Engineered Materials

Details of UW Madison

Work Plans

Related to Modeling

Andrew Hanz and Hussain Bahia

EPMs – Main Research Themes

- **Use modeling to guide materials' design**
  - Micromechanics and phenomenological
  - Rheology and damage resistance
- **Focus on two main areas**
  - **Asphalt materials for critical applications.**
    - High traffic volume, slow moving, heavy axle loads,
    - extreme climate, and
    - perpetual service life.
  - **Conserving energy and natural resources**
    - Increased use of (RAP) in hot-mix asphalt.
    - emulsions for cold mix asphalt, and
    - warm mix additives

Engineered Materials- 10 Work Plans

ARC

Category	Specific Work Element	Consortium Partner- Work Elements				
		WRI	TTI	UWM	UNR	AAT
Modeling	Analytical and ***Micro-Mechanics Model*** for Mastics and Mixtures		**E1-a E1-b**			
	Damage Resistance Modeling **of Binders**			**E1b-1 E1b-2**		
	Warm and Cold Mixtures			**E1c-1 E1c-2**	**E1c-2**	
	Comparison of ***Modification Techniques***			**E2a**		
Design Guidance	Use of ***High Percentage of RAP***			**E2b**	**E2b**	**E2b**
	Critically Designed HMA Mixtures				**E2c**	
	Thermal Cracking Resistant Mixes for Intermountain States			**E2d**	**E2d**	
	Design of Fatigue and Rut Resistant Mixtures					**E2e**

Focus of this Presentation and Relationship to FHWA Focus Areas

FHWA Focus Areas	*Asphalt Research Consortium Program - Related Tasks*
• **Optimize Pavement Performance** • **Advanced Quality Systems**	**E1b-1** **Damage Resistance Characterization**
• **Environmental Stewardship**	**E1c-1** **Warm Mixes**

E1b-1: Rutting Resistance of Asphalt Binders – Modeling Considerations

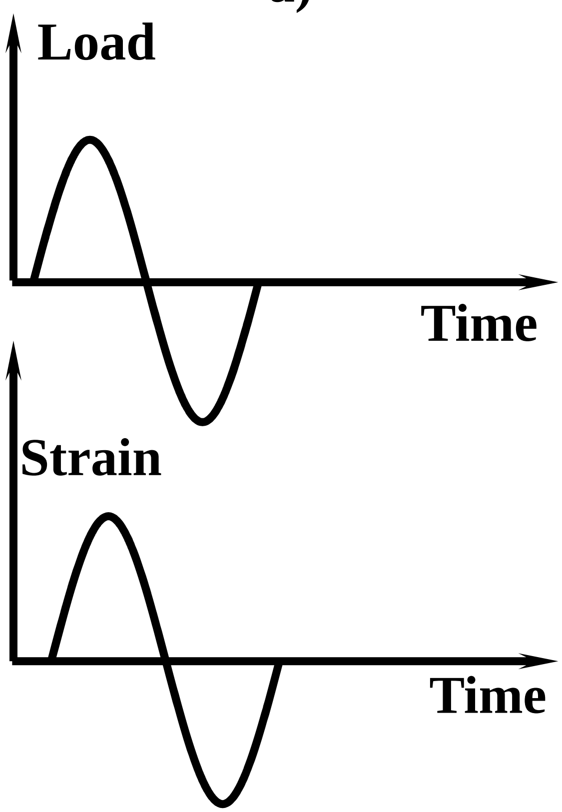
- Type of Loading
  - Must be consistent with actual traffic loading
- Stress Level
  - Representative of binder stresses realized in the mix.
  - Quantify the effects of accumulated damage – nonlinear behavior.
- Effects of Modification on Performance
  - Polymer / additive effects:
    - Damage Resistance
    - Elastic Recovery

E1b-1: Rutting Resistance of Asphalt Binders – Modeling Considerations

- Type of Loading Reflects Actual Conditions

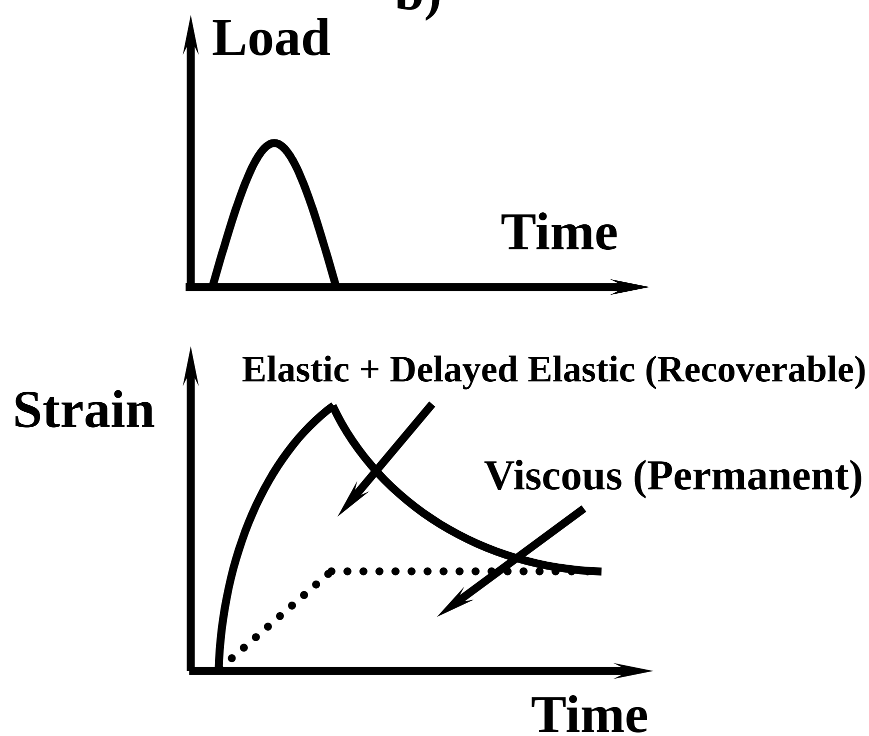
Cyclic

a)

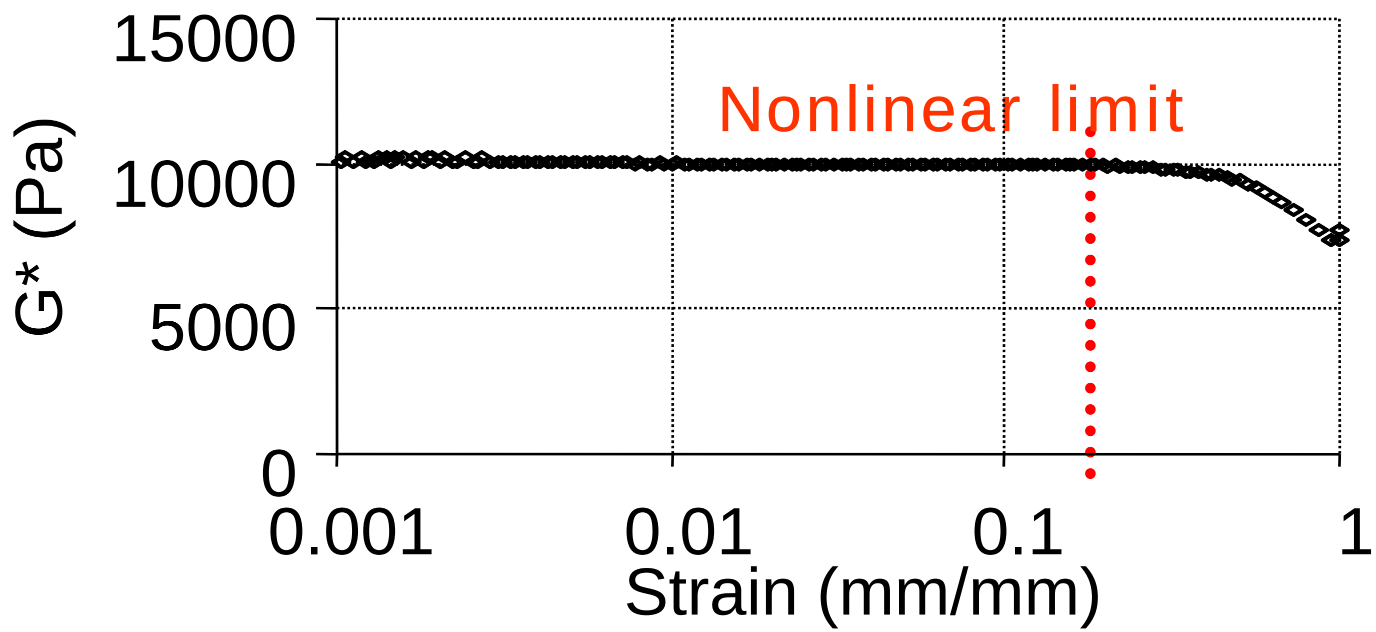


Impulse Load with a Rest Period – Considers Recovery

b)

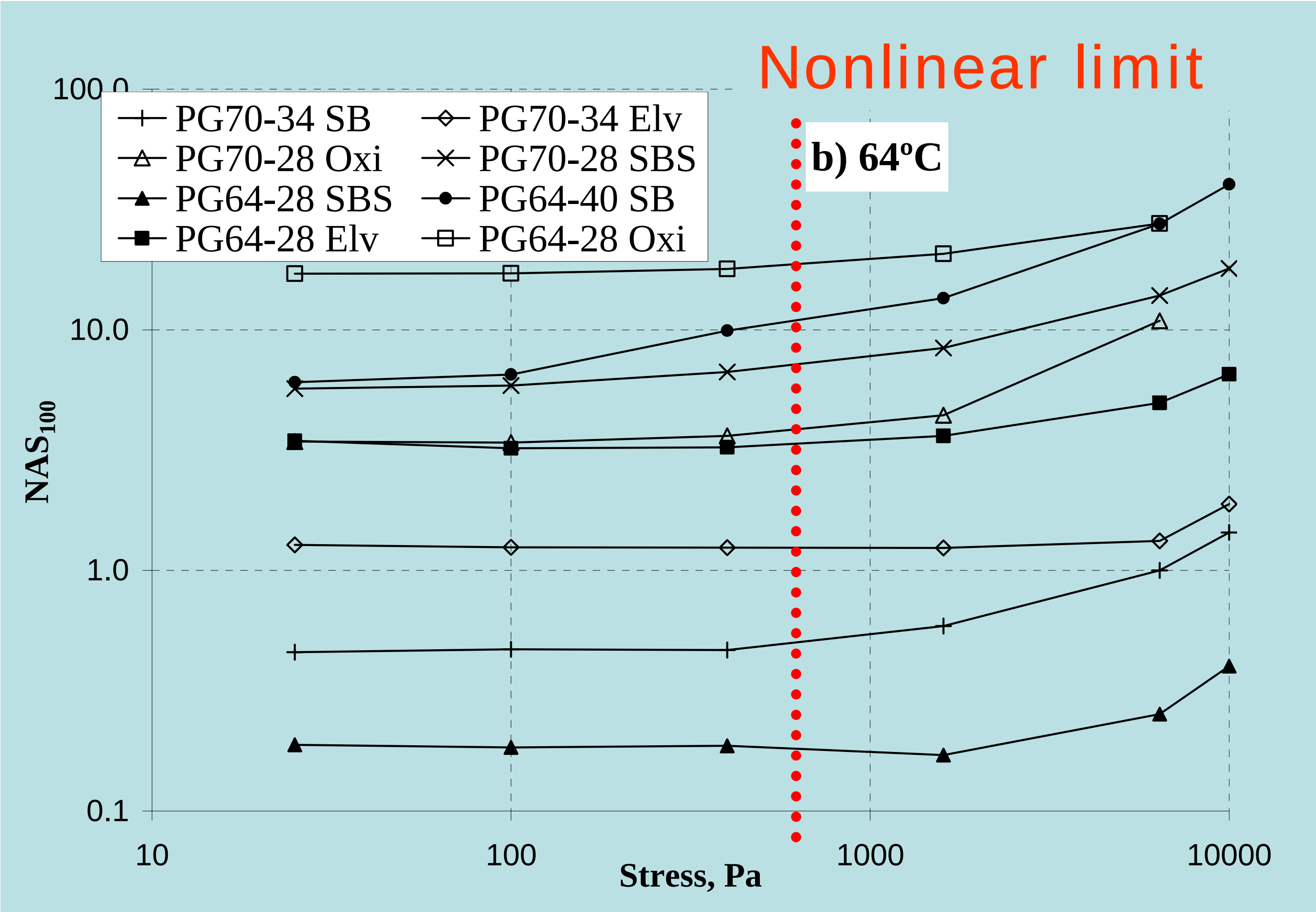


E1b-1: Rutting Resistance of Asphalt Binders – Strain Level



- Strain levels in the binder estimated 0-500 times those realized in the mix.
- Clearly non-linear behavior must be considered

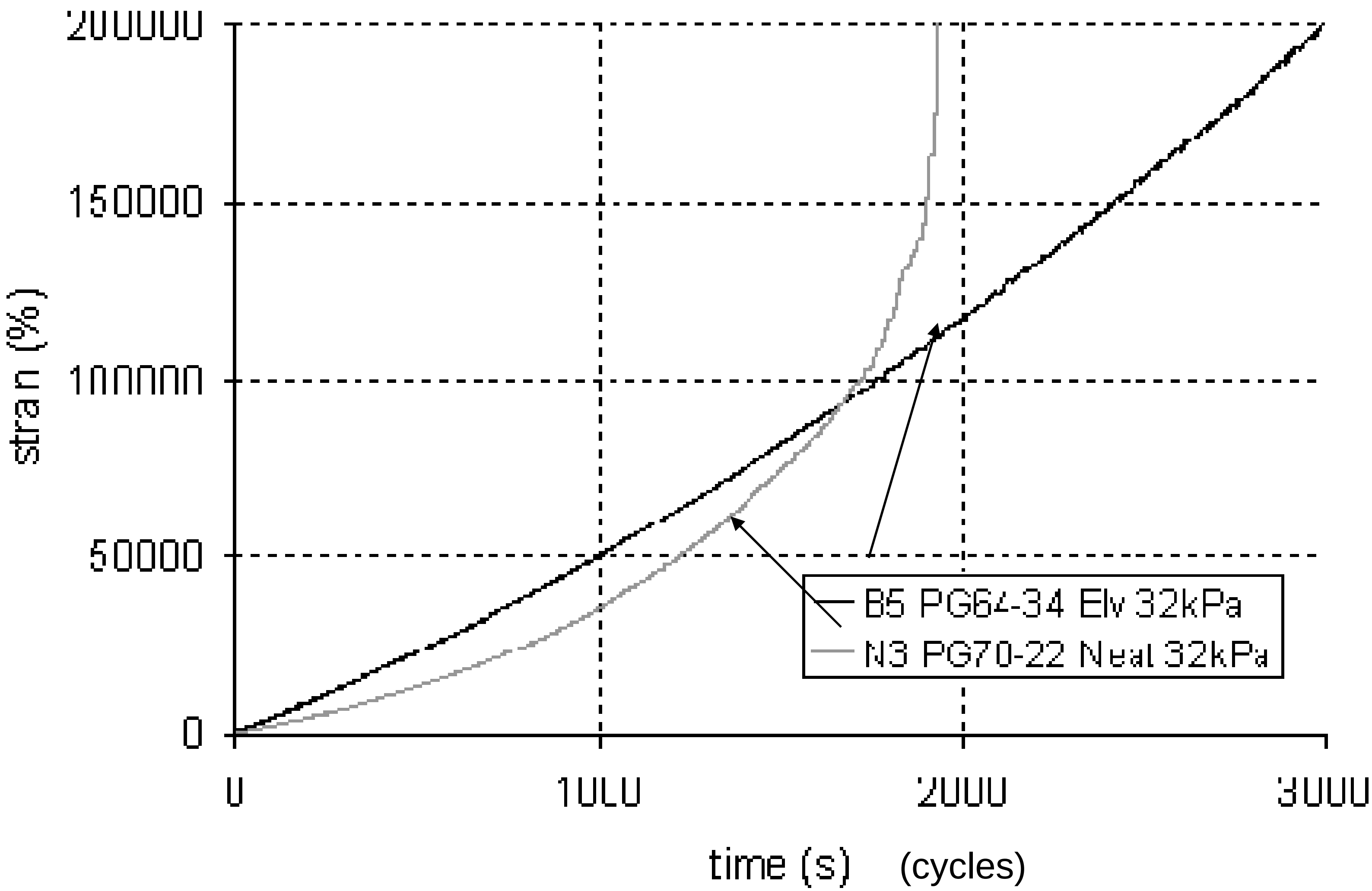
Normalized Accumulated Strain after 100 cyles NAS_{100}



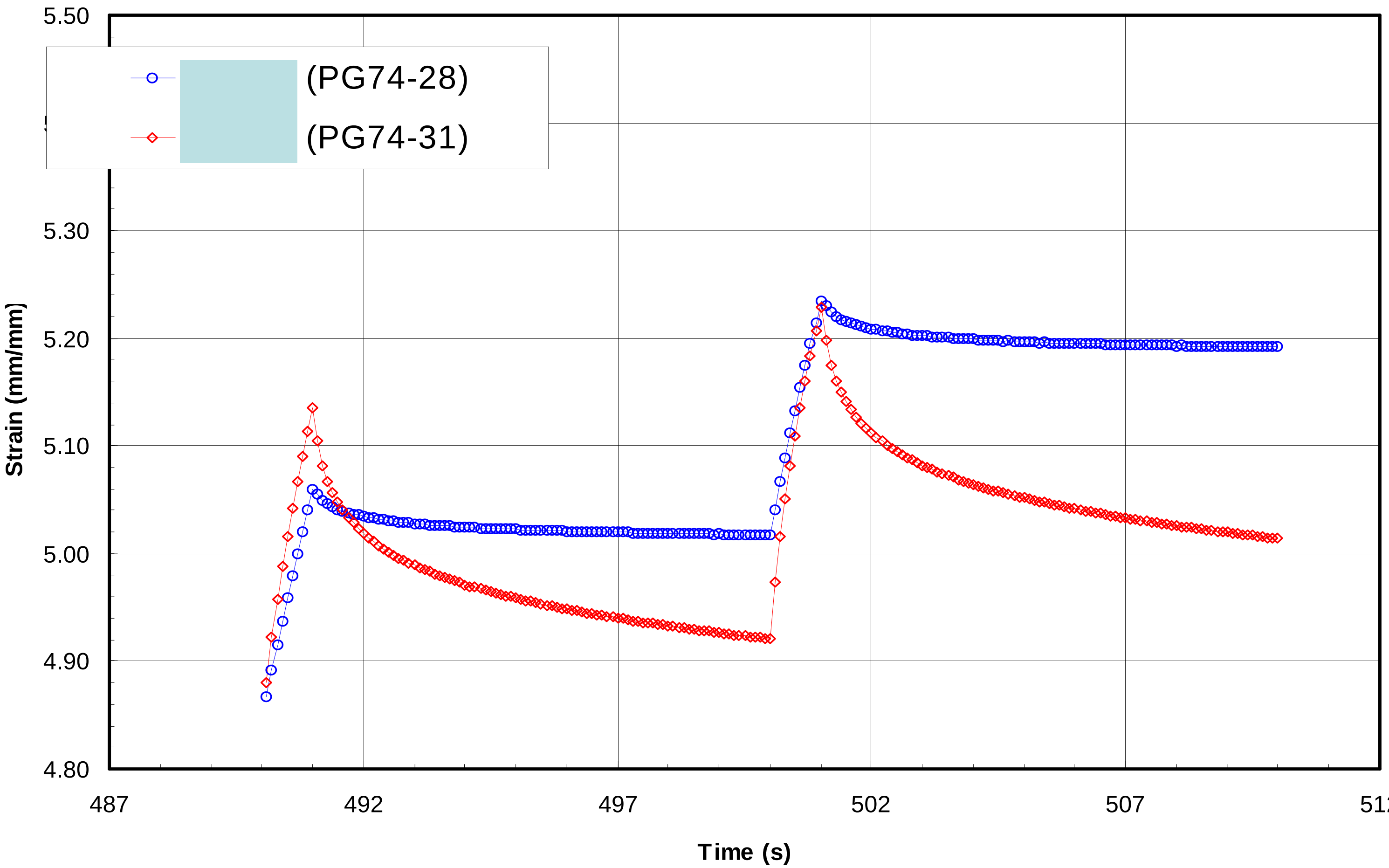
Delgadillo, Cho & Bahia – TRR 2006

Effect of Accumulated Loading Time
Repeated Creep Testing

Delgadillo & Bahia – 2007 Unpublished data



E1b-1: Rutting Resistance of Asphalt Binders – Effects of Polymers - Recovery



E1b-1: Rutting Resistance of Asphalt Binders – Hypothesis

- **Hypothesis**
  - Binder needs to be **characterized at different stresses and loading times** in order to accurately predict the rutting performance of mixtures
  - **Will be coordinated with D'Angelo's work**
    - **AAPT 2007: Recoverable Compliance Jnr**
    - **Expand on Unpublished work by UW**
    - **Need for model at higher stress levels and loading times.**

E1b-1: Rutting Resistance of Asphalt Binders – Experimental Plan

- Literature Review
  - Methods of Binder and Mixture Rutting Evaluation
  - Relationship between binder and mix rutting.
- Selection of Materials Parameters
  - Binder:
    - High Temp PG Grade (PG 58-xx – 76-xx)
    - Modifier: SBS, Elvaloy, SB, EVA, PPA, oxidized
  - Mix
    - Gradation: Fine, Coarse, OGFC
    - Aggregate Shape: Angular and Rounded
    - Asphalt Content: Design and Design + 0.5%

E1b-1: Rutting Resistance of Asphalt Binders – Experimental Plan

ARC

- Analysis and Interpretation:
- Model relationship between binder and mixture rutting as a function of:
  - stress level, aggregate properties, and mix volumetric properties
- Include significance variables in prediction of traffic volume effects:
  - Stress level (non linear behavior)
  - Temperature
  - Total Time of Loading
  - Aging (RTFO)
  - Number of Cycles

E1b-1: Rutting Resistance of Asphalt Binders – Deliverables

- Standard Test Procedures and Recommendations for Specifications
  - Evaluate MSCR Protocol and suggest revisions
  - Inclusion of procedure and limits for PG binder specification
- Limits will be based on correlations to mixture response and LTTP data for Rutting Performance.

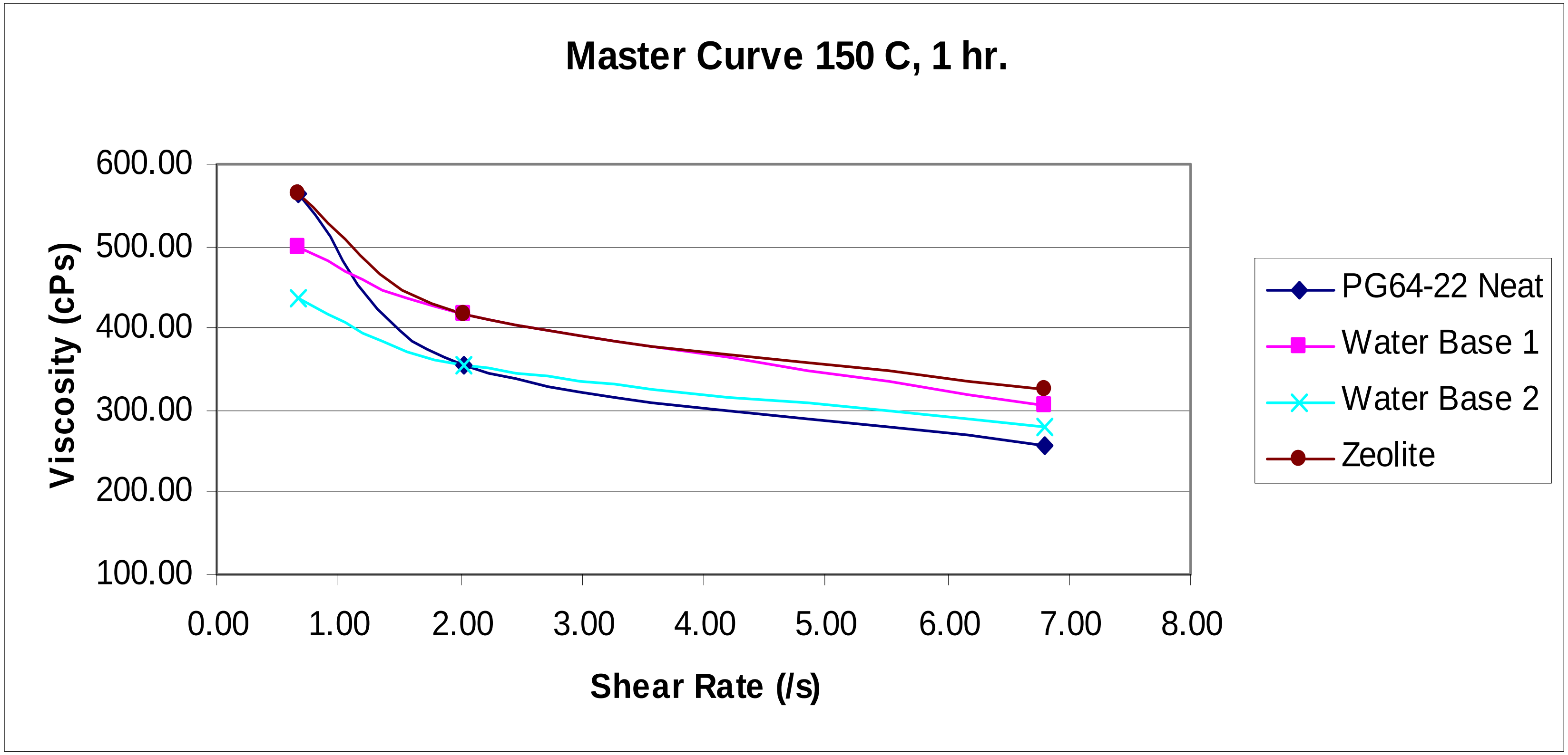
E1c-1: Warm Mixtures and Relationship to Modeling

- Focus will be on quantifying effects of various additives on binders, mixtures, and environment.
- Models Needed in the Following Areas
  - Prediction of Reduction in Mixing and Compaction Temperatures
  - Prediction of Reduction in Emissions
  - Effect of Additives on Mixture Durability and Performance
- Will be coordinated with
  - NCHRP 9-43 (Mixture Design Procedure for WMA)
  - NCHRP 9-47 (Field Validation of WMA)

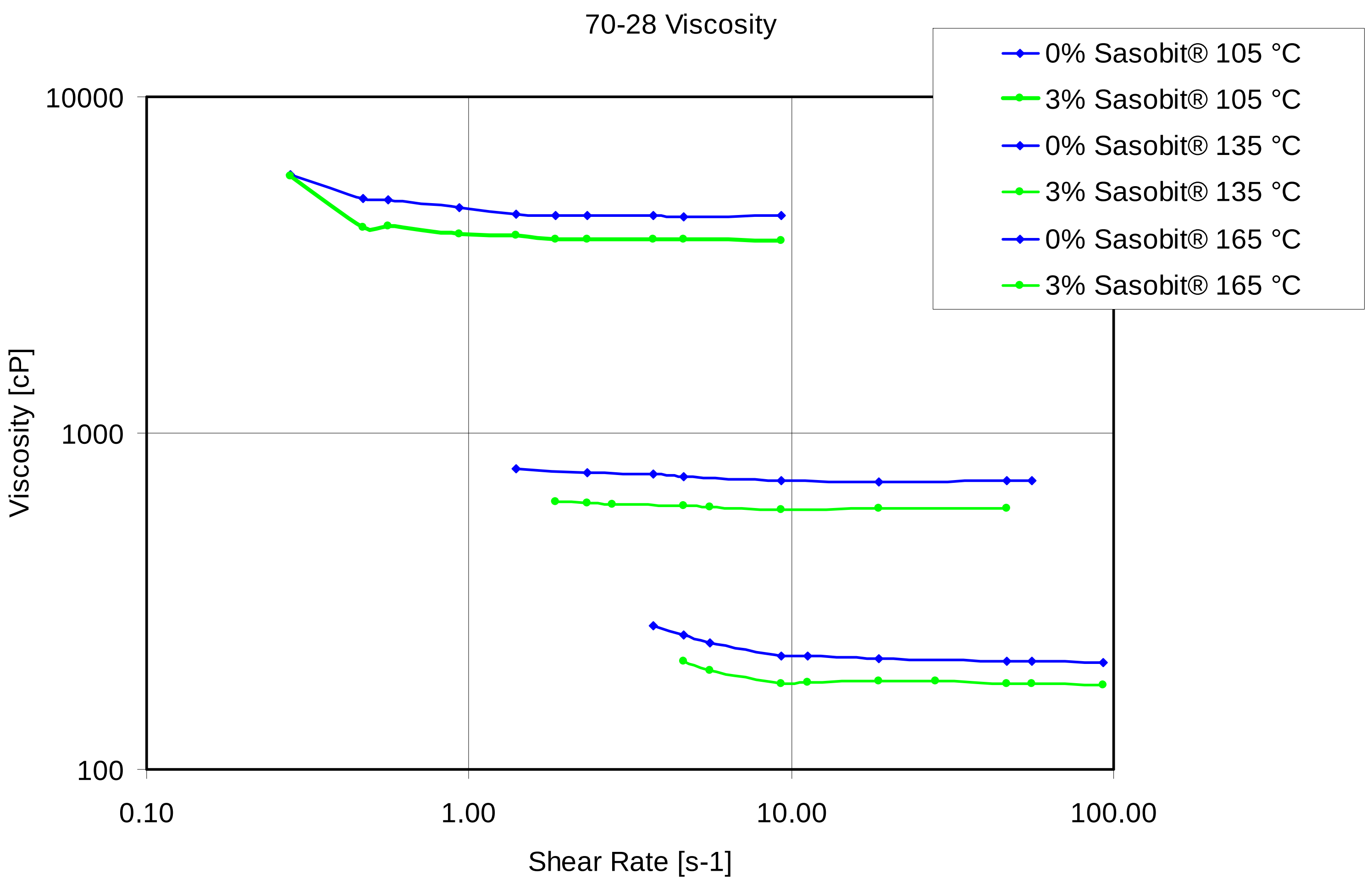
Prediction of Temperature Reduction – Focus on Binder

- Asphalt Binder
  - viscosity and temperature sensitivity
  - Content in mix (film thickness)
- Additive
  - Type – Wax Based and Hydrated Mineral
  - Concentration
  - Curing / setting rate

Reduction in Viscosity for Mineral Additives



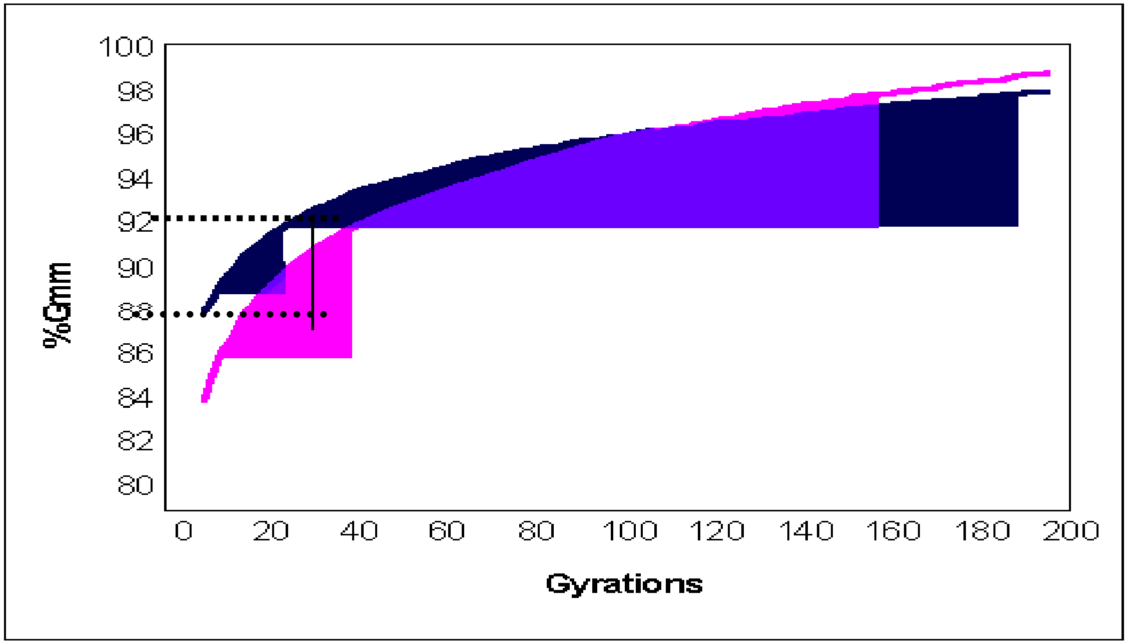
Reduction in Viscosity for Wax Additive



Prediction of Temperature Reduction – Focus on Mixture

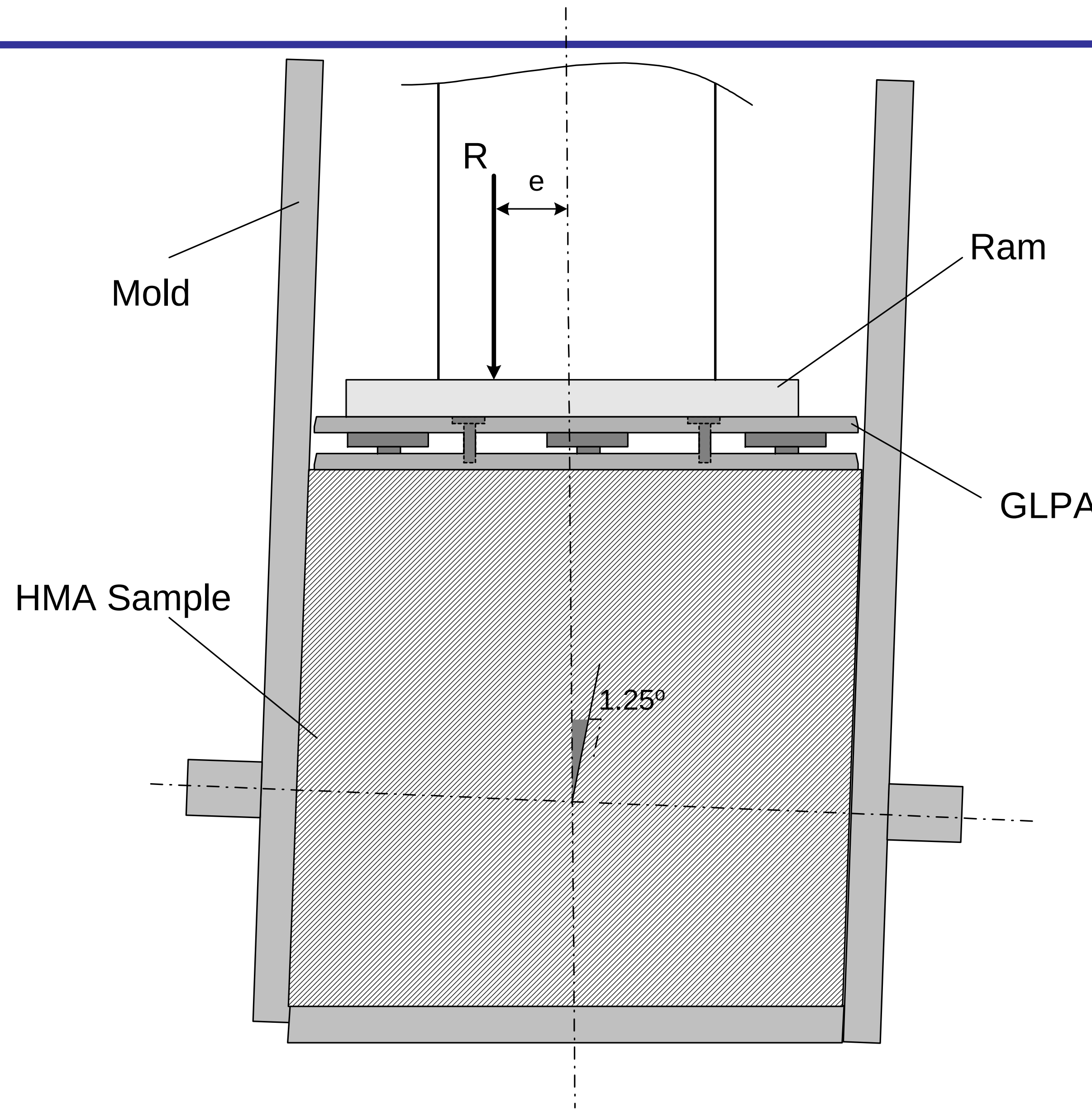
- Mix Design Protocols will be coordinated with NCHRP 9-43
- Mixture
  - How are trends found in binder related to mixture behavior?
    - viscosity and temperature sensitivity
    - Content in mix (film thickness)
  - What aggregate/mix properties are significant?
    - angularity
    - surface texture
    - NMAS
    - VMA
  - Evaluate effect of compactive effort – 600 ksi vs. 250 ksi.
- Evaluation Criteria: Reduction in Compaction Effort
  - Gyratory Load Plate Developed at UW will be used to measure compactive effort (from 88-92%Gmm)

Quantifying Compactive Effort Using the Gyratory Load Plate



Lower Compactive Effort is recognized by a smaller area under the compaction curve from 88 – 92% Gmm

PDA



PDA Used in the SGC Compaction Mold

Modeling Environmental Impacts

- Quantify the Effects of Mixing and Compaction Temperatures on:
  - Emissions
    - Less Dust
    - Less Exhaust
  - Energy Savings
  - CO2, CO, N.., S..
- Literature Review will be conducted to develop methodology
- Efforts will be Coordinated with NCHRP 9-47

Modeling Effects on Mixture Performance and Durability

Models for Prediction of Additives on Binder and Mixture Mechanical Durability and Performance

- Rutting potential
  - Binder repeated creep
  - Mixture repeated creep
- Fatigue Resistance
  - Binder
  - Mixture
- Thermal Cracking
  - Binder
  - Mixture
- Moisture Damage
  - Binder (PATTI- DSR Cohesion)
  - Mixture
- Mixture Testing Protocols will be coordinated with NCHRP

Field Evaluation of Models

- Interpretation and Analysis of Test Results will be used to develop models.
- Models will be evaluated in field trials
  - Reduced mixing and compaction temperatures
    - laboratory density vs. in-place density
  - Reduction in Compactive Effort
    - Number of roller passes to achieve target density
  - Mixture Performance and Durability
    - Performance Surveys will be conducted to evaluate predicted vs. actual distress
- Will be coordinated with NCHRP 9-47

Thank you

ajhanz@wisc.edu

Focus

Asphalt Research Consortium

The Consortium will systematically develop and evaluate:

•*appropriate tests, procedures, and guidelines for extending the life cycle and improving the overall performance of asphalt pavements;*

•*develop new models or advance existing models that capture pavement performance;*

•*work cooperatively with other Federal research activities to minimize duplication;*

•*to optimize the overall research effort; and disseminate knowledge learned*