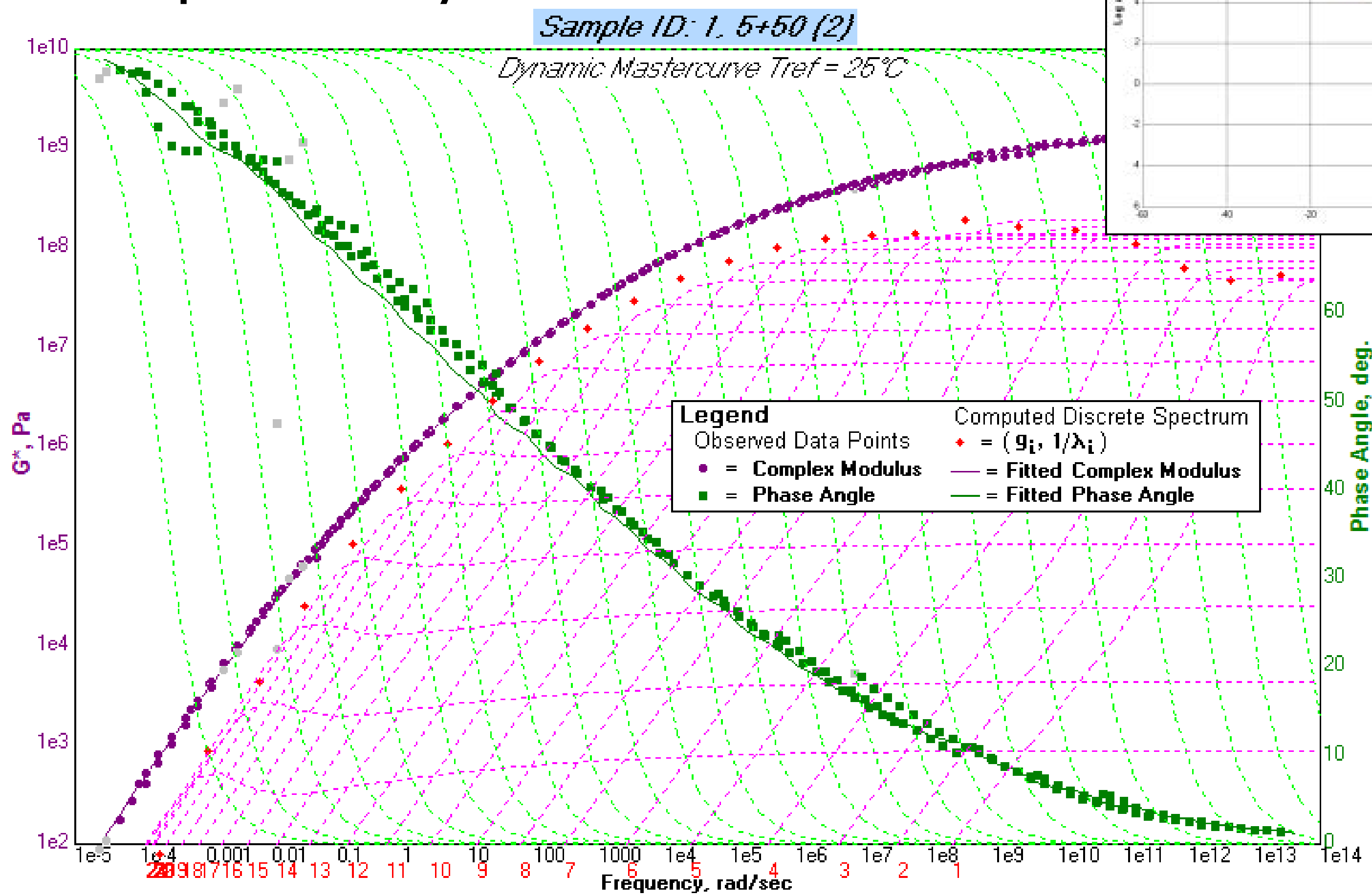
- Why master curves?
  - Tests conducted at multiple loading times and frequencies
  - The data is analyzed in a manner that the stiffness of the mix can be determined over a wide range of loading times (frequency) or temperature
  - Enables simple comparisons to be made
  - Etc., etc.

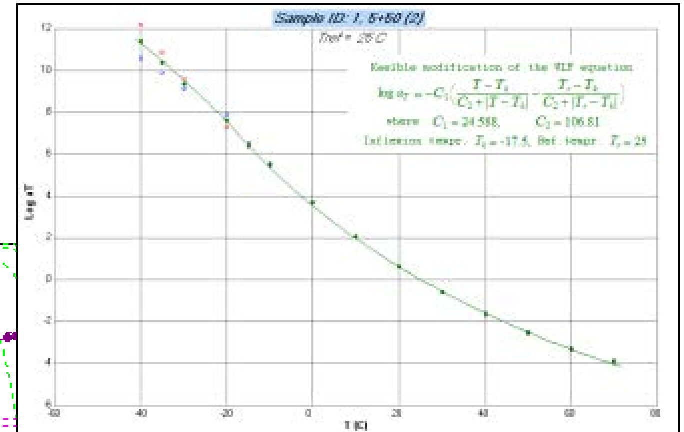
Binder – example data set



Binder Master curve of G*, 25ºC

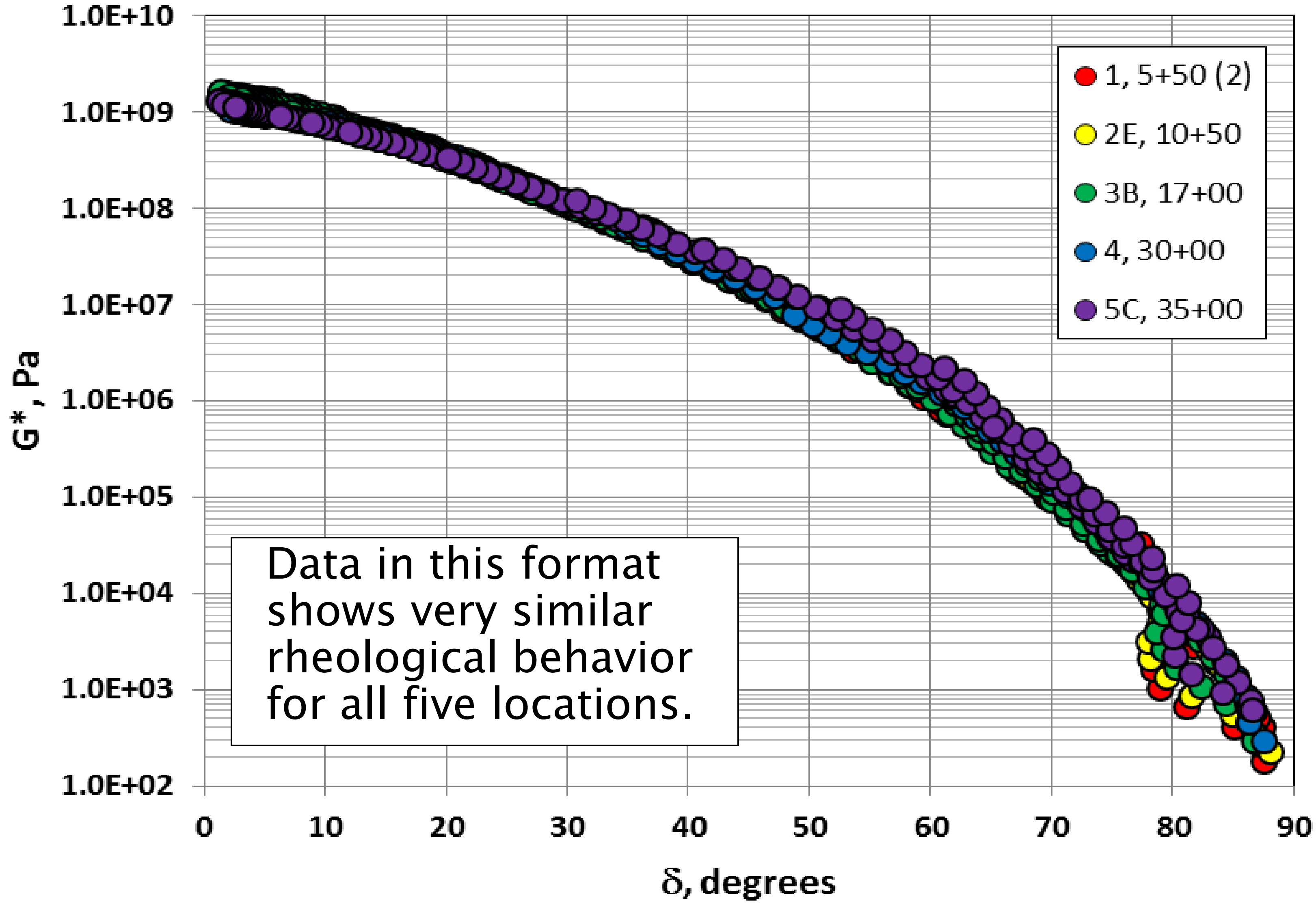
Plot of G* and δ versus frequency shows time dependency





Plot of shift factor versus temperature shows temperature dependency

Black space



1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
G*, Pa
0
10
20
30
40
50
60
70
80
90
δ, degrees
1, 5+50 (2)
2E, 10+50
3B, 17+00
4, 30+00
5C, 35+00
Data in this format shows very similar rheological behavior for all five locations.

Master curves

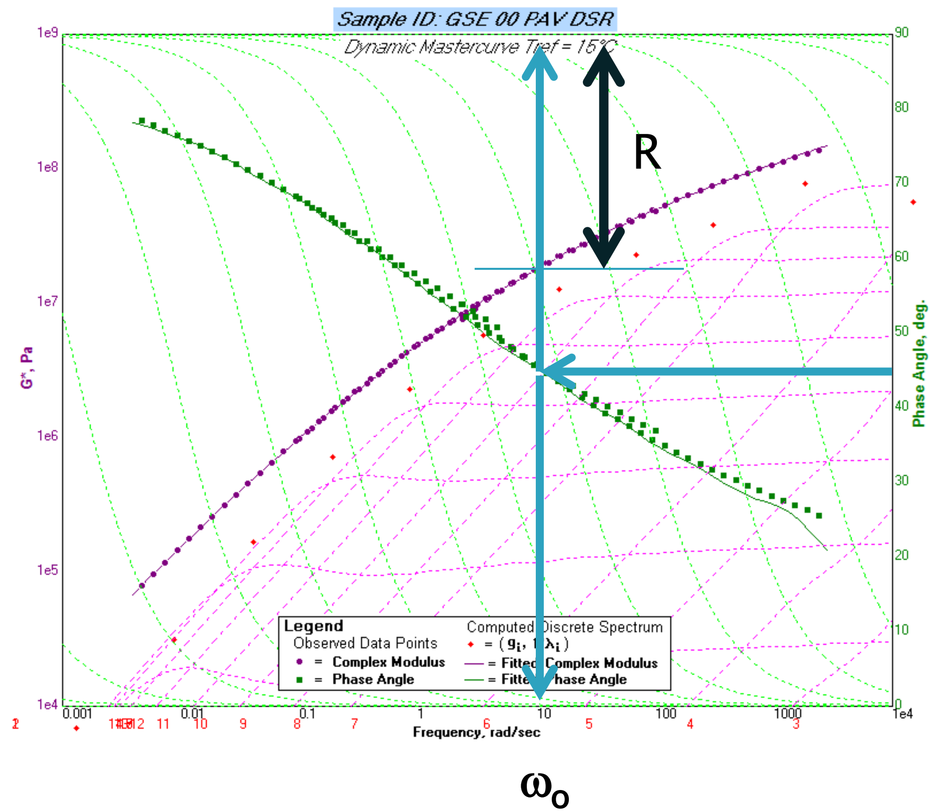
- Shape and position analyzed to provide information on aging
- Critical parameters
  - Rheological index
  - Cross over frequency

Rheological model and shape

- Considered way theological shape of master curve changing
- Rheological Index – R and crossover frequency ω_o

$$G^*(\omega) = G_o[1+(\omega_o / \omega)^{\beta}]^{-\kappa/\beta}$$

$$R = \log 2/\beta$$



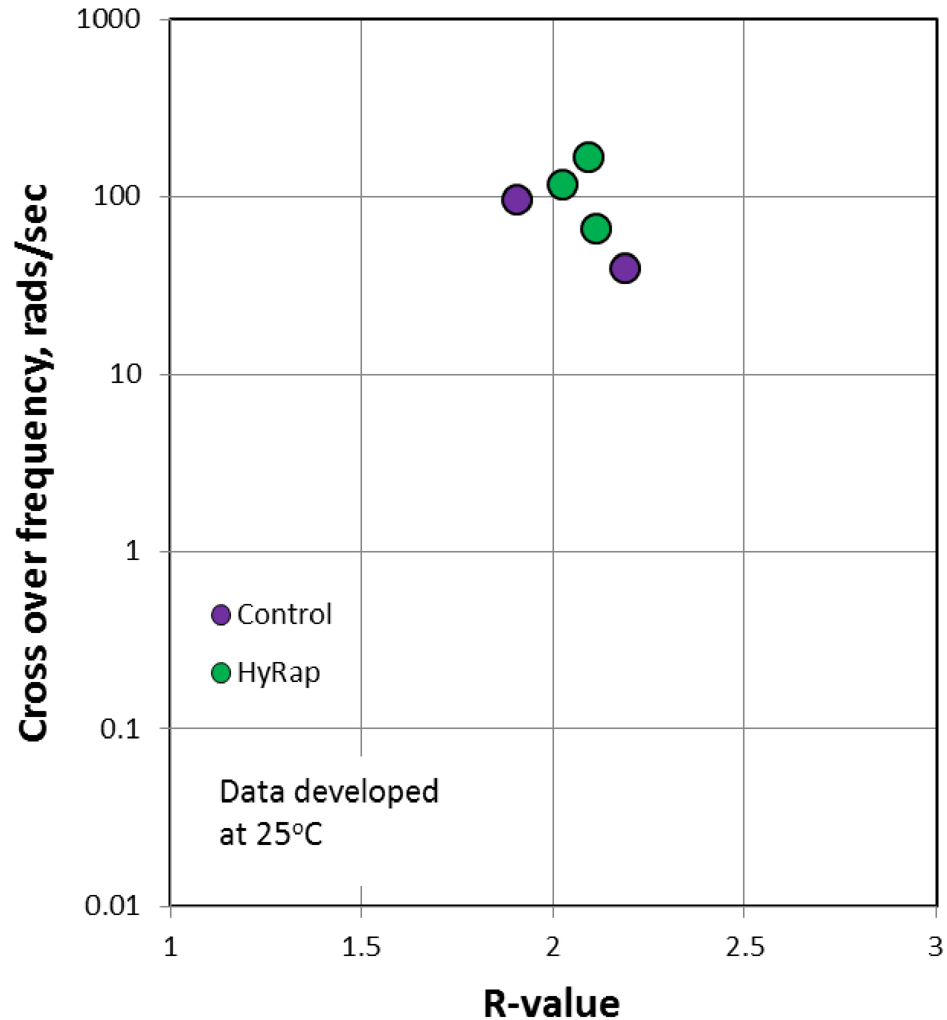
- R is the distance between the G* curve and the glassy modulus (typically 1E9) at the point where $\delta = 45^o$ or G'=G" (as a log number)
- ω_o – crossover frequency is the frequency at this same point

R and ω_o

- R – provides information with regard to the relaxation spectra, it is also related to the chemical composition of the binder
- ω_o – provide the position of the master curve and the hardness of the material
- As materials age
  - R increases with oxidative aging
  - ω_o reduces as materials get harder

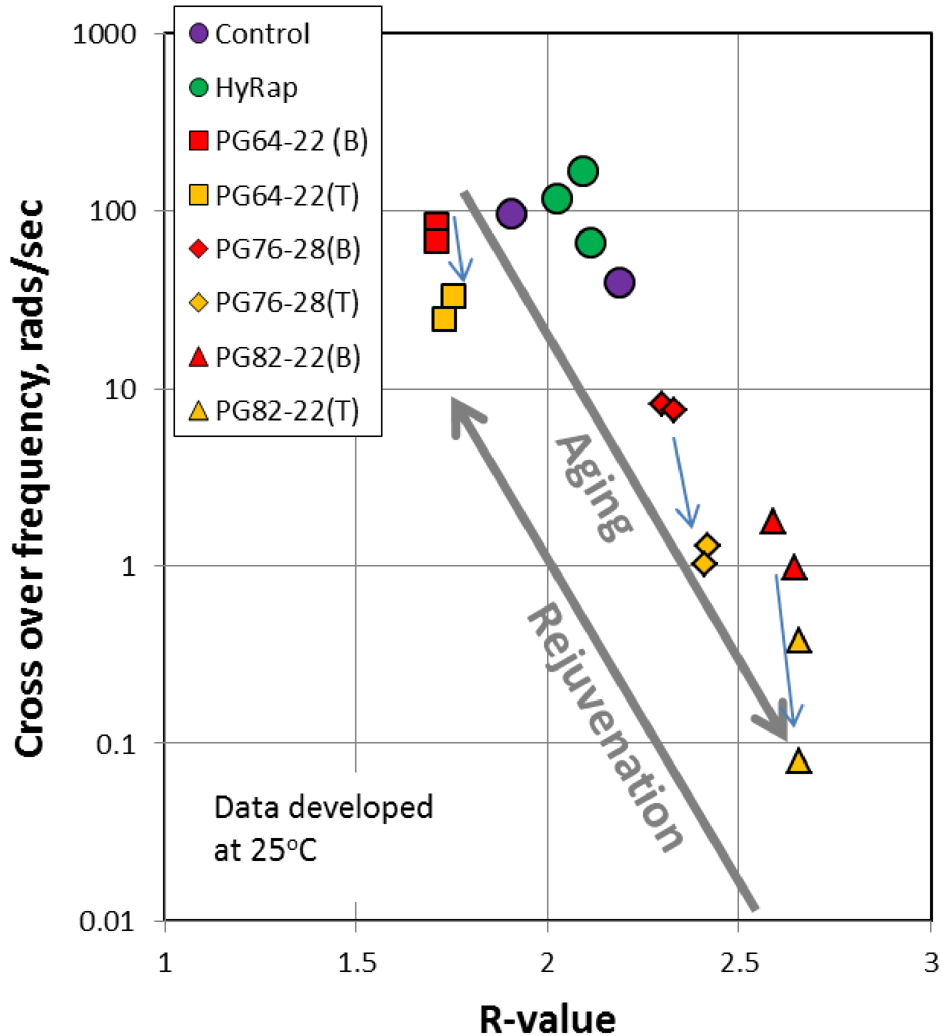
ω_0 and R-value

- Values obtained from binder recovered from cores
- Both binders very similar



ω_0 and R-value

- Values obtained from binder recovered from cores
- Both binders very similar
- When compared to other binders the material shows good performance

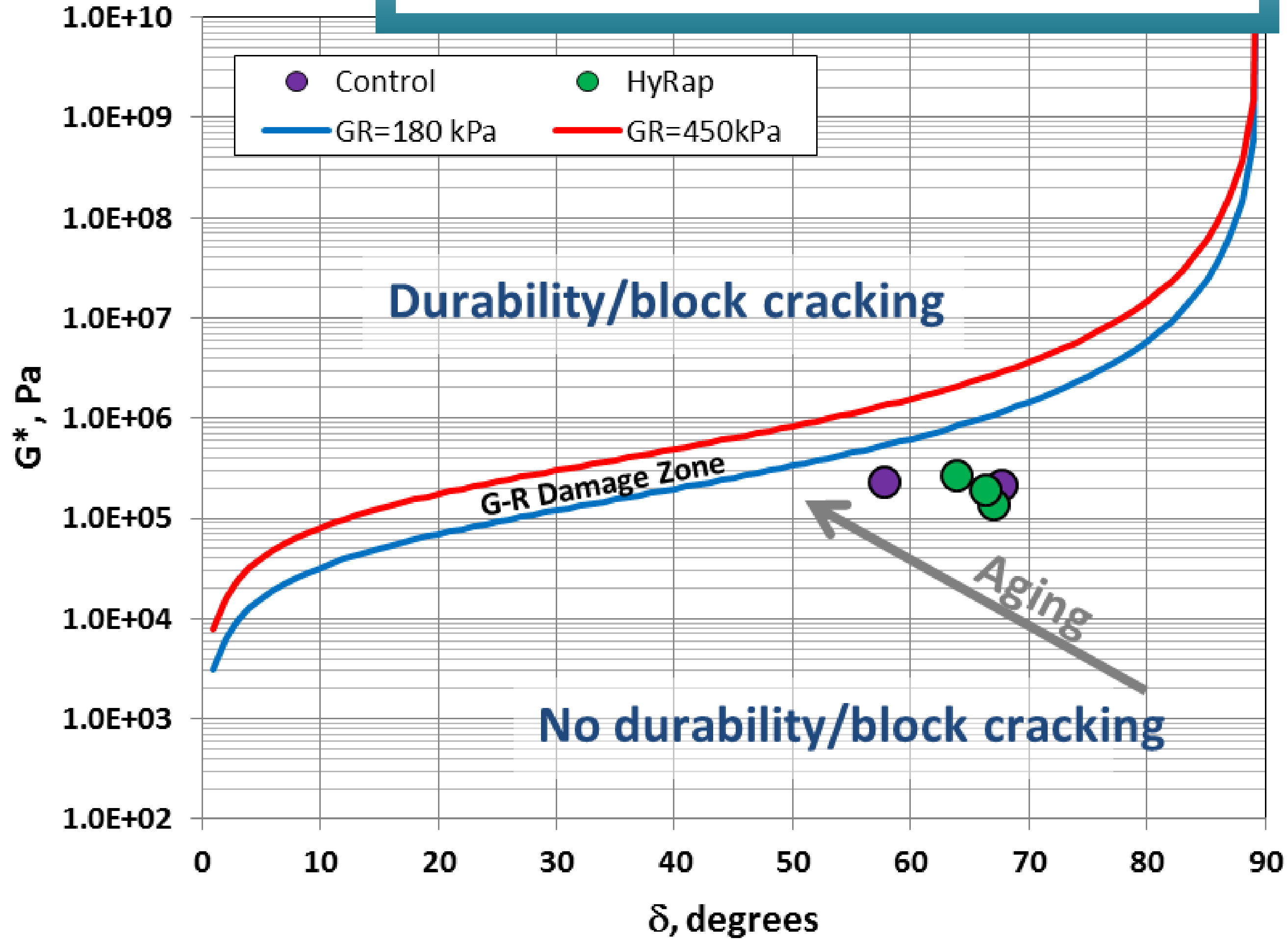


G-R parameter

- Glover-Rowe parameter introduced to predict durability/block cracking.
- Binder in this show no propensity for cracking
- Similar performance from both HyRap and conventional

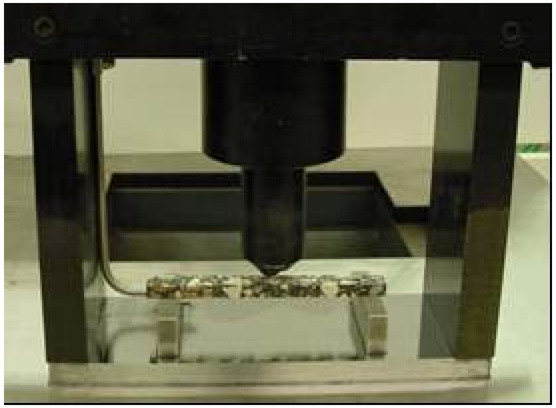
Damage onset: $G^* ((\cos\delta)^2/\sin\delta) = 180\ kPa$

Significant cracking: $G^* ((\cos\delta)^2/\sin\delta) = 450\ kPa$

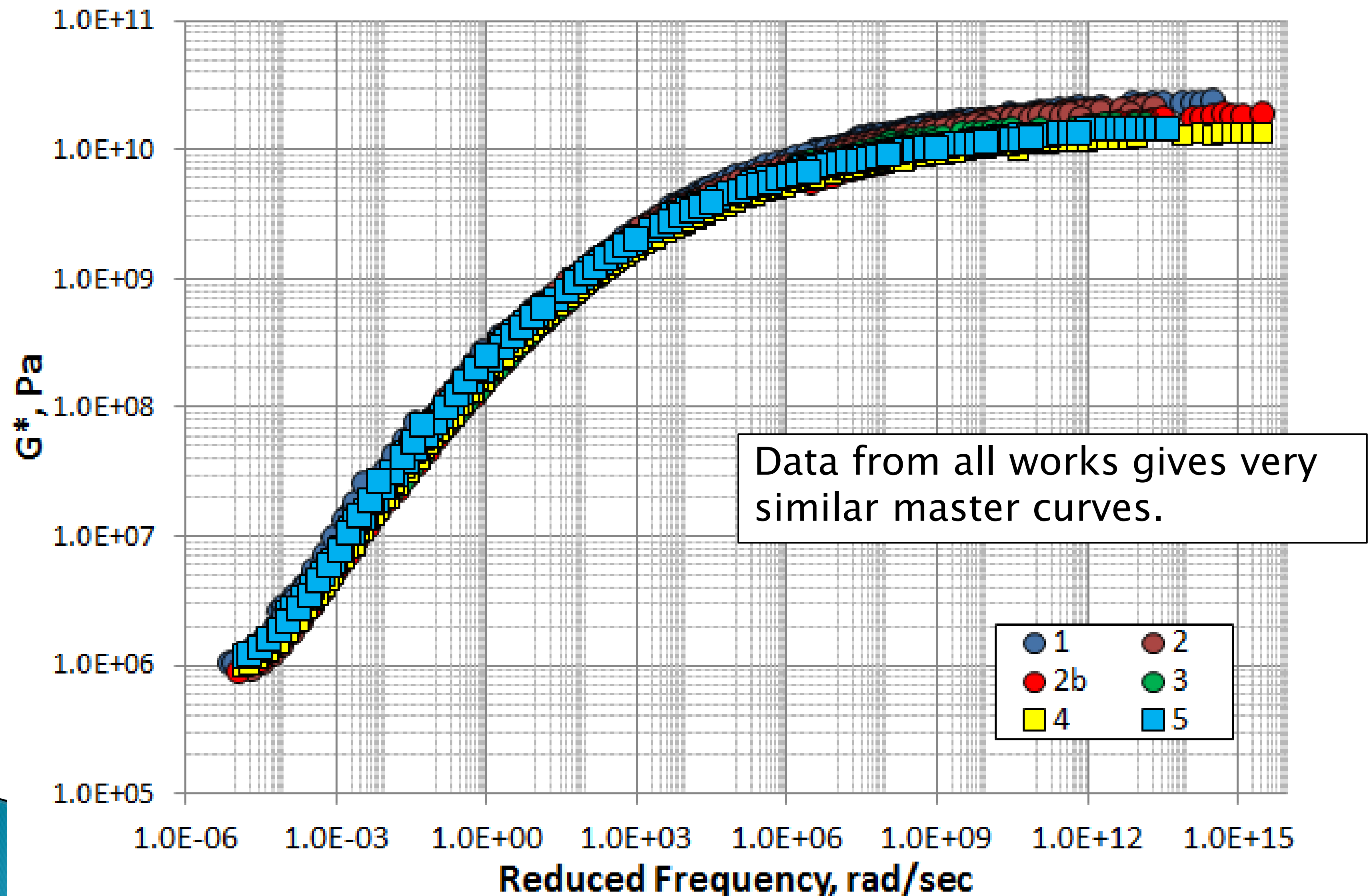


Mix testing

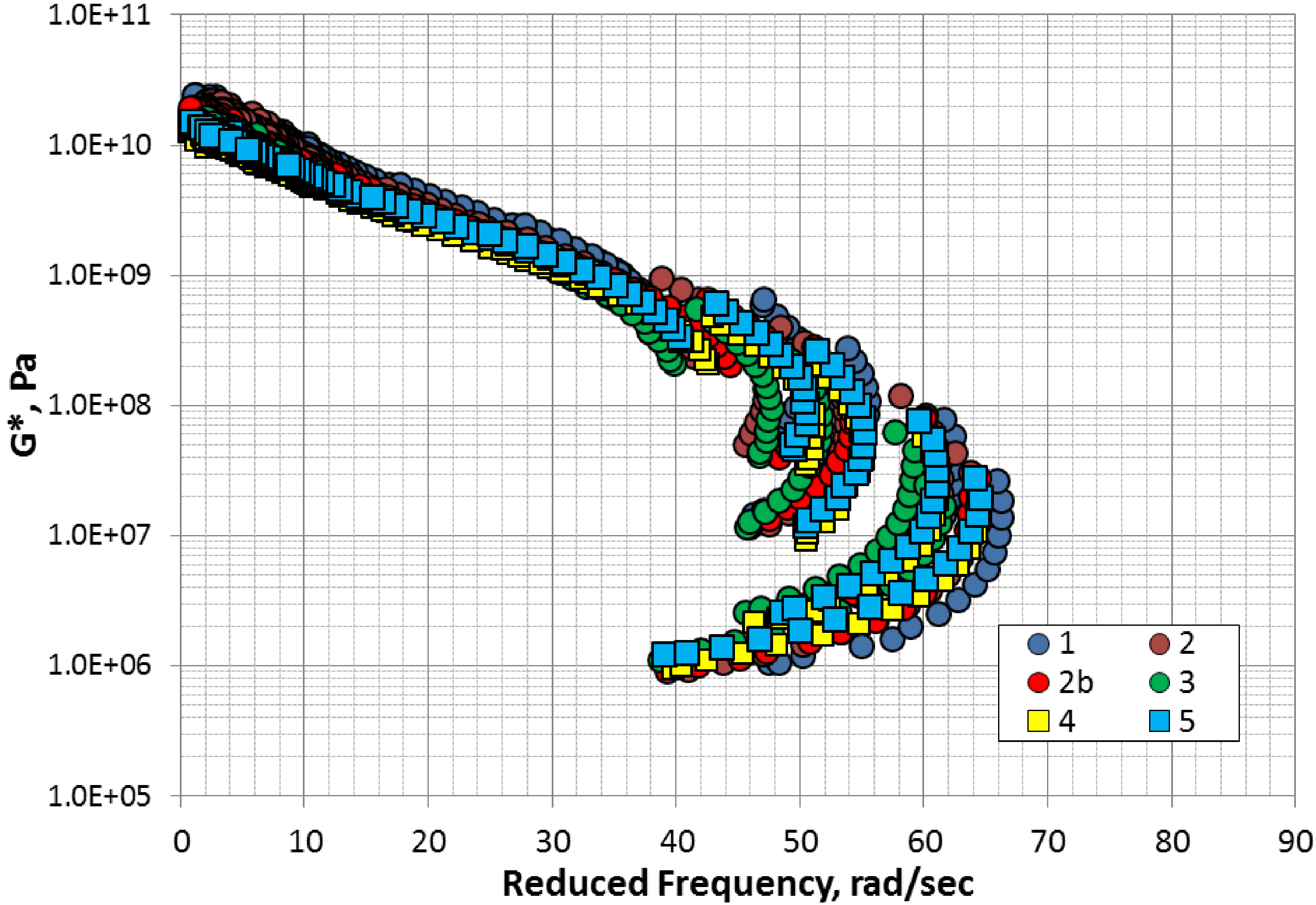
- On slices produced from core samples
- Torsion bar testing for master curve development
- Three point bending test for flexural strength



Mix Master curve of G*, 25°C

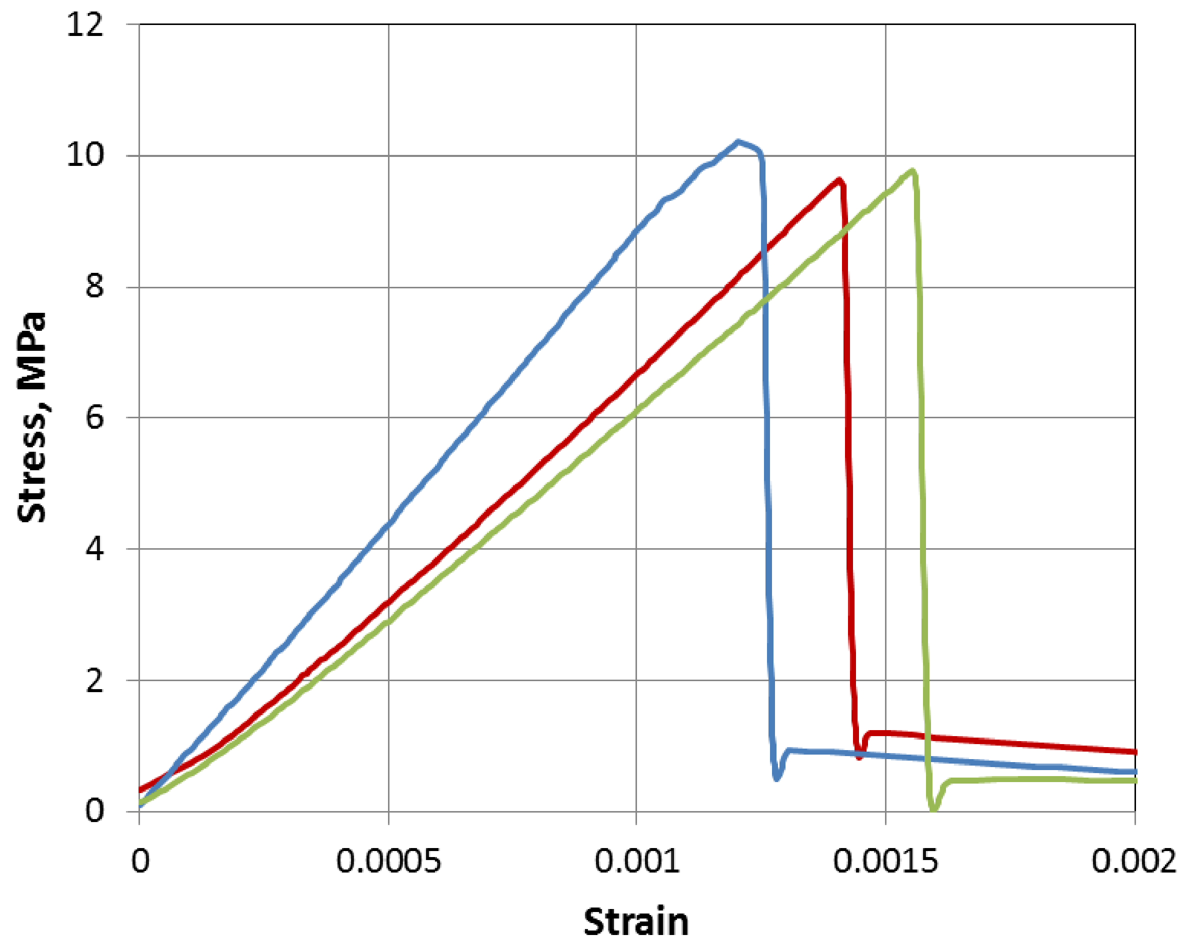


Master curve, Black space

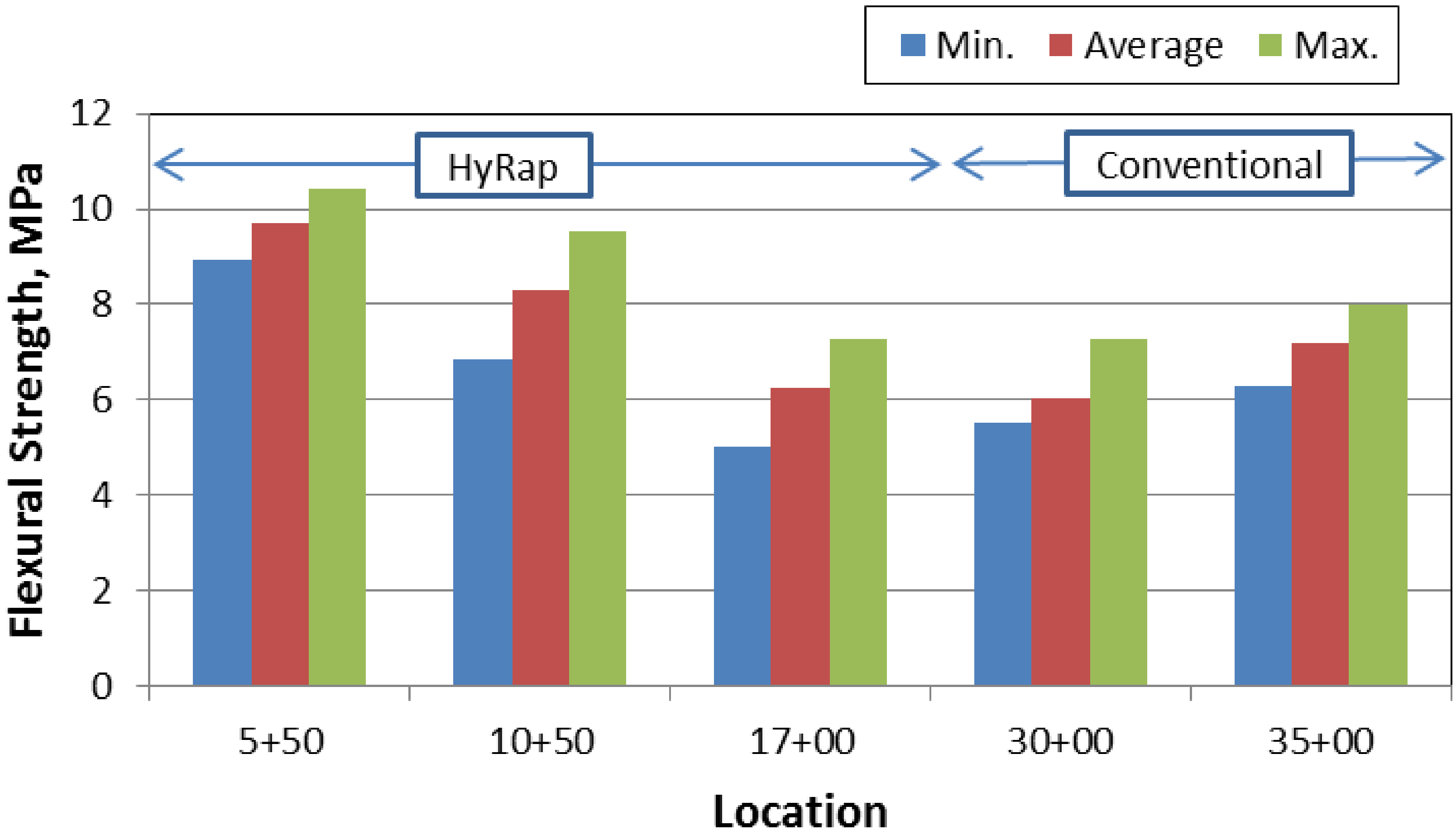


Mixture flexural strength

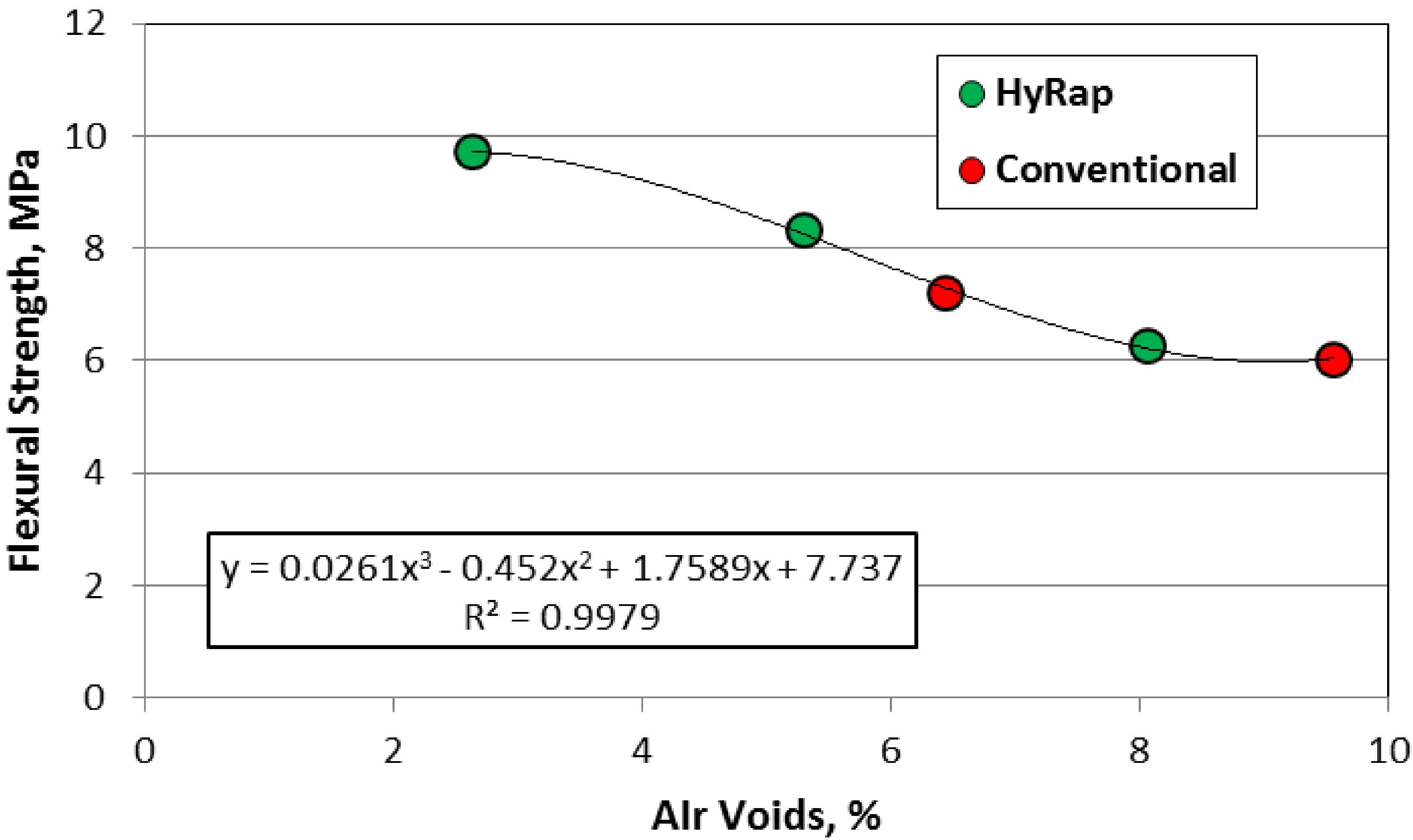
- Conducted in triplicate on BBR samples
- Loading rate selected to ensure brittle failure occurred
- Provides indication of cracking propensity at low temperatures



Tensile strength



Tensile strength, normalization with air voids



Summary

- Performance of Eggeman Rd very good after 2-year
- Volumetrics acceptable
- Gradation – slightly fine of 47% (47.2 to 49.3) on 2.36mm – results in an acceptable 9.5mm mixture for Category 1 and 2 roads
- Recovered PGs similar on High RAP to other sites and control
- Master curve shows control materials have similar stiffness (G*) compared to High RAP materials
- Tensile properties show that materials have similar cracking resistance
- Difficult to differentiate between conventional and HyRap performance

Thanks for listening …

Questions?

Comments!