MARC MODIFIED ASPHALT RESEARCH CENTER

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Petersen Asphalt Conférence

Effects of Foaming on Performance of Binders Modified with (PPA) Additive

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Objectives & Roles of Research Team

- **Objective: Foaming is widely used for WMA production. Investigate the effect of foaming on the performance of PPA modified binders.**
- **Why so many authors ? Real contributions:**
  - **Olga and Rene made the plan**
  - **Cris and Raquel conducted testing and analysis**
  - **Henry paid for the "beers"**
  - **Hussain is presenting!**
  - **No one wants to answer questions…**

Materials:

- Asphalt Binders:
  - Flint Hills PG 64-22 and Valero PG 64-16.
- Polyphosphoric Acid (PPA):
  - ICL- Concentrations of 0.8% and 1.5%.
- Water

Test Methods and Conditions:

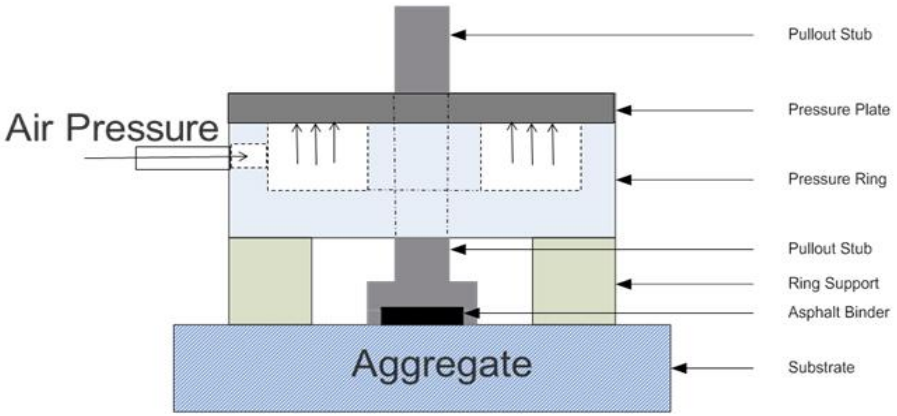
Property	Test	Details/ Test conditions
Workability	Viscosity	• Same as below
Performance Grading (HT)	DSR - Continuous Grading	• Unfoamed asphalt binders • Foamed and cured for 2 and 24 hrs at 135°C • Foamed and cured for 2 and 24 hrs at room temp
Rutting Resistance	MSCR Test @ 64 C	• Foamed, cured for 24h curing at 135C+ RTFO
Fatigue Resistance	Linear Amp. Sweep (LAS) @ 25 C	• Foamed, cured for 24h curing at 135C+ RTFO,
Bond Strength & Moisture Damage	•BBS @ 22 C •Mixture T283 ITS at 25 C	• Foamed/ unfoamed asphalt binders • 24 h curing at 135C

Wirtgen WLB-10 Laboratory Foaming Plant

Water added = 2.2- 2.3%

Temp =160 °C

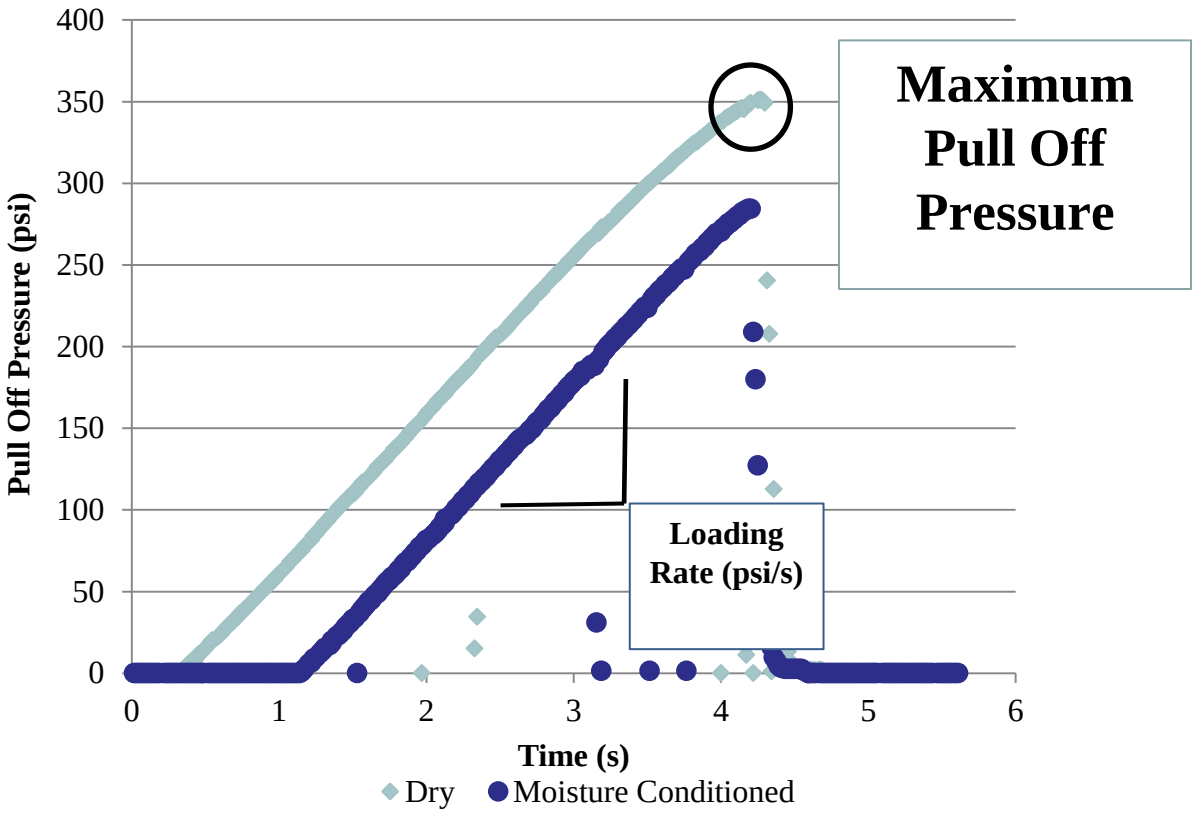
Bitumen Bond Strength Test



$$POTS = \frac{(BP \times Ag) - C}{A_{ps}}$$

Ag = contact area of gasket with reaction plate (mm^2)
BP = burst pressure (kPa)
Aps = area of pull stub (mm^2)
C = piston constant

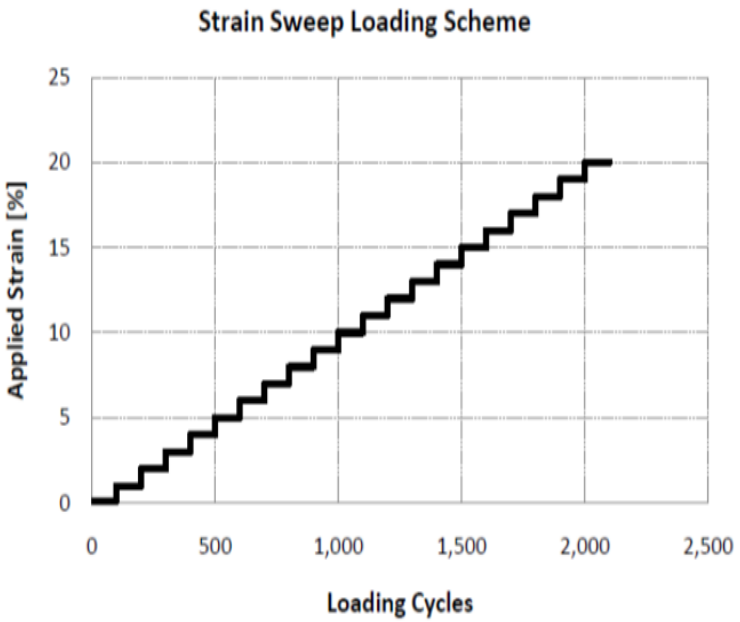
BBS Test – Typical Results

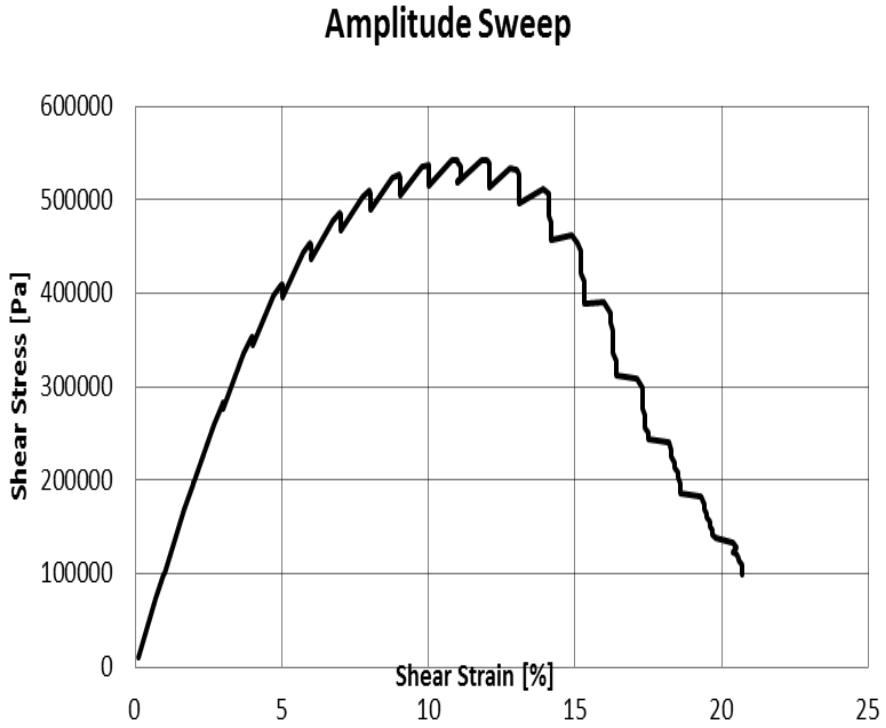


Cohesive Failure

Adhesive Failure

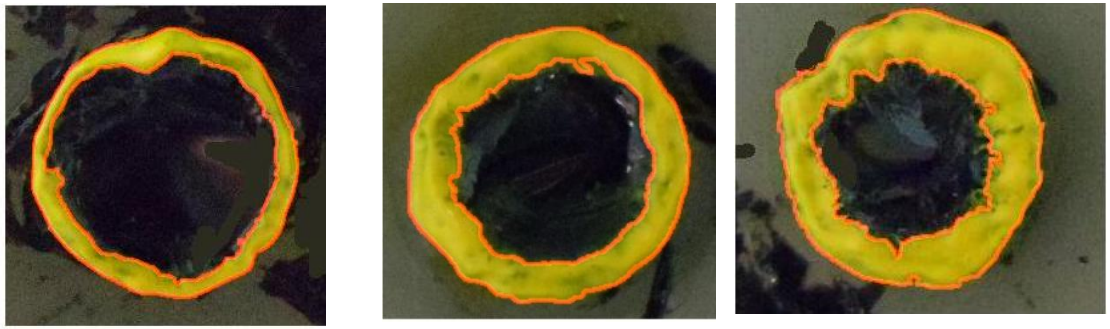
Linear Amplitude Sweep Test





Progression of Fatigue Fracture

Increasing loading duration



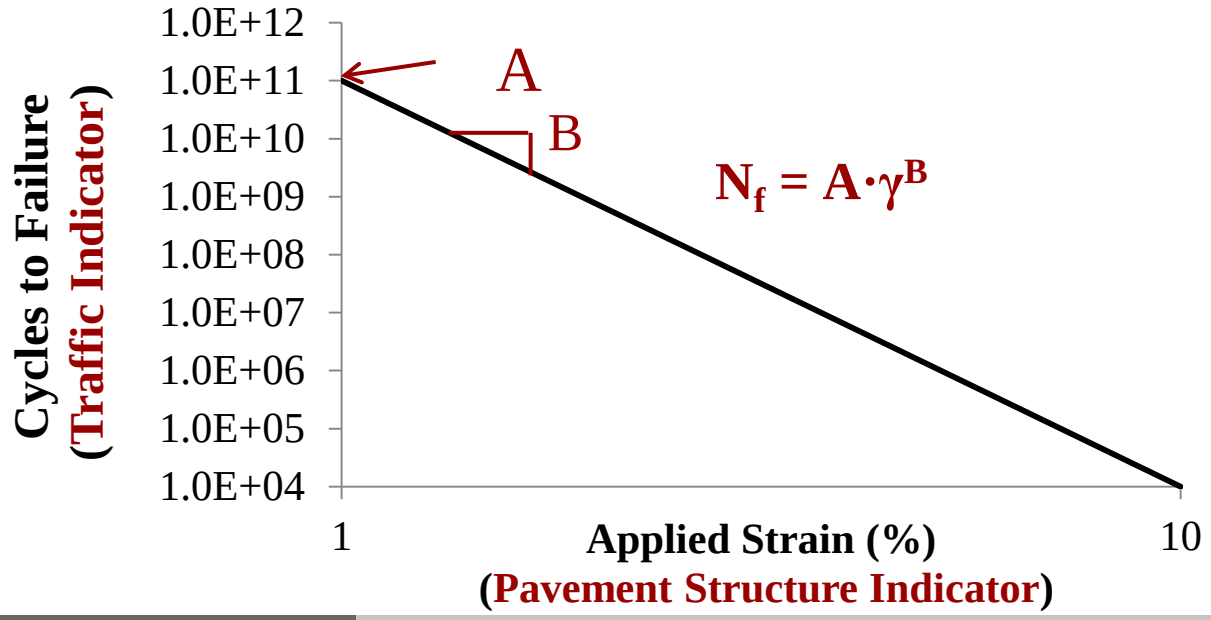
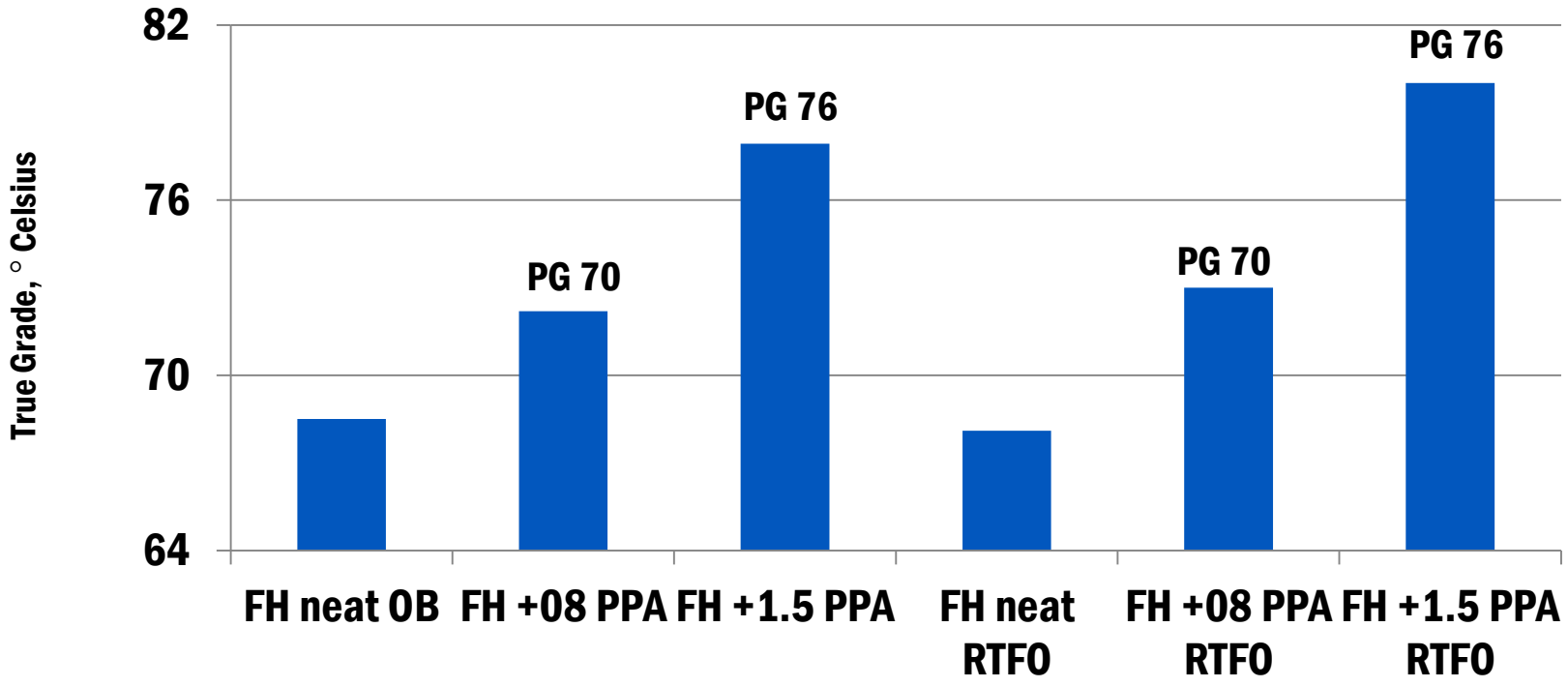


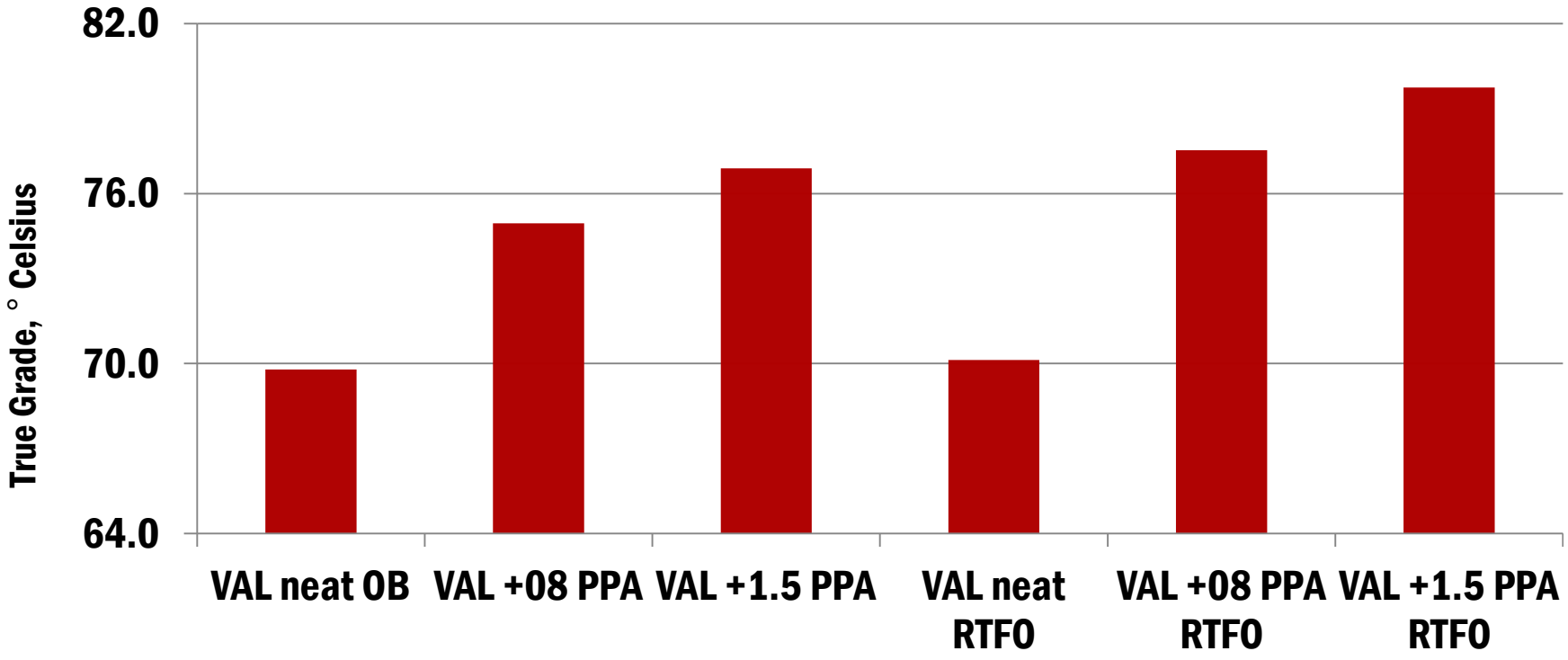
Image analysis used to determine crack length

Source: Hintz 2012

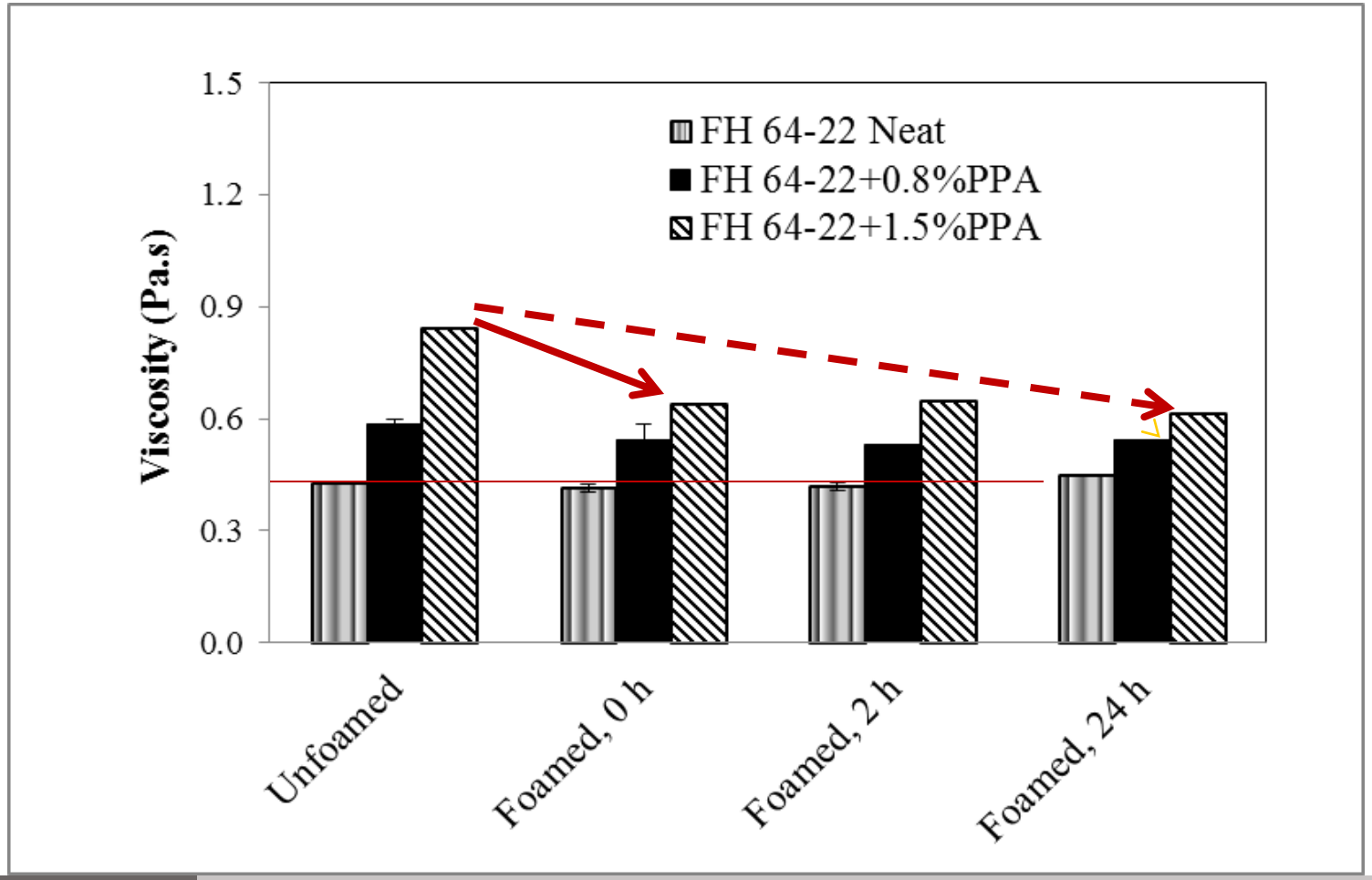
Continuous PG Grading Un-foamed, Neat and RTFO- Flint Hills Binder



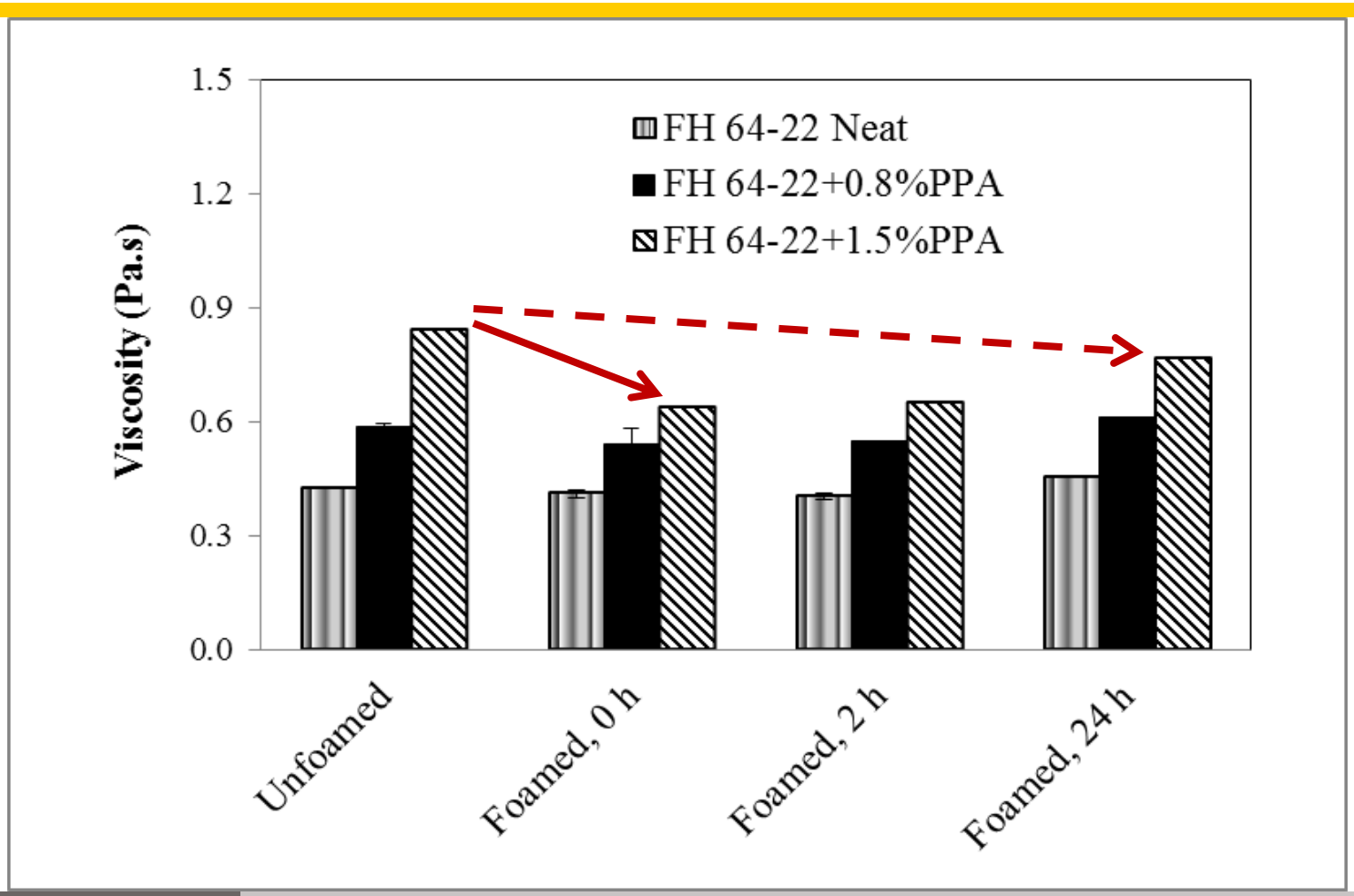
Continuous PG Grading Un-foamed, Neat and RTFO – Valero Binder



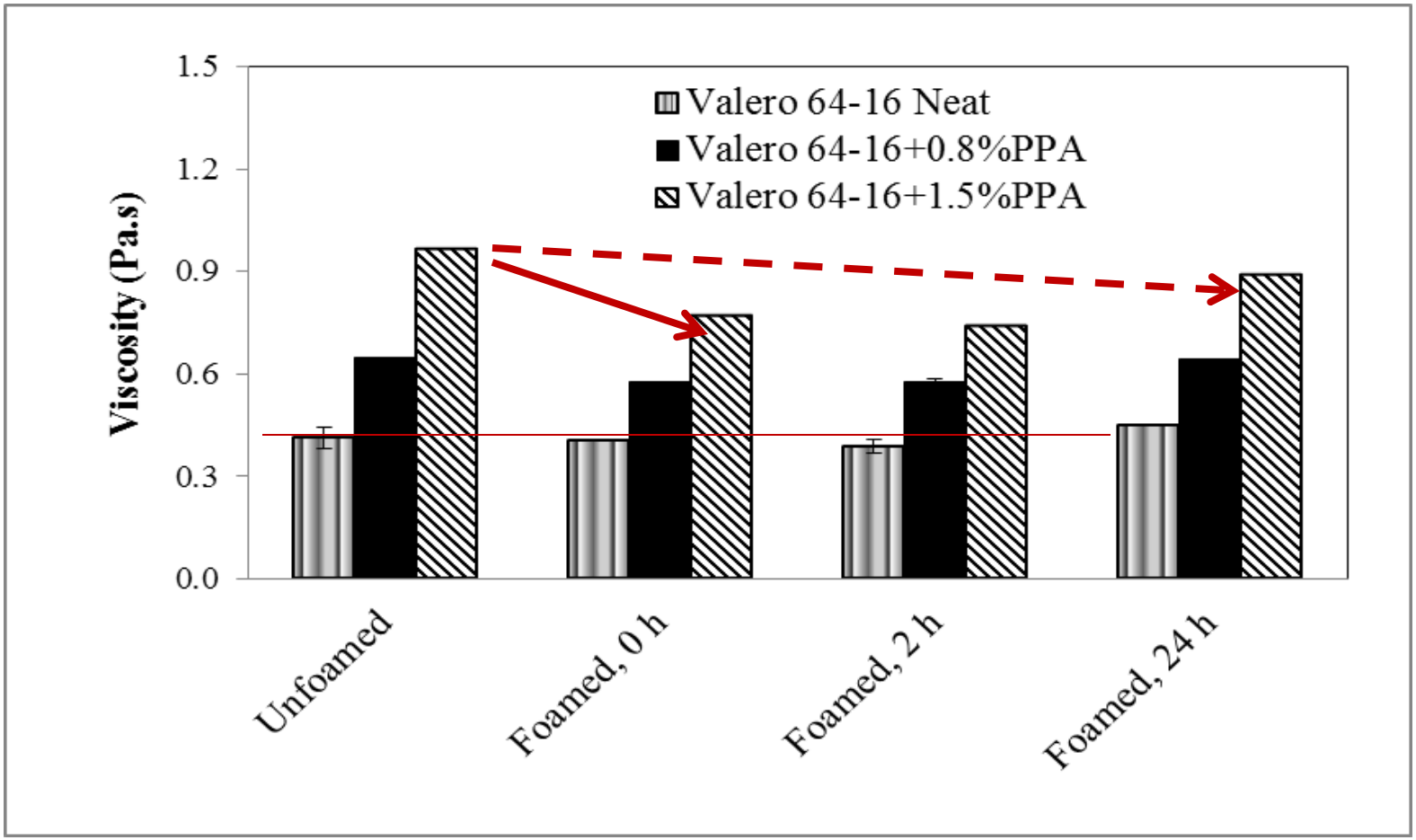
Foaming Results-Viscosity-FH Curing at *Room Temperature* ~ 23 C



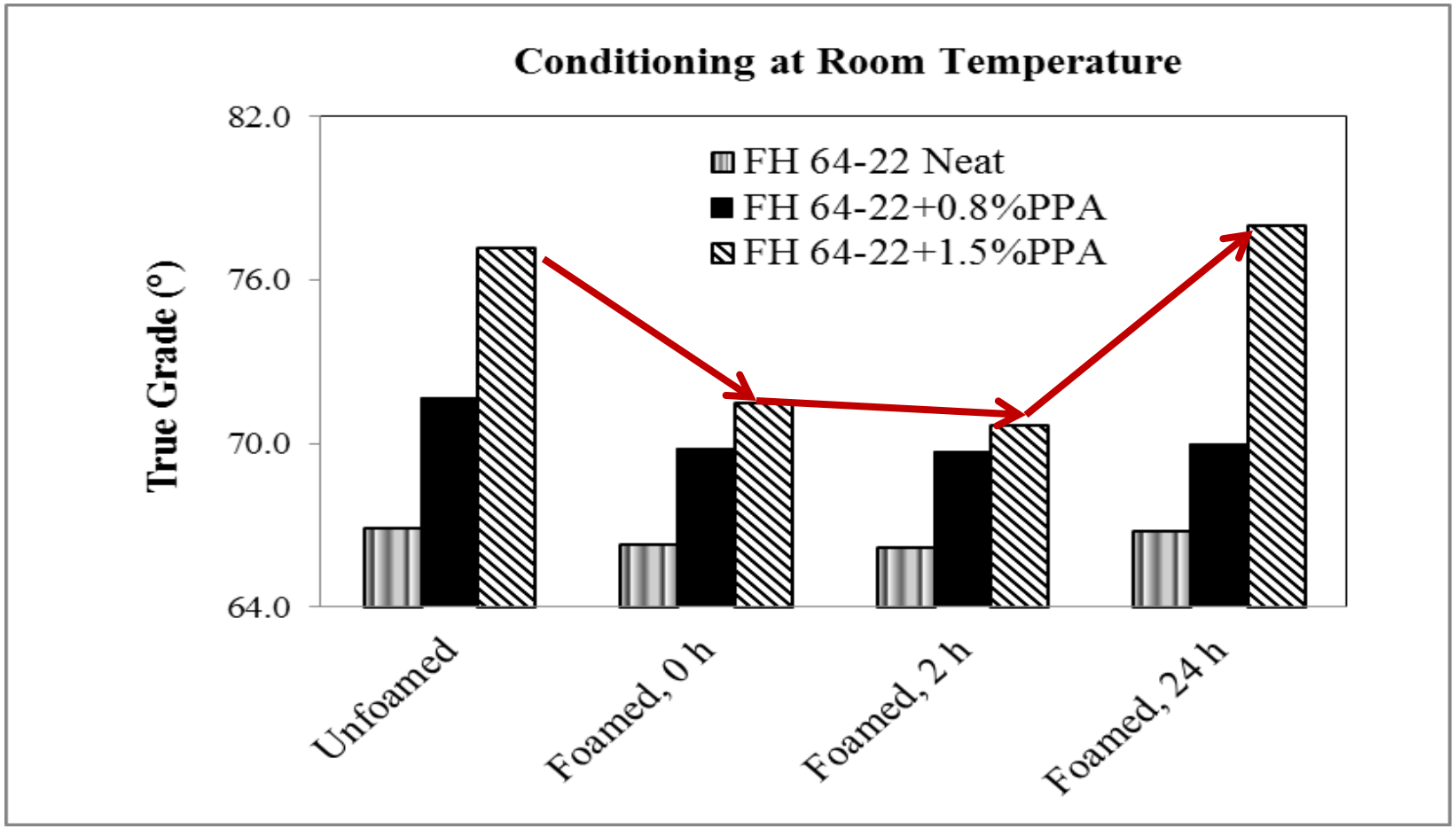
Foaming Results-Viscosity-FH Curing at *135°C*



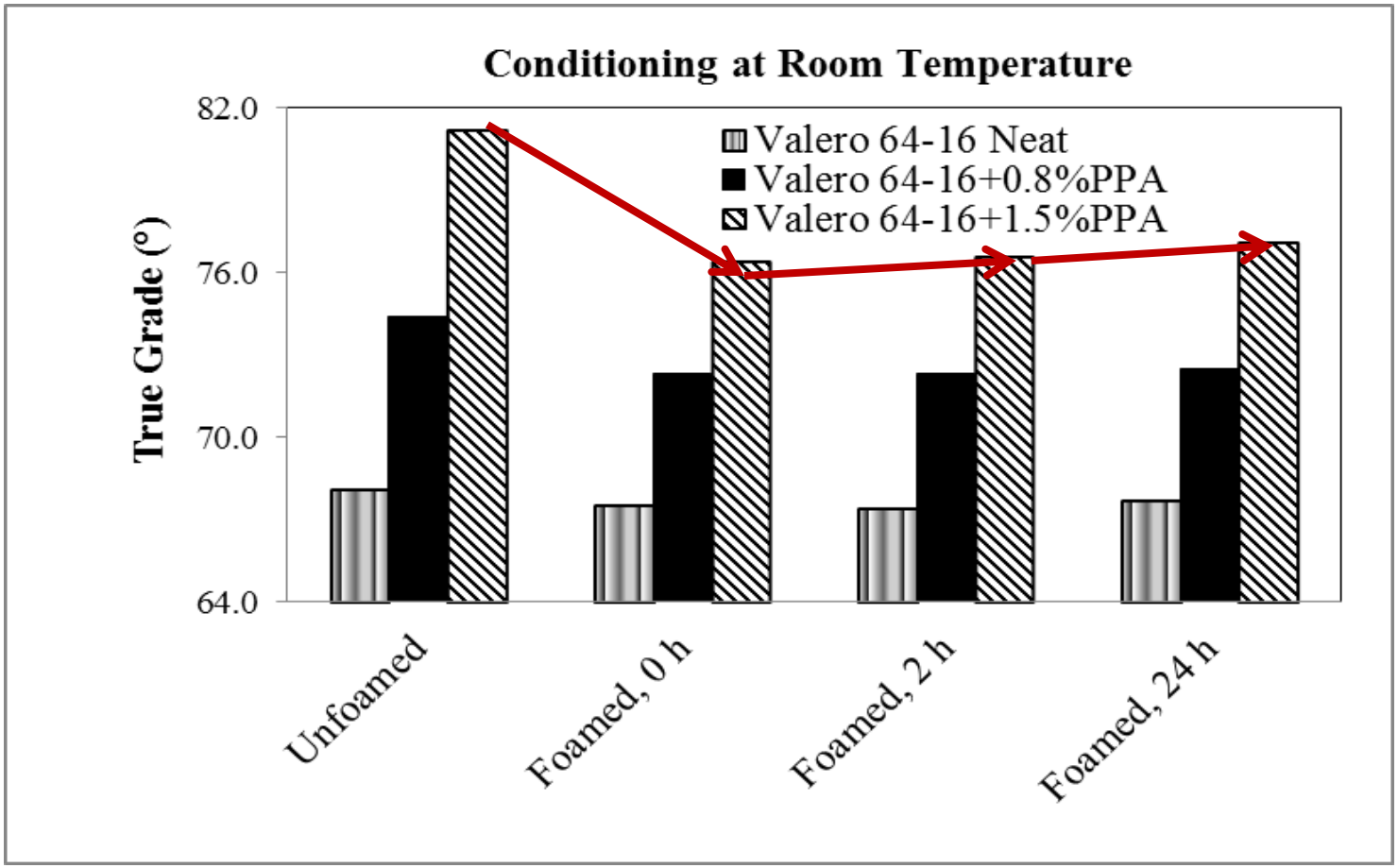
Foaming Results-Viscosity-Valero Curing at 135°C



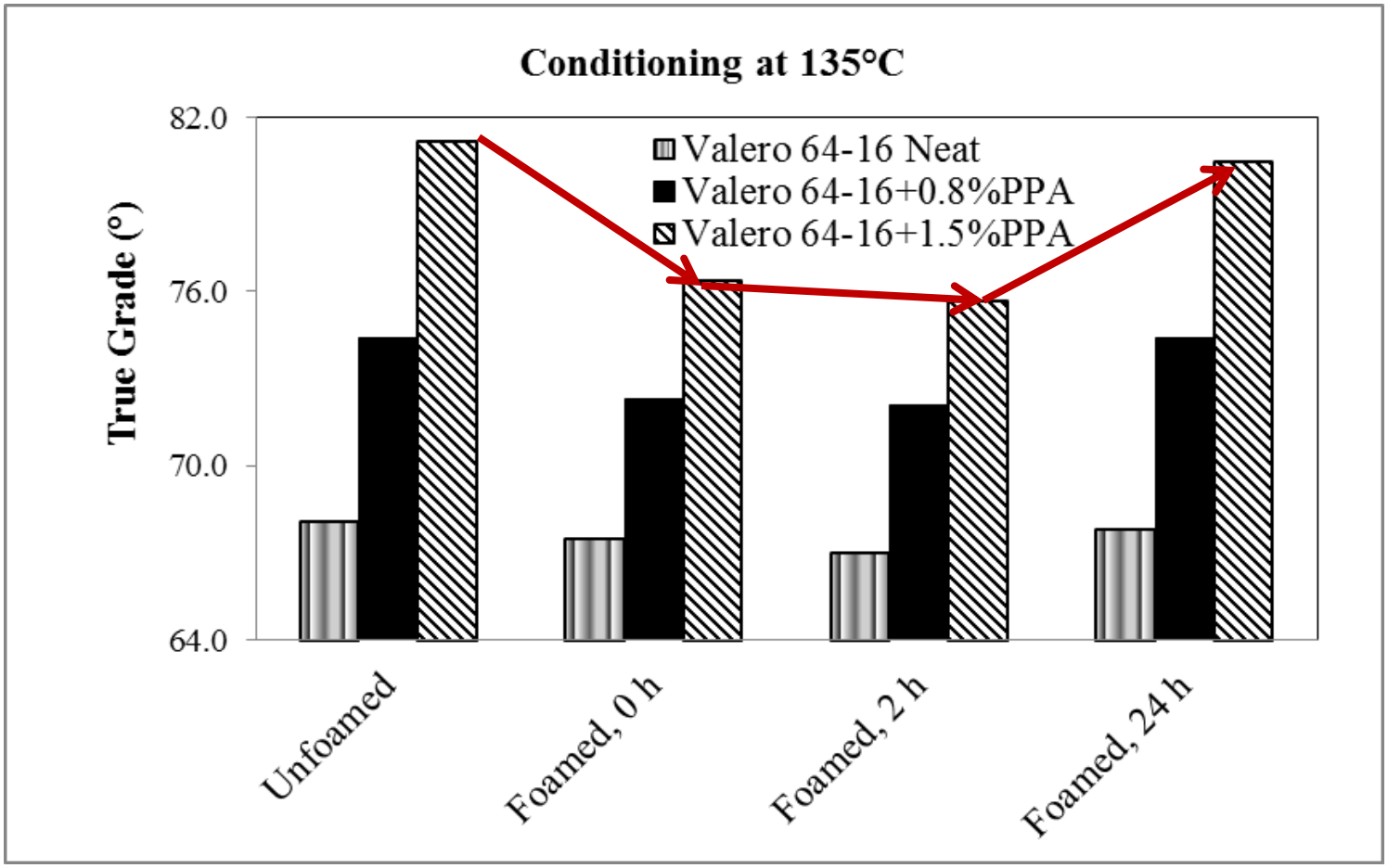
Recovery of Continuous Grade Flint Hills binder - @ Room Temp (22-23 C)



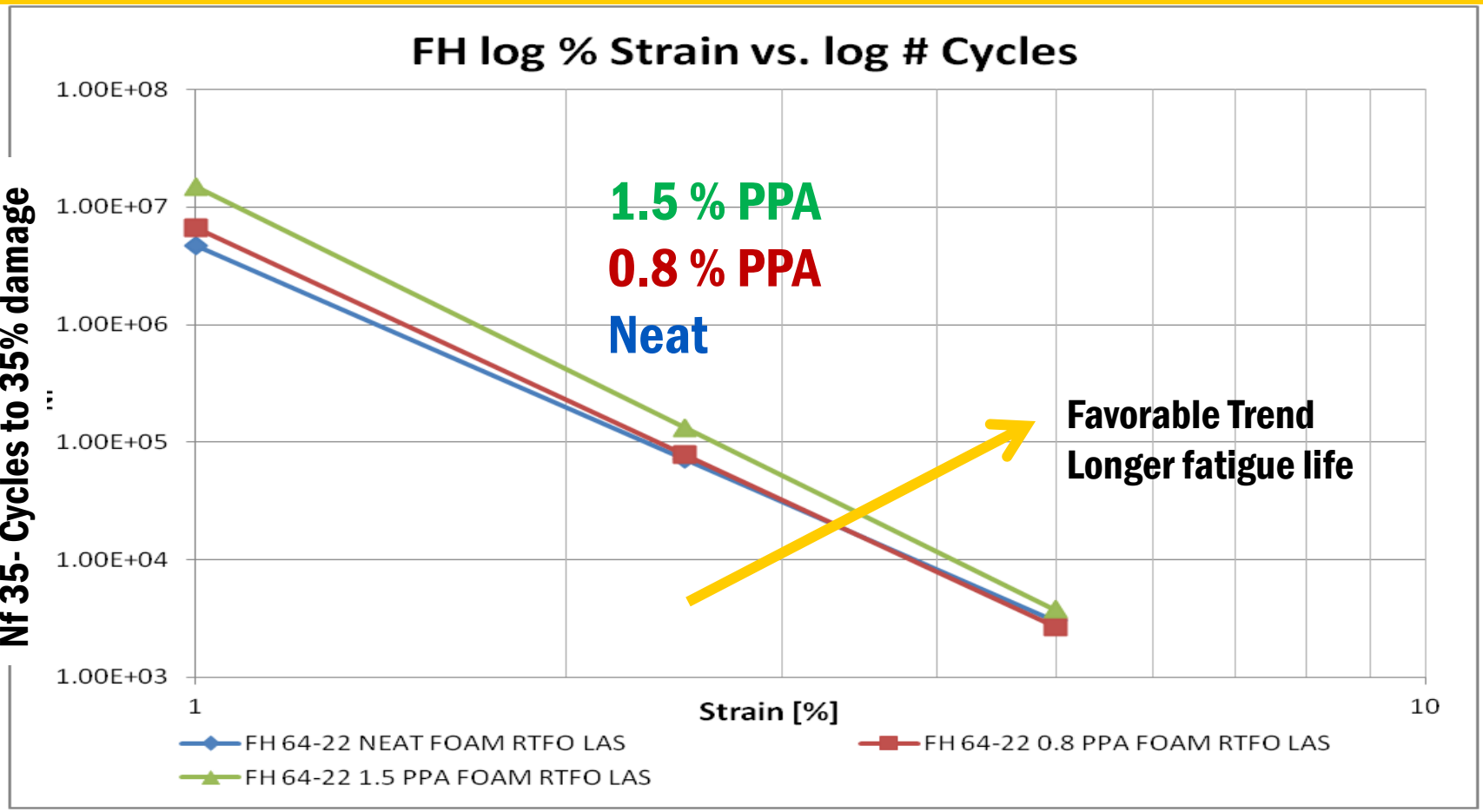
Results-Continuous Grade Valero Binder at Room Temperature



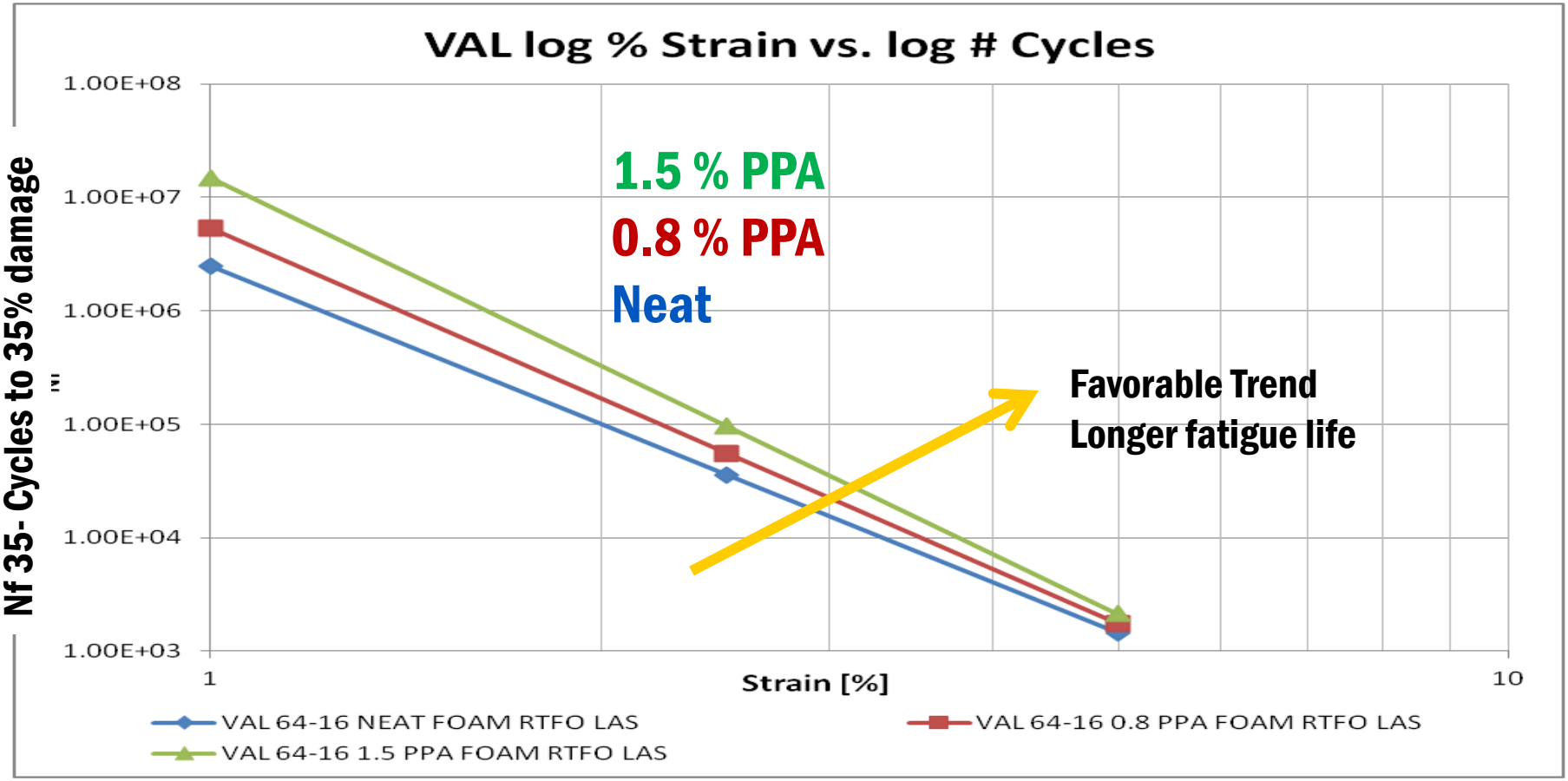
Results-Continuous Grade Valero Binder at 135 C



Fatigue – LAS Results
Foamed + Cured 24 hrs @ 135 + RTFO

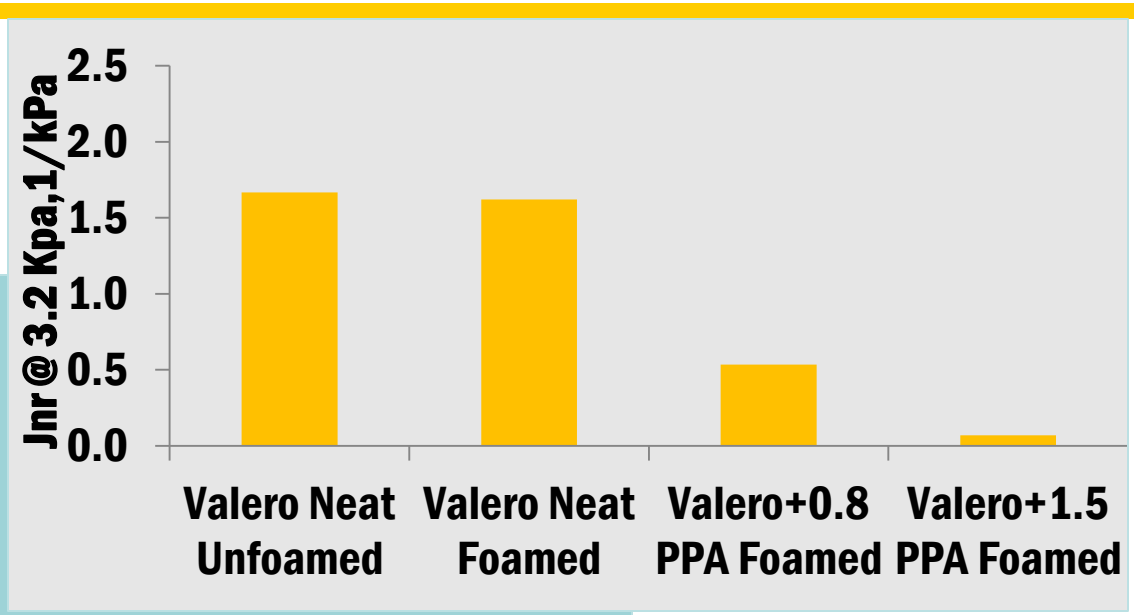


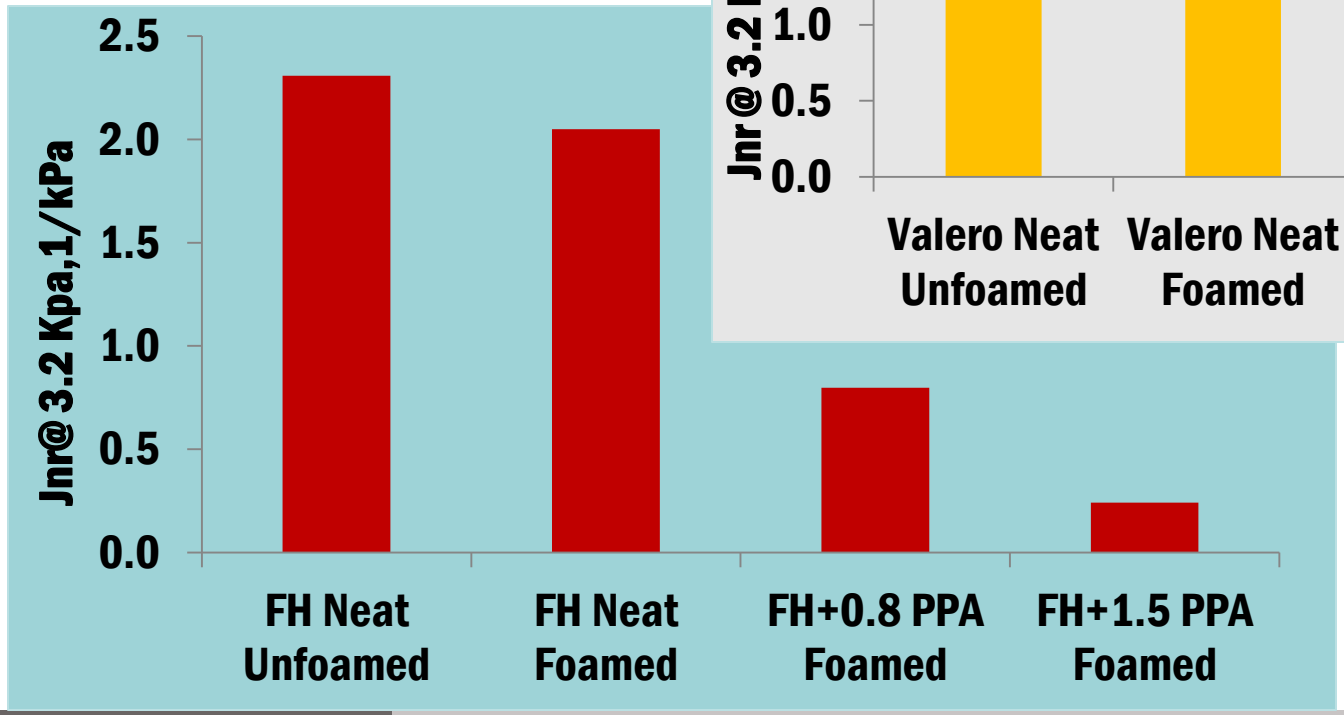
Fatigue – LAS Results – Valero Foamed + Cured 24 hrs @ 135 + RTFO



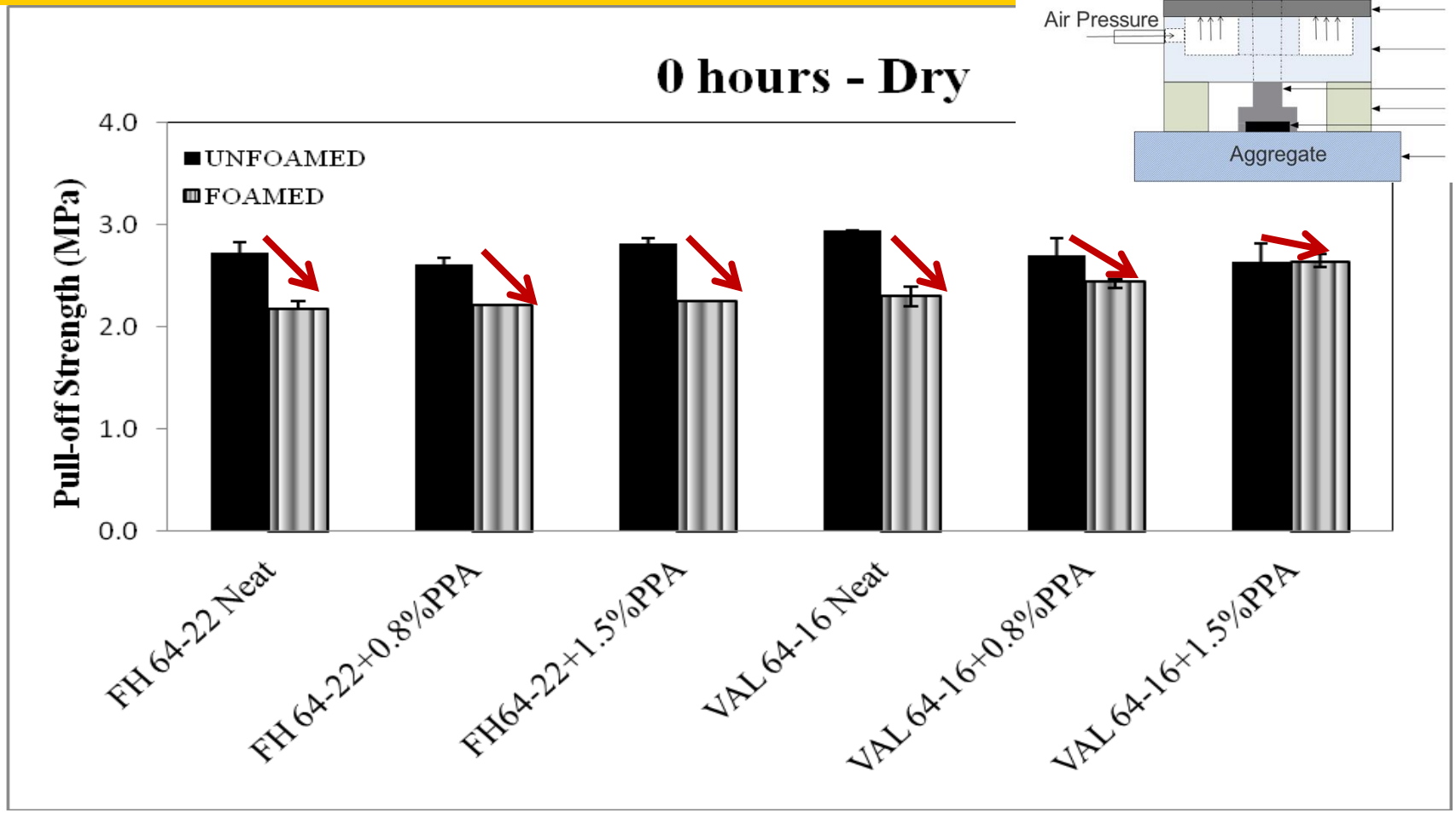
MSCR Results

Foamed + Cured for 24 hrs @135 C + RTFO

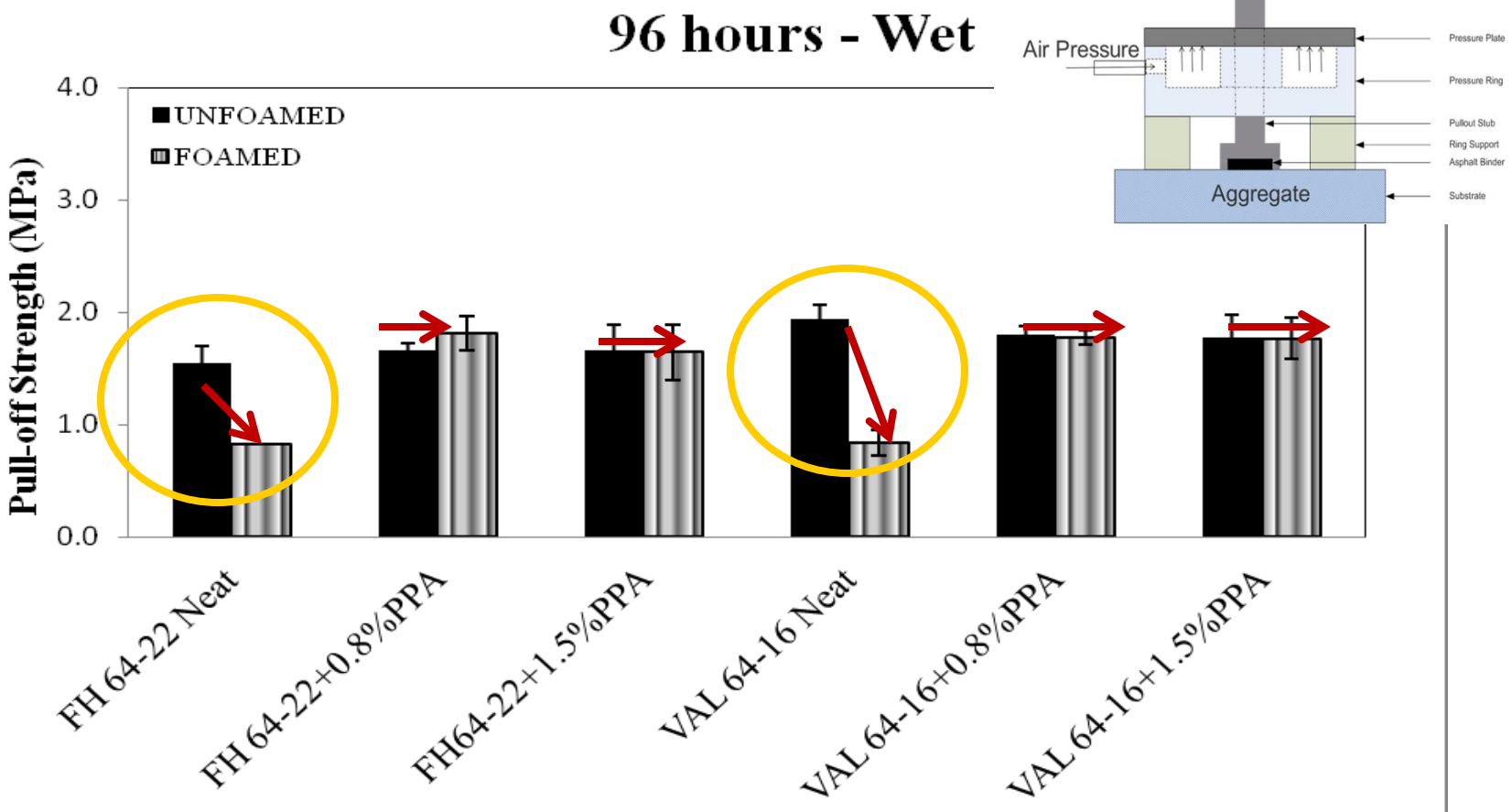




Effects on Bond Strength with Aggregates - dry



Effects on Bond Strength – Wet (96 h at 40 C)



Results-Bond Failure and Effect of Mositure – Foamed Binders

Neat Binder
FH 64-22
Dry

Neat Binder
FH 64-22
Wet 96 hrs

Modified Binders

FH 64-22 + 0.8 PPA – Wet 96 hrs

FH 64-22 + 1,5 PPA – Wet 96 hrs

Results-Bond Failure and Effects of Moisture – Foamed Binders

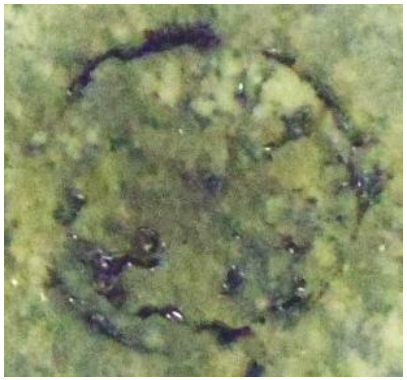
FH 64-22 - Dry

FH 64-22 – Wet, 96h

FH 64-22+0.8%PPA - Wet, 96h

FH 64-22+1.5%PPA - Wet, 96h

VAL 64-16 - Dry

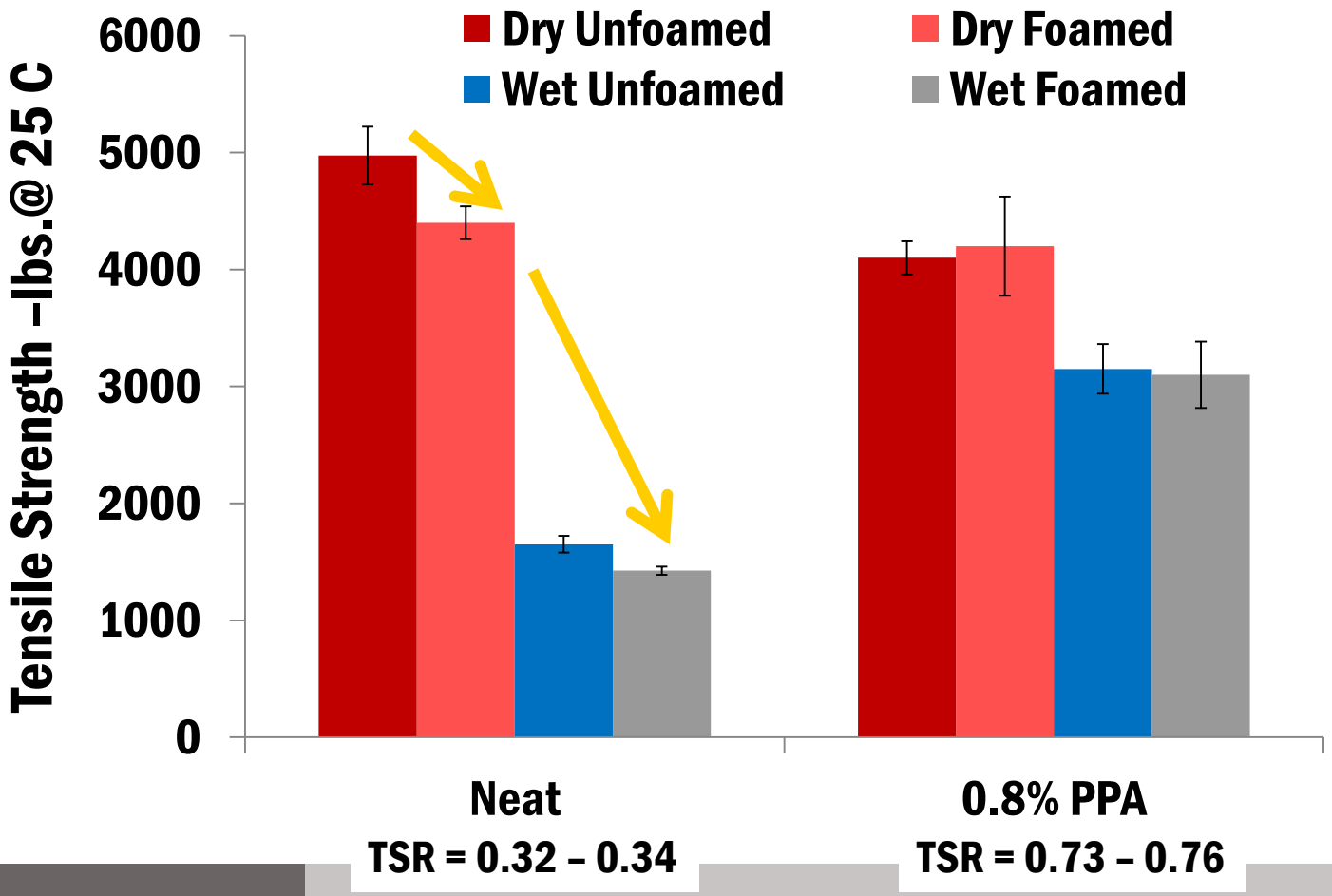


VAL64-16 – Wet, 96h

VAL64-16+0.8%PPA - Wet, 96h

VAL64-16+1.5%PPA - Wet, 96h

Results-Mixture's Indirect Tensile Strength & Moisture Effects



Conclusions- Viscosity

- **Effect of PPA on Viscosity:**
  - 0.8% of PPA caused only minor increase in viscosity.
  - 1.5% of PPA increased viscosity by ~ 0.31 - 0.44 Pa.s .
- **Effect of Foaming on Viscosity:**
  - Foaming reduced viscosity of PPA modified binders slightly more than the base binders, in particular when 1.5 % PPA was used.
  - Curing for 24 h at 135 C caused PPA binders to recover .
  - When storing at room temperature, the recovery takes longer time.
- **In all cases the margins of change are small and not important considering the limit of 3.0 Pa-s.**

Conclusions- PG grades

- **Effect of Foaming on PG True Grade (TG):**
  - Foaming does not have significant effect on the high temperature TG of base binders (effect is less than 1.0 C).
  - However the initial effect on TG of PPA-modified is significant.
  - For the binders modified with 0.7-0.8 % PPA, the effects are less than 2.0 C and there is a clear recovery of the grade after 24 h conditioning at 135 C or at room temperate.
  - Conditioning at room temperature shows less recovery, but there appears to be a trend that higher temperature storage could expedite this.
  - **For the binders modified with 1.5% PPA, the initial effects on TG are higher (2-6 C reduction in grade). Conditioning at 135 for 24 h can cause almost full recovery of the grade before foaming.**

Conclusions – Bond strength and moisture effects

- Effect of Foaming on Binder's Bond to Aggregates:
  - Foaming cause a minor reduction in initial-dry bond strength with aggregates.
  - All samples containing PPA however show significantly higher bond strength after 96 hours of wet conditioning.
  - Failure modes after moisture conditioning were mainly cohesive for PPA binders, which indicates bond at the aggregate-binder interface is greater than the cohesive strength of the foamed binders.

Conclusions – Fatigue and Rutting of binders

- Foaming did not affect fatigue and rutting performance of PPA binders.
- Fatigue life of PPA modified foamed binders are equal or better than base binder.
- Also, the rutting resistance as measured by the Jnr compliance at 3.2 kPa is much better of the PPA binders than the base binder.

Acknowledgments

- PARC organizing committee for accepting the paper .
- Henry for the beer !
- Trevor Schultz and Dr, Andrew Hanz for the moisture damage data and foaming help.
- MARC partners for the support.
- Presentation posted at UWMARC.org
  - Questions : please e.mail me bahia@engr.wisc.edu