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Estimating the effect of warm mix additives on workability of asphalt mixtures

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Two Main Objectives

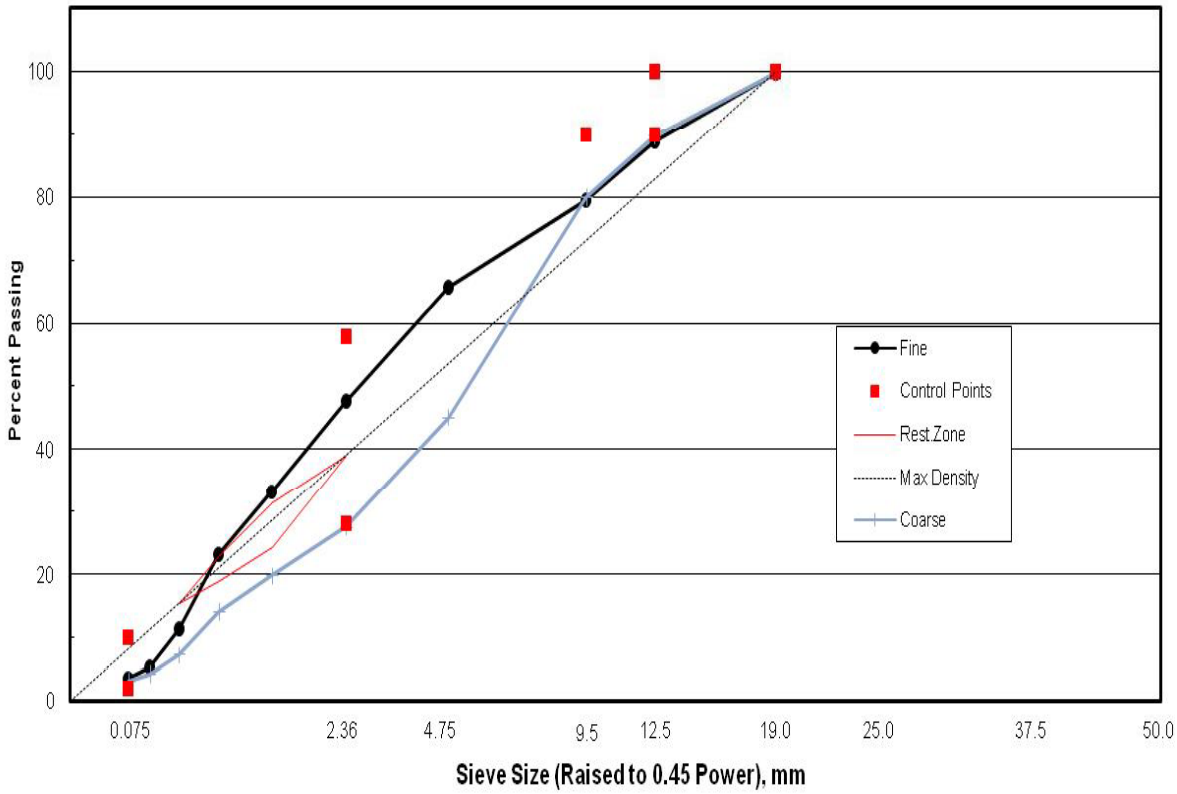
- Evaluate claims about how Warm Mix Additives (WMA) work.
  - Reducing viscosity
  - Micro-foaming
  - Lubrication
- Determine how much is needed.
  - WMA content versus temperature reduction
  - ***Cost is based on content, justify use by saving heat energy***

Experimental Design - Materials

- Five Warm Mix Additives:
  - Two surfactants: Revix and Rediset,
  - One wax additive (Sasobit), and
  - Two foaming processes.
- Two base binders:
  - Unmodified PG64-22 and
  - SBS modified PG 76-22
- Two Mixture Gradations: Fine and Coarse

Aggregates and Mixtures

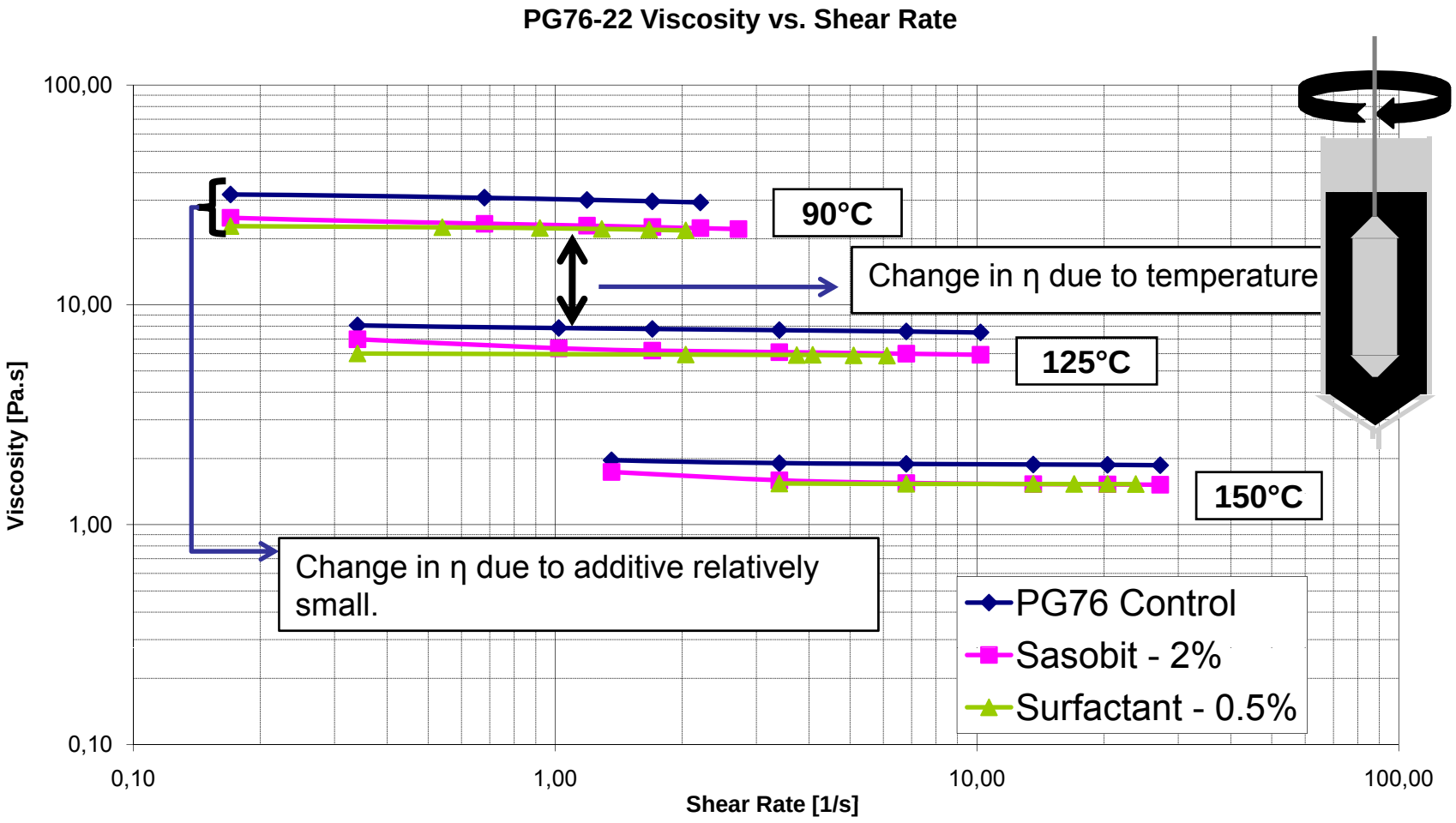
- Mixture testing
  - Fine and Coarse graded mixes
  - 10 million ESAL, mix design
    - (N_{des} =100)
  - Granite aggregate source



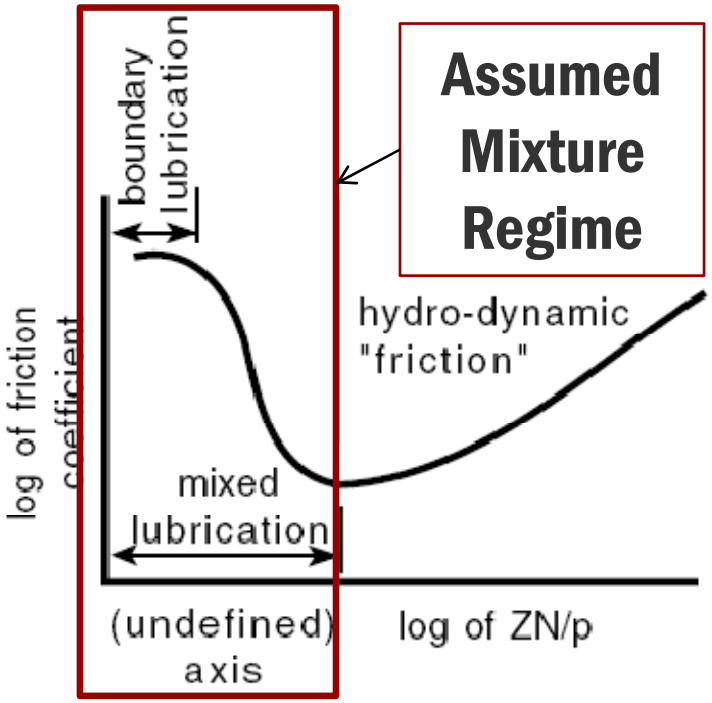
Experimental Plan - Testing

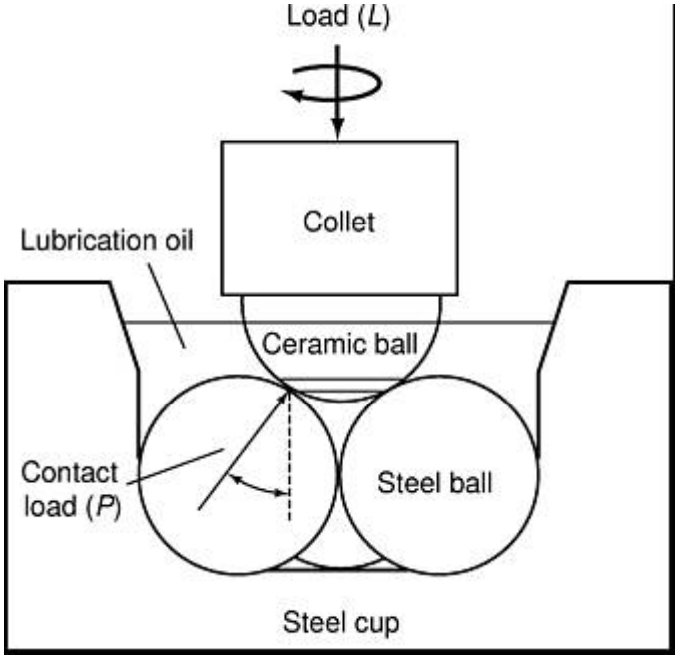
- **Binder** Workability:
  - Asphalt Binder **Viscosity – Rotational Viscometer**
  - Asphalt Binder **Lubricity – New DSR test**
- **Mixture** Workability:
  - Aggregate **Coating: Percent Coated**
  - Gyratory **Compaction Indices**:
    - > Construction Force Index using he PDA - (CFI)
    - > Number of Gyrations to 92 % Gmm- N92

Effects on Viscosity – PG76-22



Asphalt Lubricity Test – Based on ASTM D5138-05 for lubricants (Determination of the Coefficient of Friction of Lubricants Using the Four Ball Wear Test Machine)





Friction as a function of viscosity (Z), pressure (P), and speed (N).

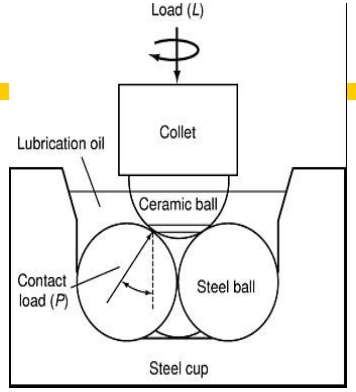
Measurement Tool

Asphalt Lubricity Test:
- Photo of new fixture for DSR

Tip of Rotating Chuck

Entire Assembly (no clamping)

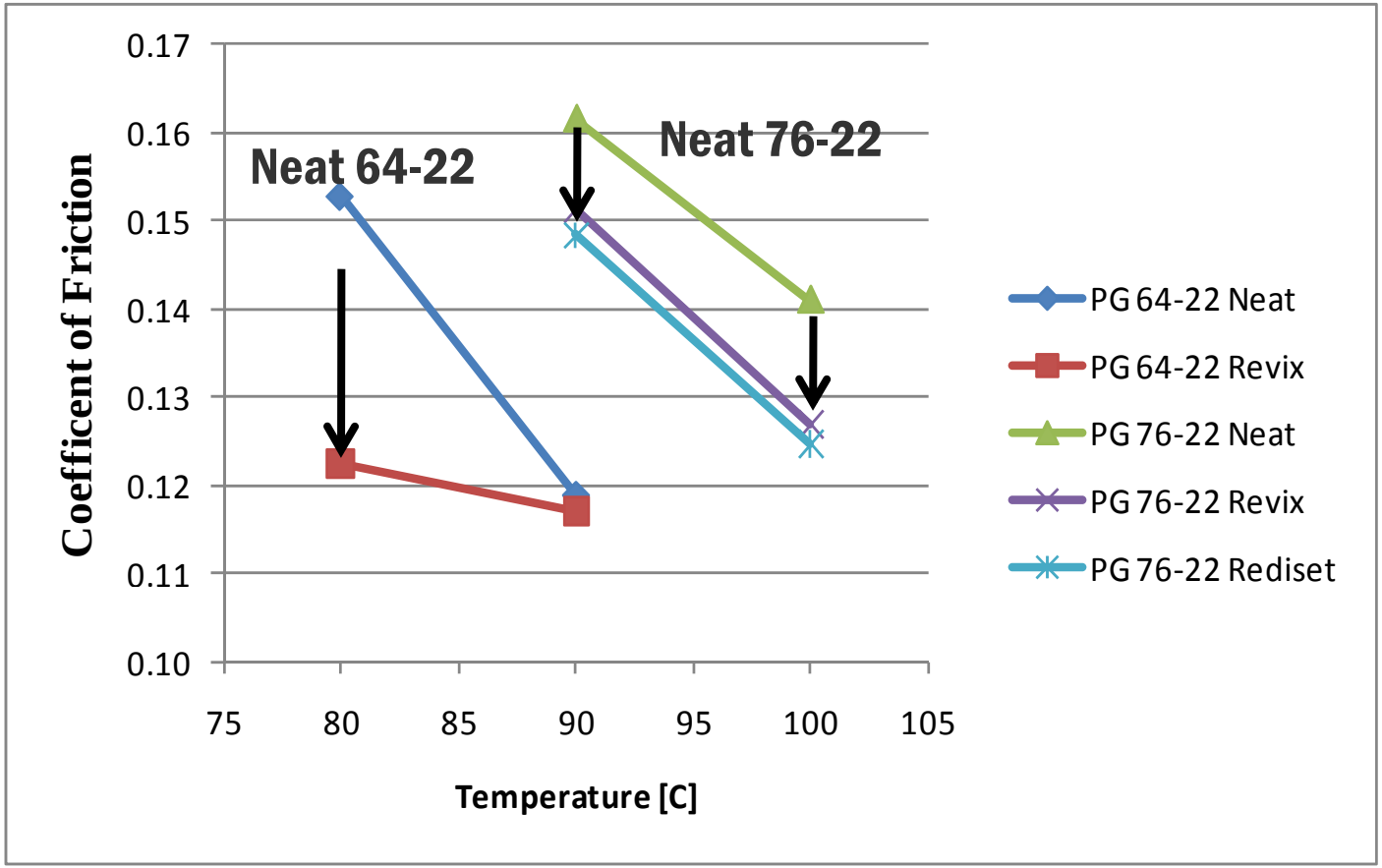
Clamped Ball Assembly



Coefficient of Internal Friction

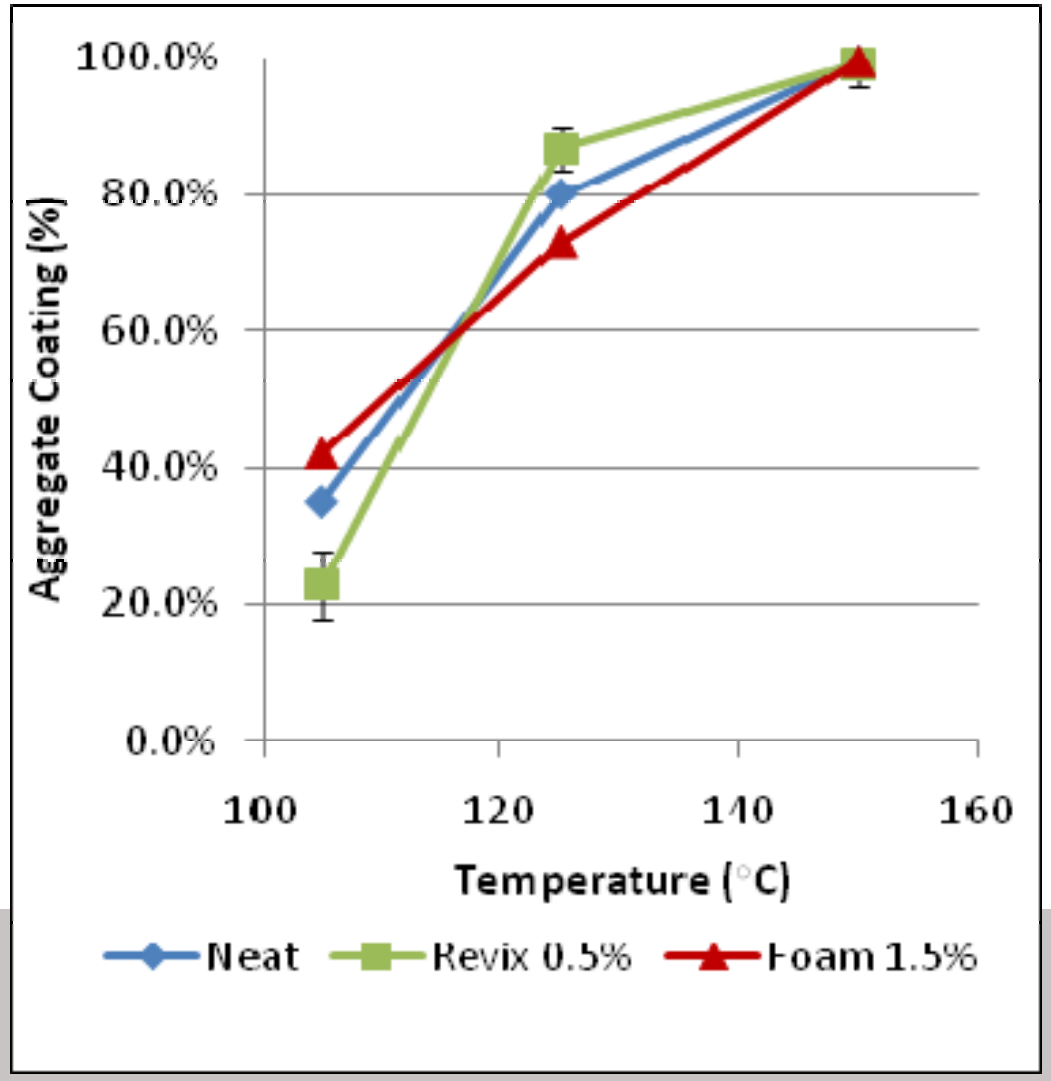
$$\mu = C \times \frac{T}{P \times d}$$

Effects on Asphalt Lubricity – Initial Results

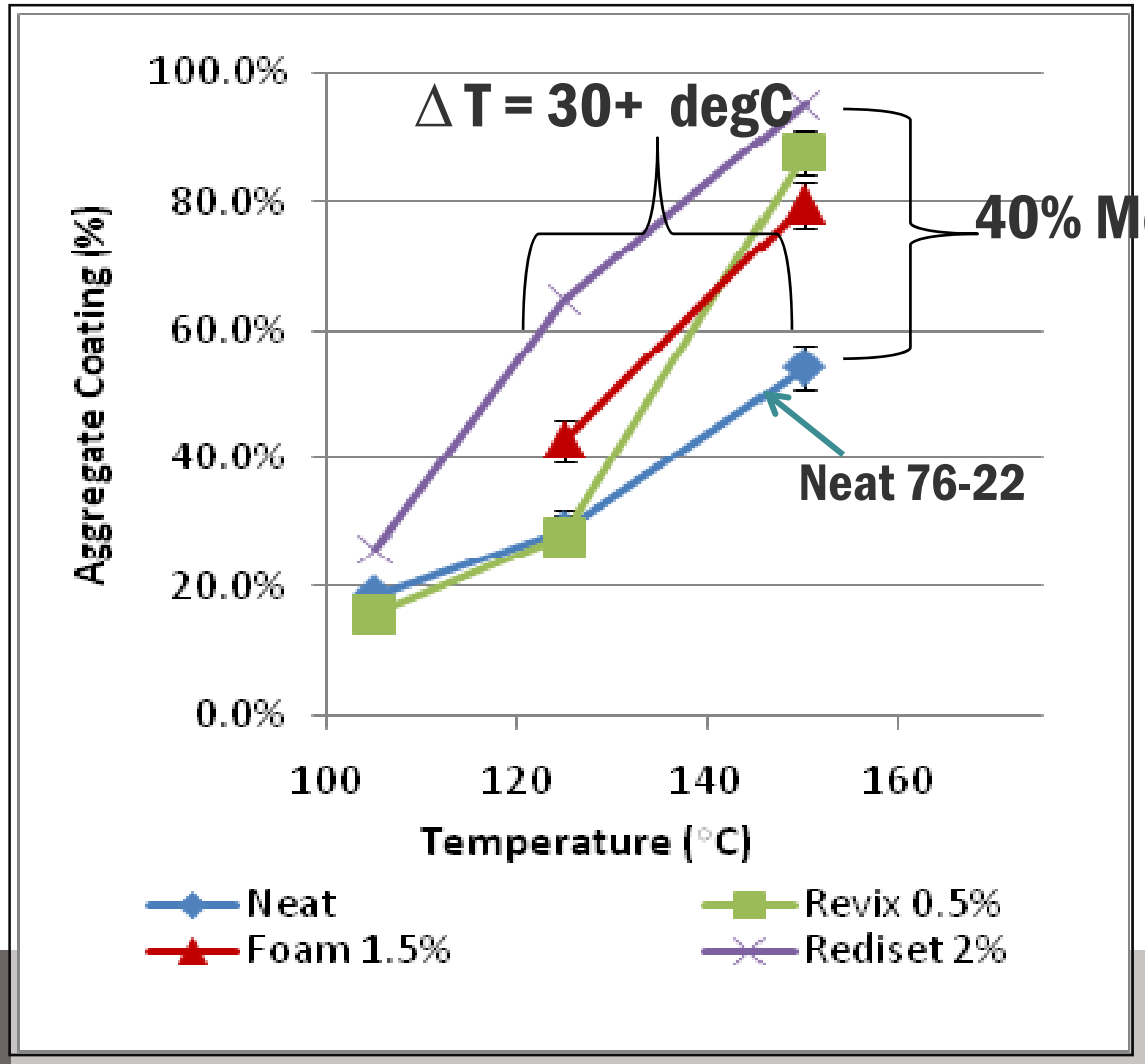


Aggregate Coating (coarse mix) (the AASHTO T195 procedure)

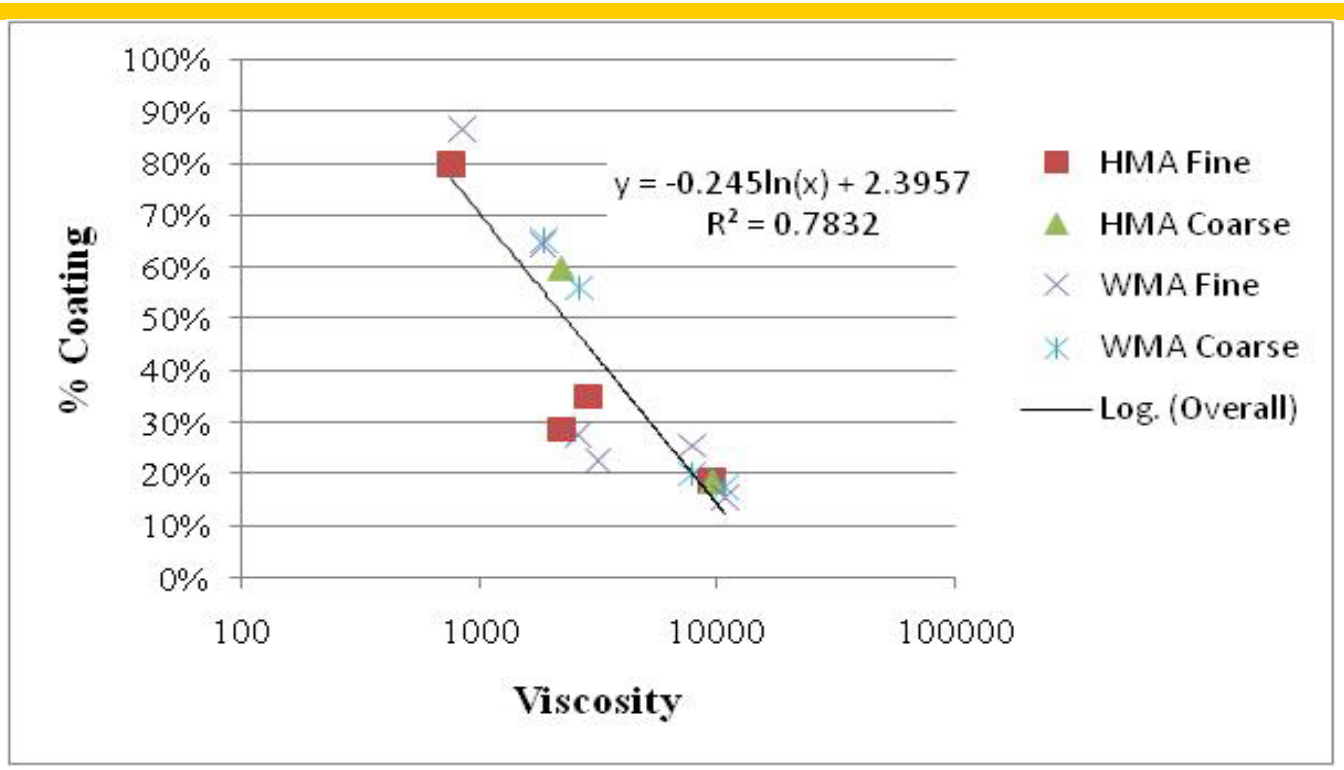
- PG 64-22



Aggregate Coating (fine gradation)



Coating of Aggregates as a function of Binder Viscosity

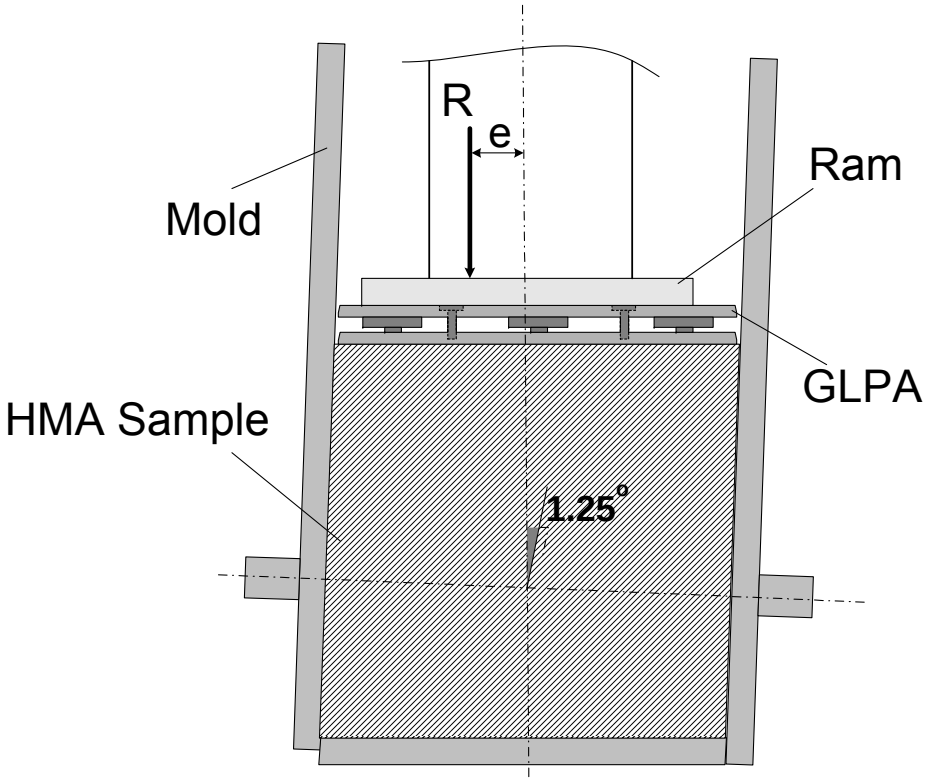


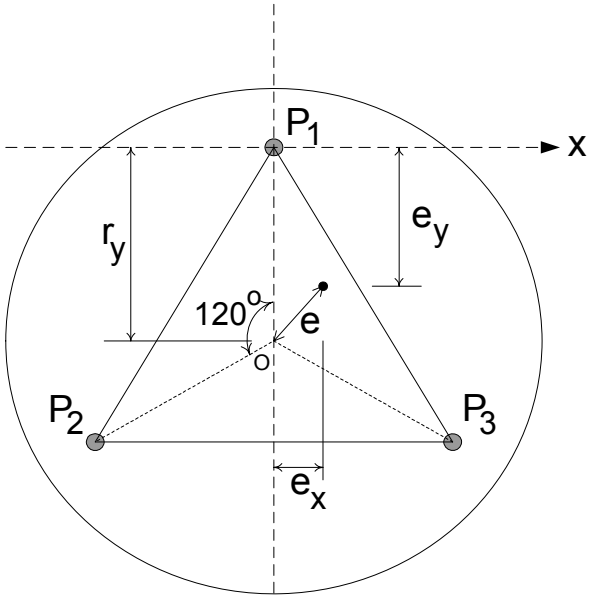
Viscosity Required for 95% Coating ~ = 350 cPs

(This is for 90 secs (1.5 min) mixing)

Use of the Gyratory Compactor with the PDA to Measure Resistance to Compaction

Use of the Pressure Distribution Analyzer to Calculate Resistance to Densificatuon





$$R = P_1 + P_2 + P_3$$

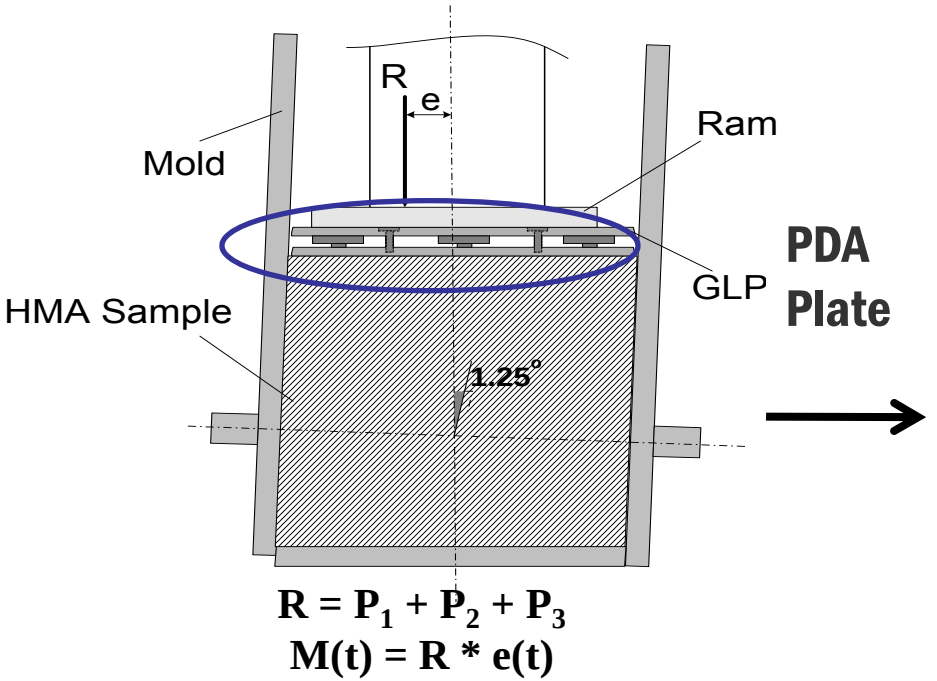
$$M(t) = R * e(t)$$

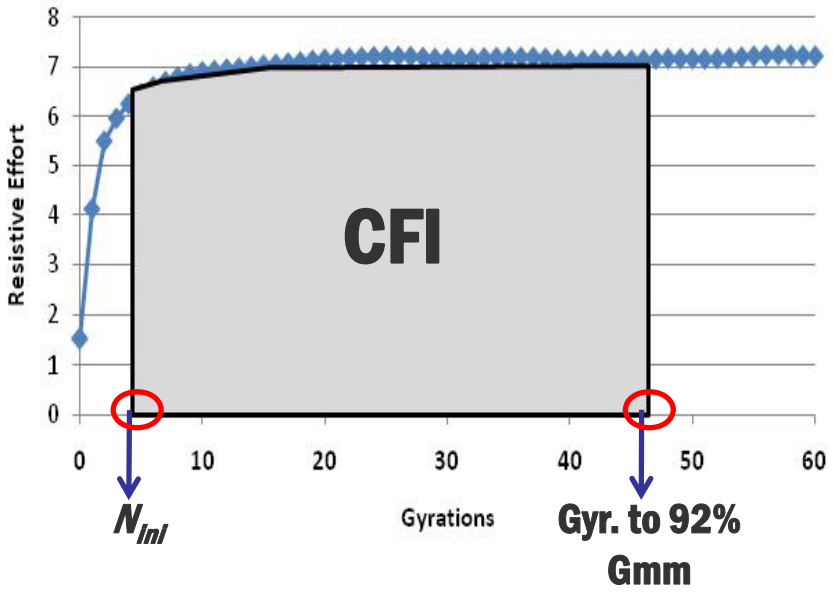
$$\sum M_x = 0 \Rightarrow e_y$$

$$\sum M_y = 0 \Rightarrow e_x$$

$$e = \sqrt{e_x^{\,2} + (r_y - e_y)^2}$$

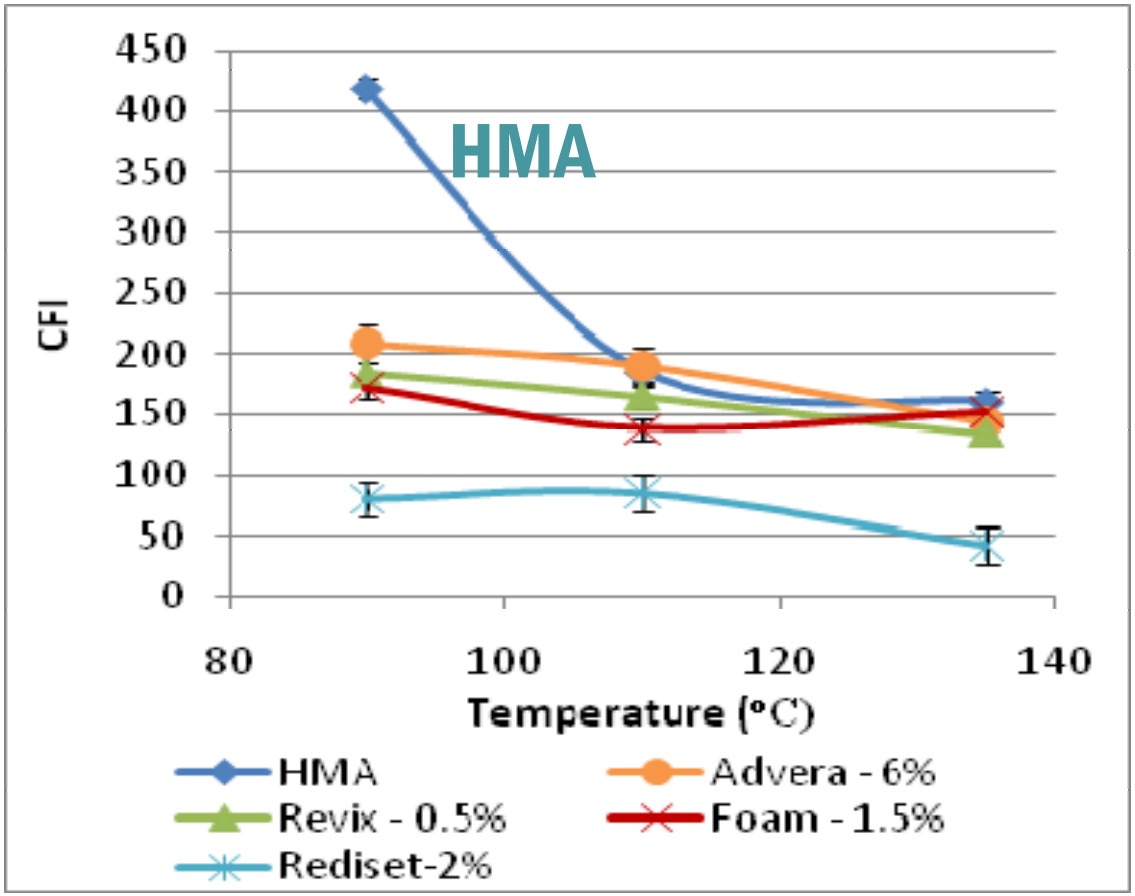
Mixture Compaction- Densification Measured in Gyartory + PDA





- Pressure Distribution Analyzer (PDA) allow for
  - Calculating resistive forces in the mix during compaction (*w*)
  - Construction Force Index (CFI) : area under the Resistive Force (*w*) vs. Gyration curve

Effects of WMAs on CFI (Mixture Workability)



- Major WMA effects are measured only below 100°C for foaming and Revix.
- Rediset (2% by wt. of binder) shows higher effects at all temperatures.

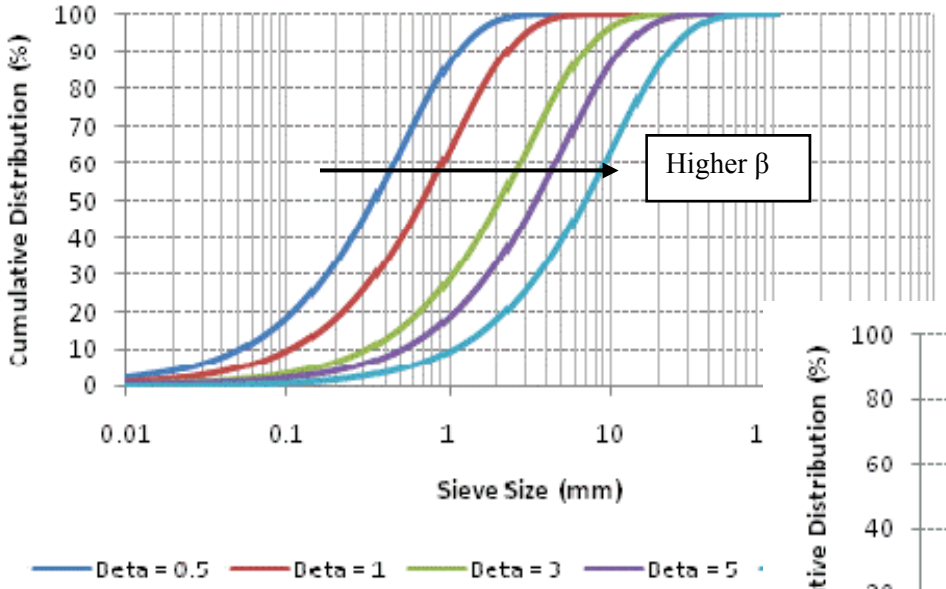
Regression Results (Compaction Force Index)

- Regression Analysis: CFI = F(Coef Fric, Visc, Bet a)

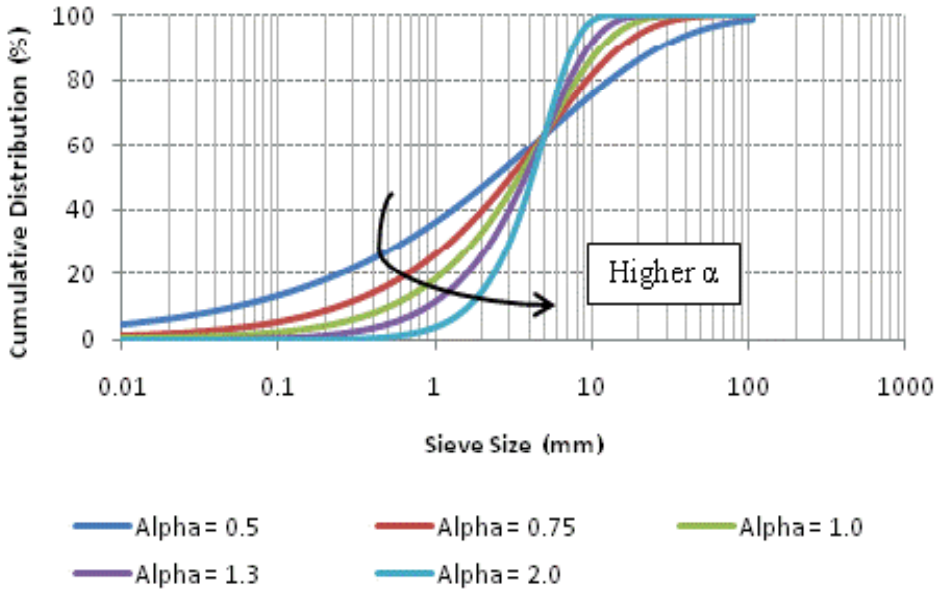
- CFI = - 945 + 4274 Coef Fric + 0.00226 Visc + 127 Beta

Predictor	Coef	SE Coef	T	P	
Constant	-945.3	266.4	-3.55	0.003	
Coef Fric	4274	2012	2.12	0.050	Binder Lubricity
Visc	0.002264	0.008923	0.25	0.803	
Bet a	127.45	18.77	6.79	0.000	Agg. Gradation

Gradation Analysis and Modeling

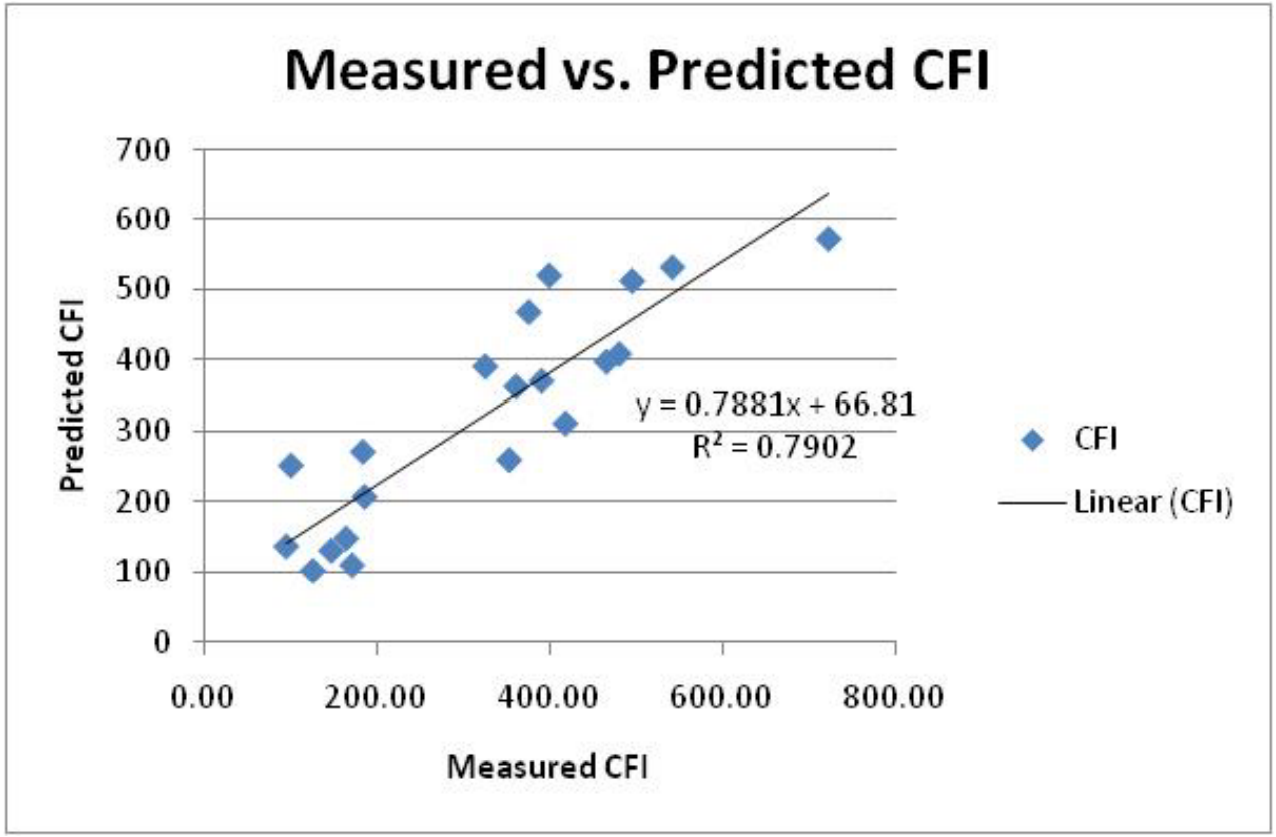


$$F(x, \alpha, \beta) = 1 - e^{-\left(x/\beta\right)^{\alpha}}$$



Weibull distribution

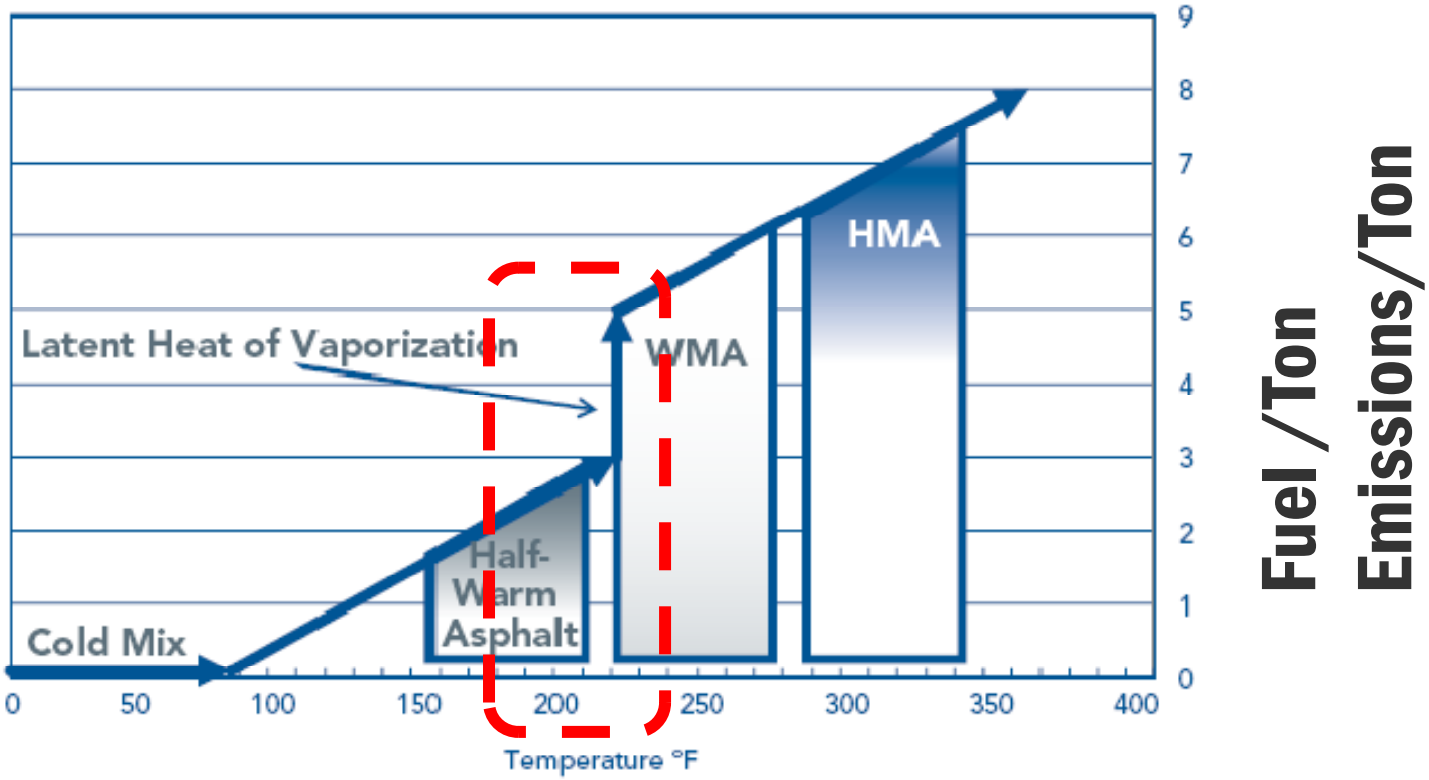
Regression Results (CFI)



Interim Findings

- Warm Mix Additives affect coating and compaction.
  - Minor reduction in viscosity
  - Important effects on lubricity (Internal resistance to flow)
- Main effects are at lower temperatures (Below 100 C).
- Cost need to be justified by energy savings or environmental impact.

Warm Mix Additives Effective Range

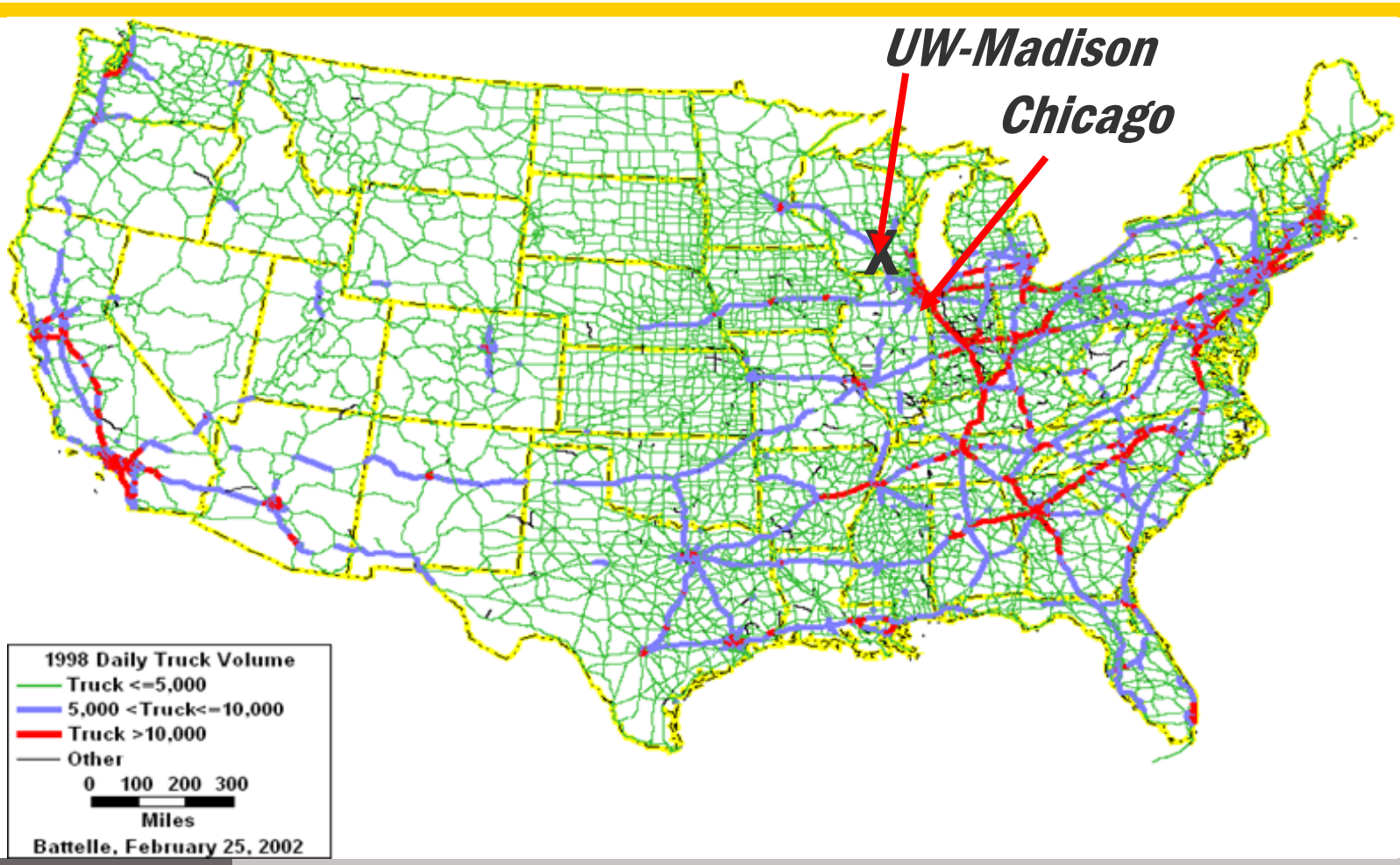


Source: FHWA

Acknowledgments

- Organizing Committee
  - Professor Soares and Sponsors
- Federal Highway Administration
- Western Research Institute
- Suppliers of additives

Thank you for attending



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