MARC MODIFIED ASPHALT RESEARCH CENTER

Using the Gyratory Pressure Distribution Analyzer GPDA to Estimate Compaction Resistance of HMA

Francois Malassenet and Tom Brovold
Troxler

Hussain Bahia and Andrew Hanz
University of Wisconsin - Madison

Background

- **Best mixture design should include:**
  - **Volumetrics and resistance to compaction for production, and**
  - **performance testing for traffic/climate**
- **Difficulty:**
  - **No current system for compaction resistance**
  - **Performance testing requires more equipment and time.**
- ***Can the SGC be used to address both?***
  - **Compactive Effort - *Workability***
  - **Aggregate Interlock - *Stability***

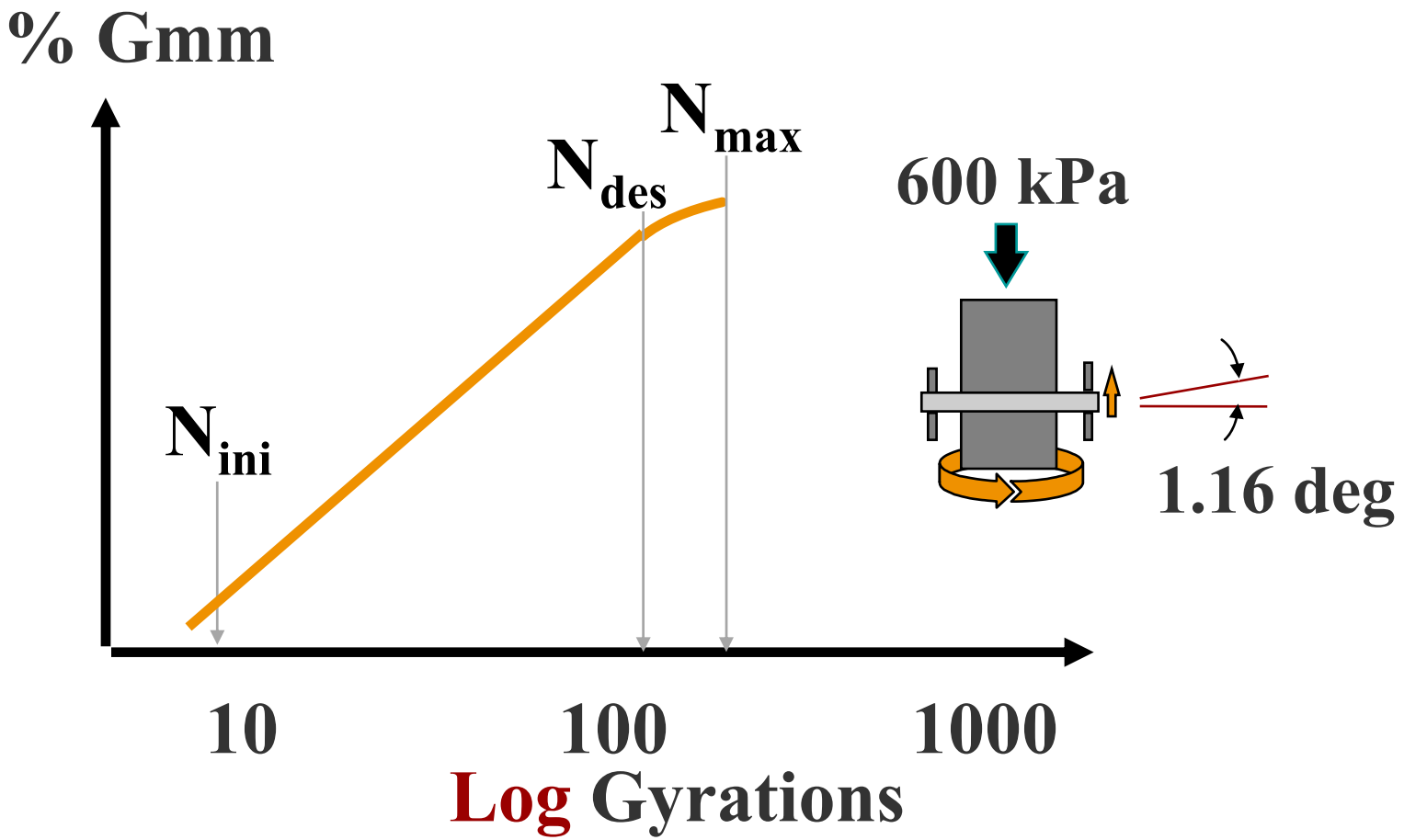
History of Using The Gyratory To estimate shear resistance

- **McRae** – Gyratory Testing Machine
  - 1960's and 1970's
- **Goetz, Ruth, and others** recommended using GTM for mix design to measure stability
  - 1980's and 1990's
- **France, Australia, and Finland** have used the Gyratory for mixture evaluation
  - 1980's and 1990's
- *In 1993 the **Superpave Gyratory Compactor** was adopted in the U.S.*

Better Utilization of SGC Since 1996-Not a new topic !

- **1996**: Use **densification slope**
  - Relationship to Mixture G*
- **1998**: Use **densification curves** to define
  - Resistance to compaction
  - Resistance to traffic
- **2000**: Use gyratory with **GLPA to measure shear** between aggregates
  - Resistance to compaction & to traffic
- **2002**: NCHRP **9-16** (Anderson et al.)
  - **Gyrations at maximum stress** relate to field rutting

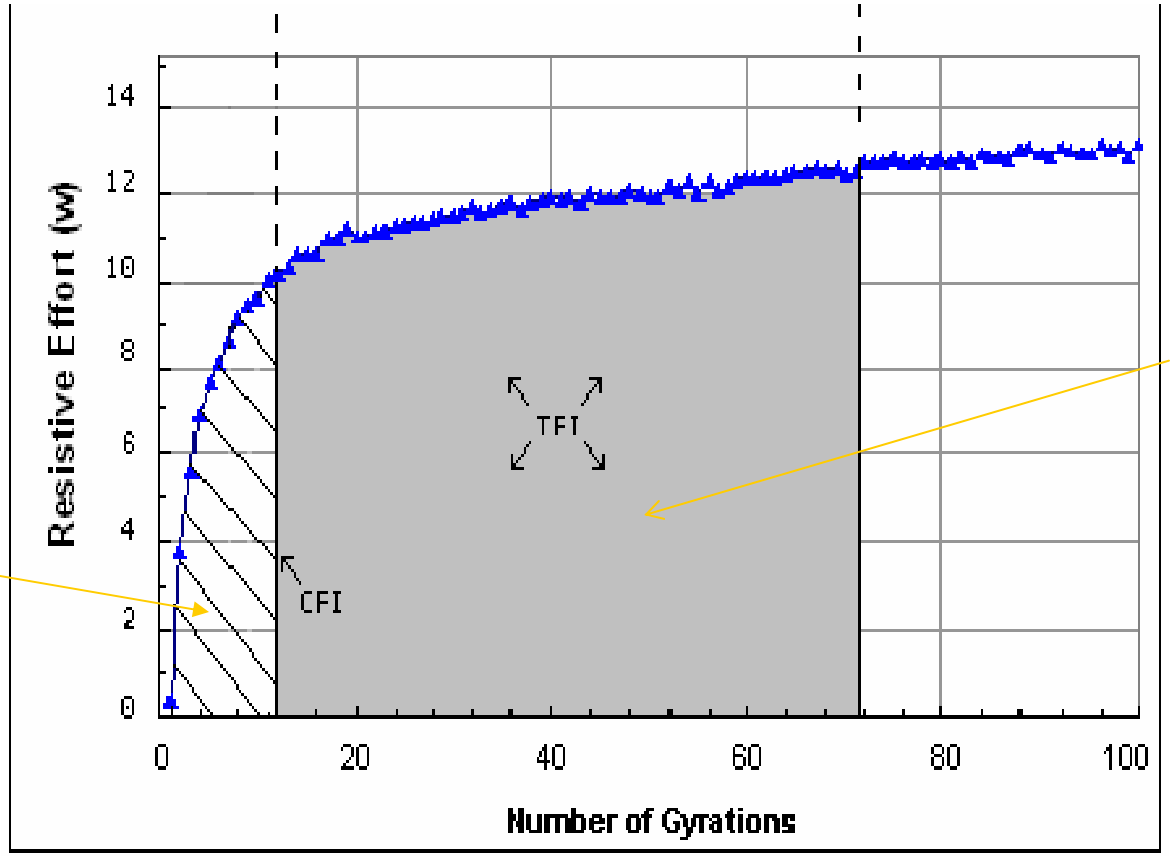
Superpave Volumetric Design Criteria



Schematic – Force Indices

Construction

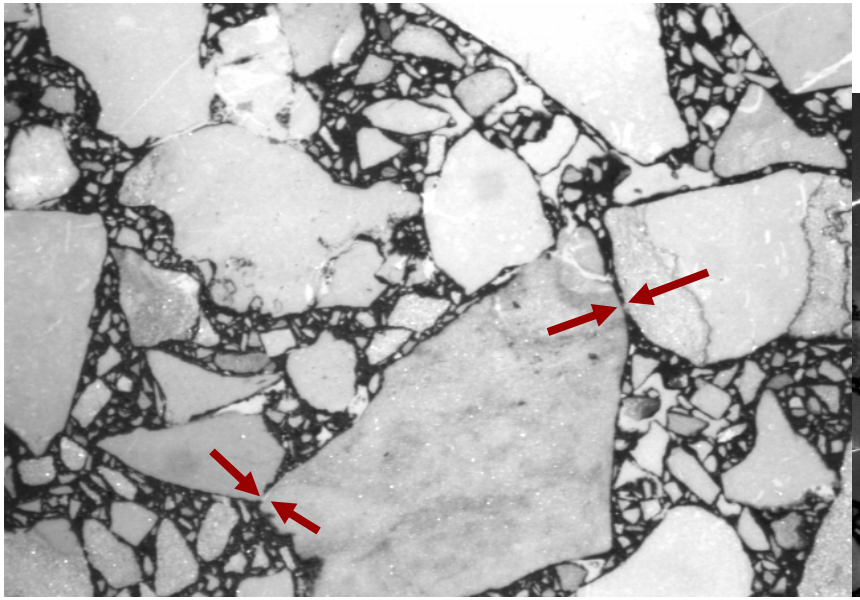
- CFI
- N_{ini} to 92% G_{mm}

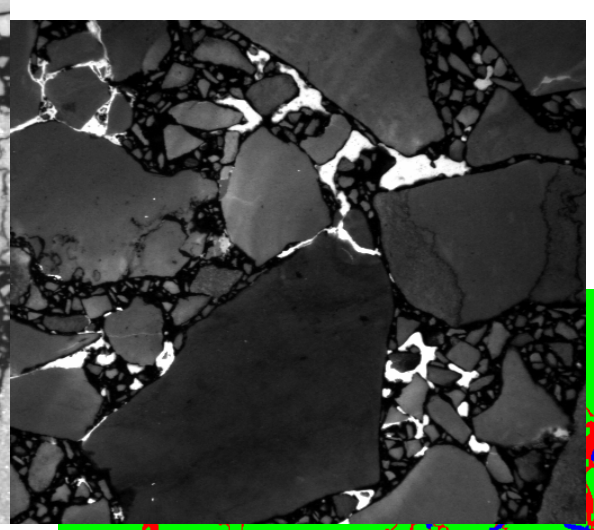


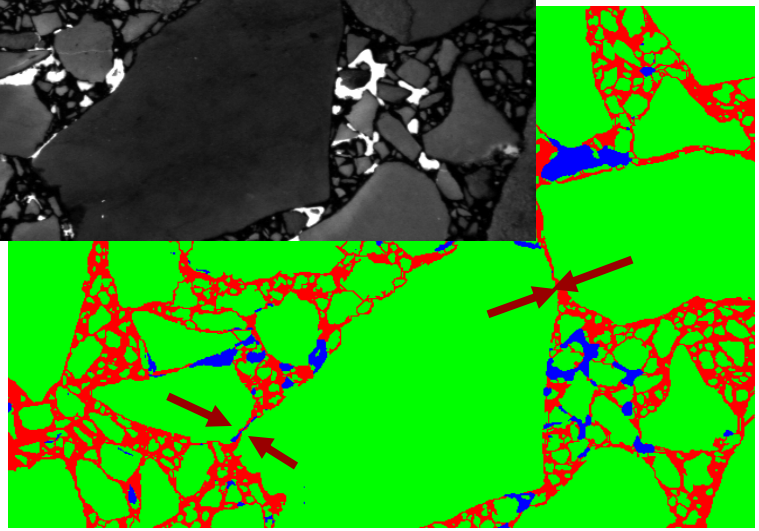
Traffic

- TFI
- 92% - 98% G_{mm}

HMA Basics:
Rocks + Asphalt + Air Voids





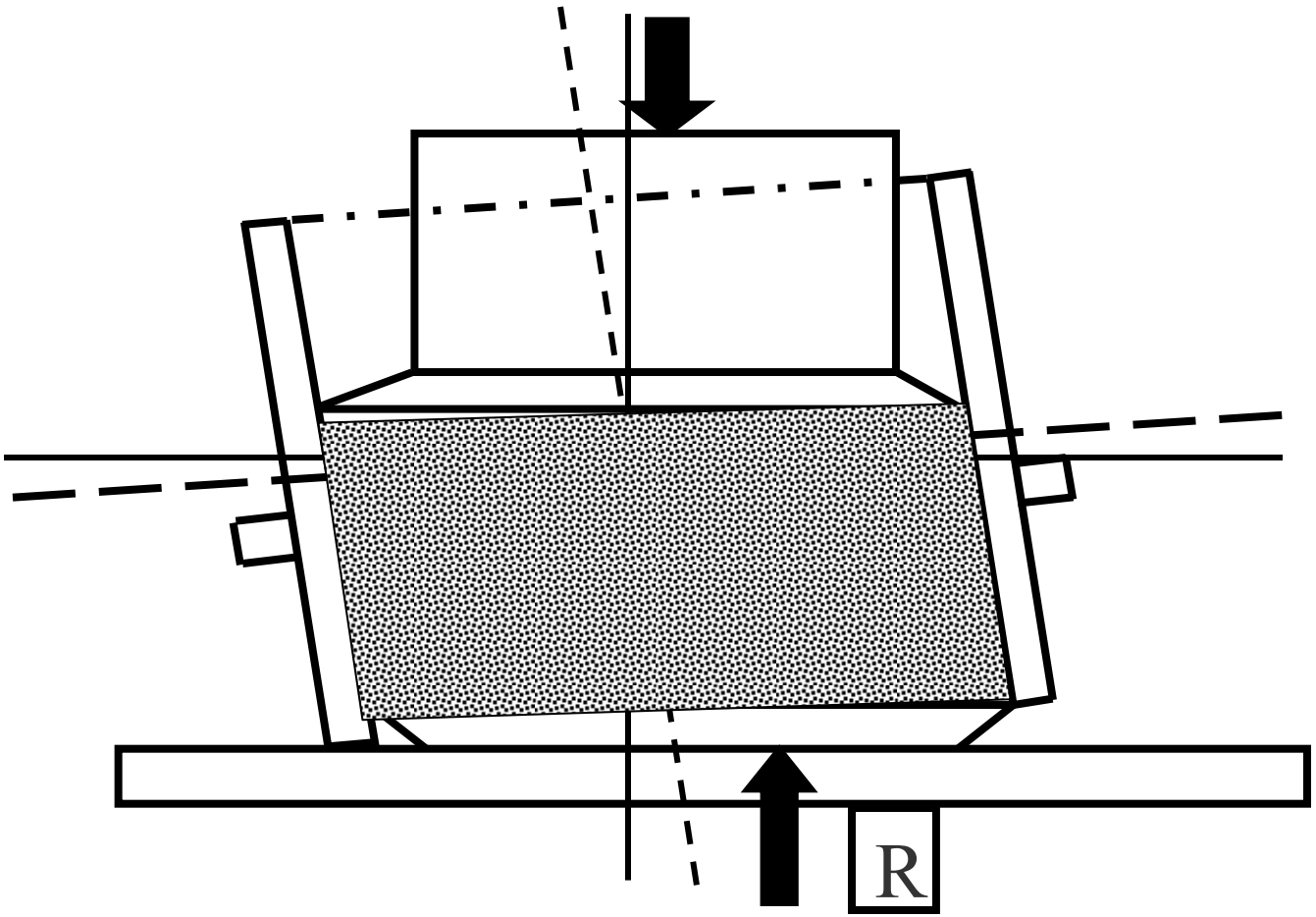


Stability of HMA:

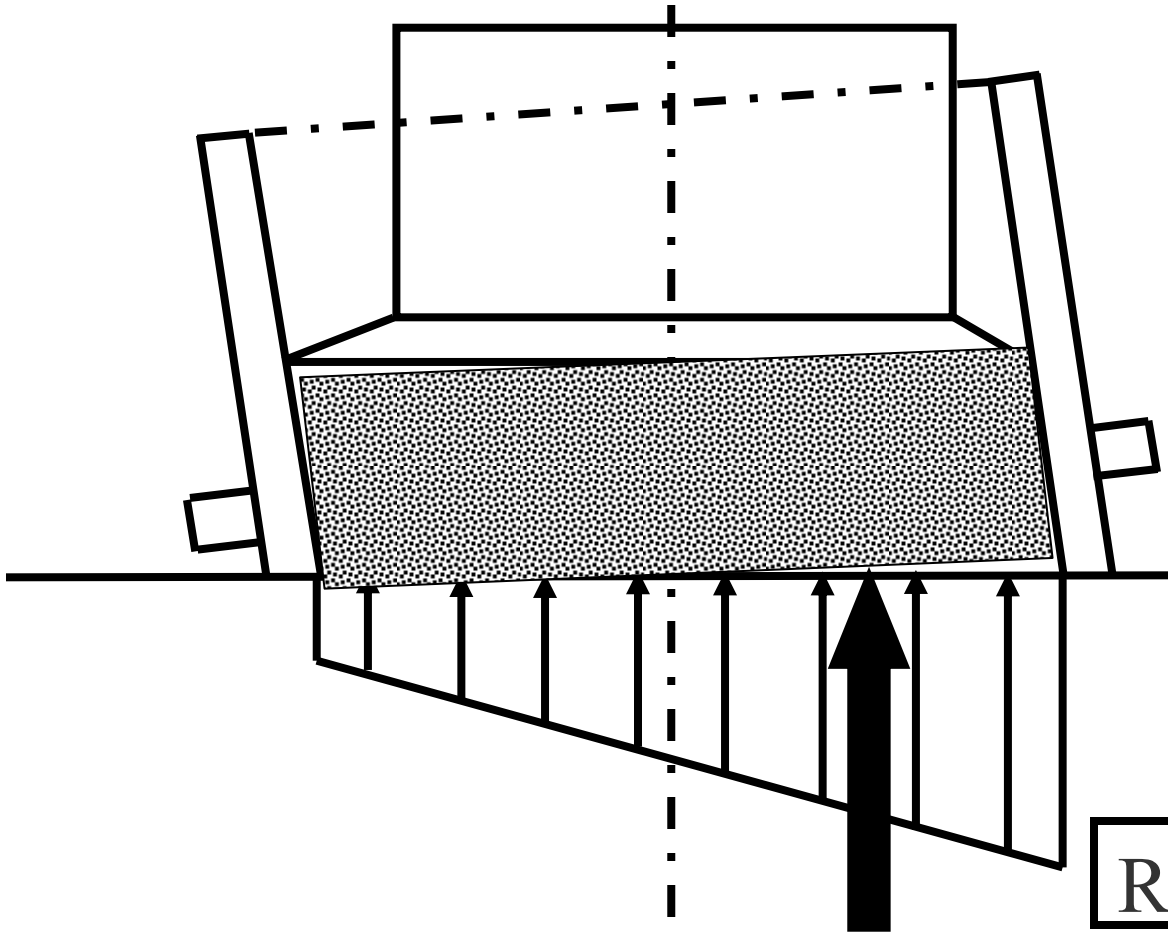
1.Rock- to – rock contacts

2.Binder rheology

What actually happens in the Superpave Gyratory Compactor?



Example 1: Behavior of a "Good Mix"

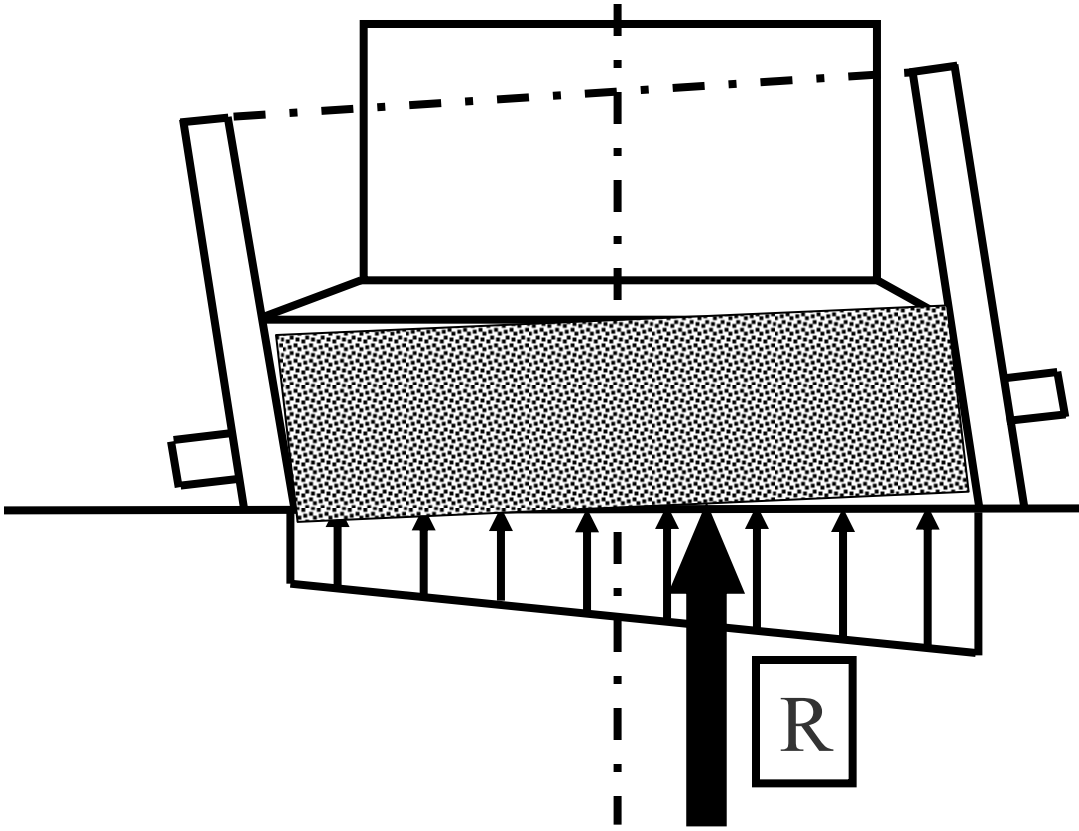


Mix A

Strong aggregate interlock

Large Moment

Example 2: Behavior of a "Bad Mix"

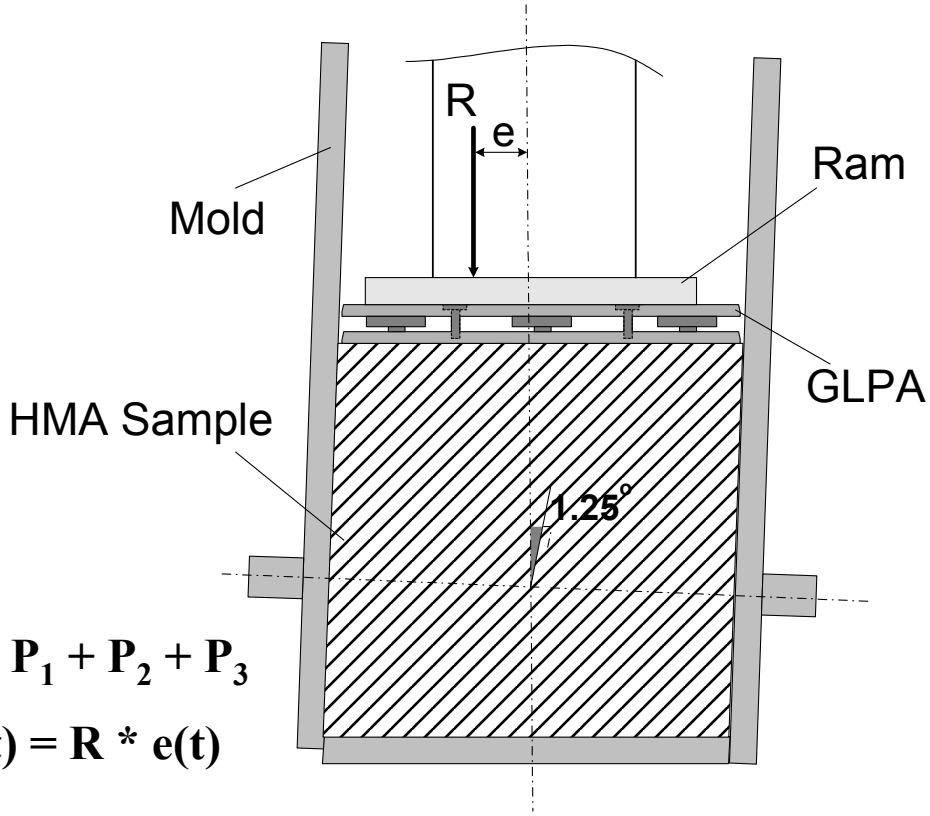


Mix B

Less aggregate interlock

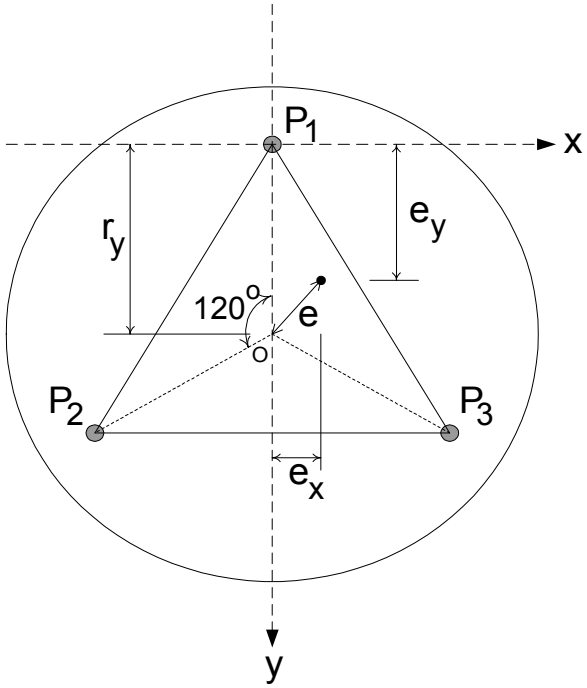
Small Moment

Use of the Shear Plate (GPDA) to Calculate Eccentricity of load



$$R = P_1 + P_2 + P_3$$

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



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

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

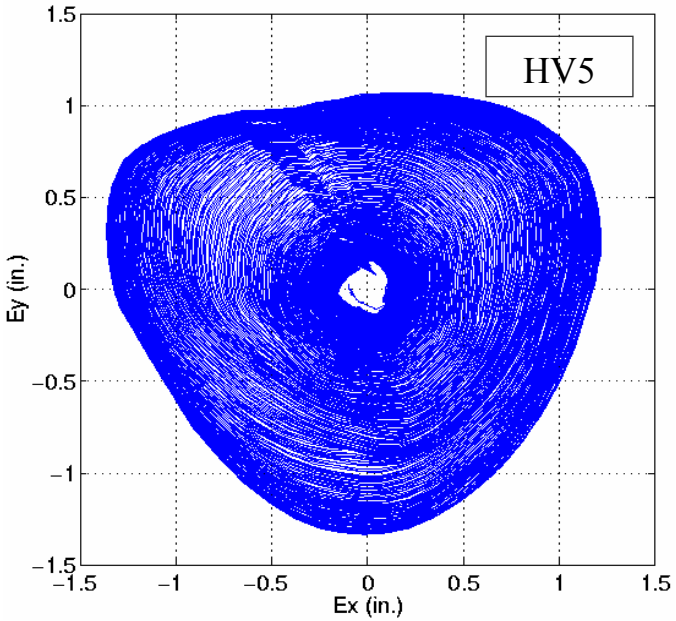
$$e = \sqrt{e_x^{\,2} + (r_y - e_y)^2}$$

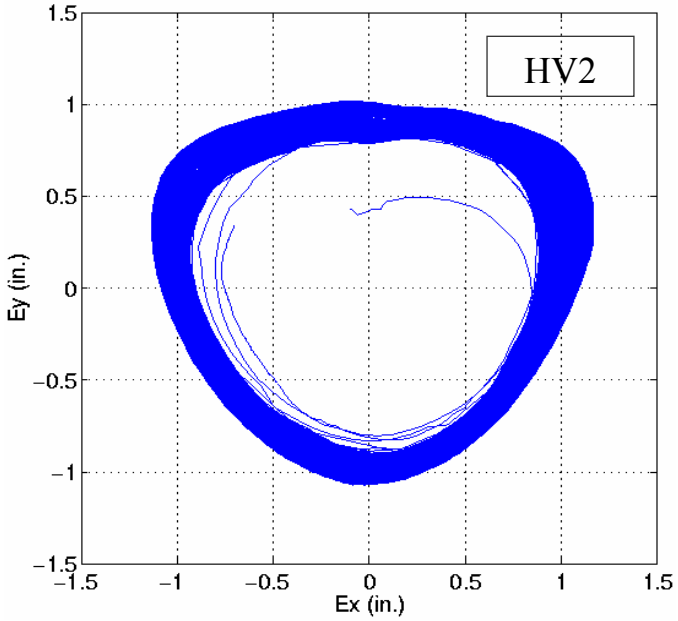
The Pressure Distribution Analyzer

GPDA Used in the SGC Compaction Mold

Sample of Collected Data and Typical Analysis

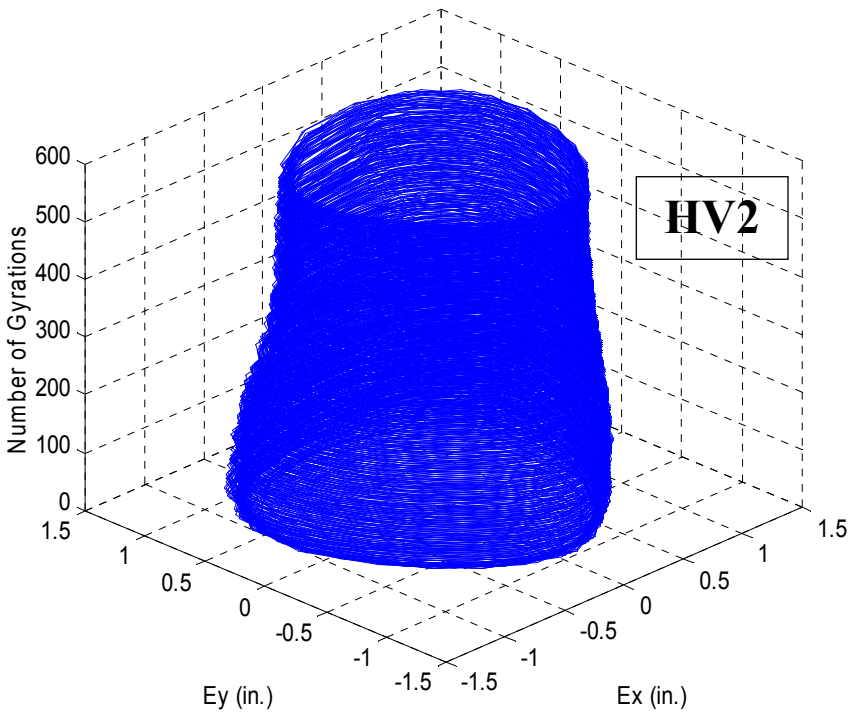
2D Eccentricity plots for HV2 and HV5 samples at 6.5 % asphalt content

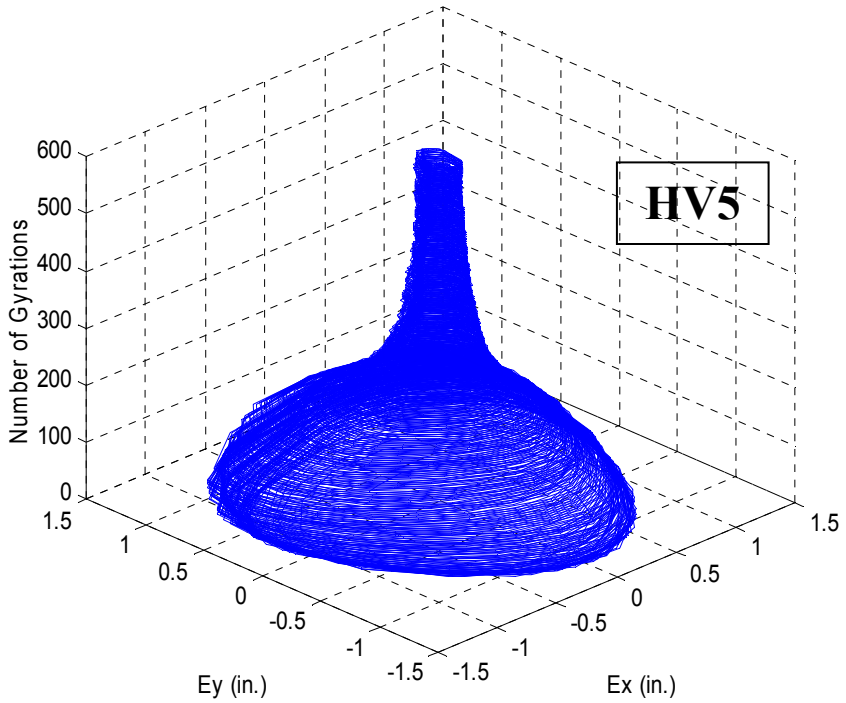




Sample of Collected Data and Typical Analysis (continued)

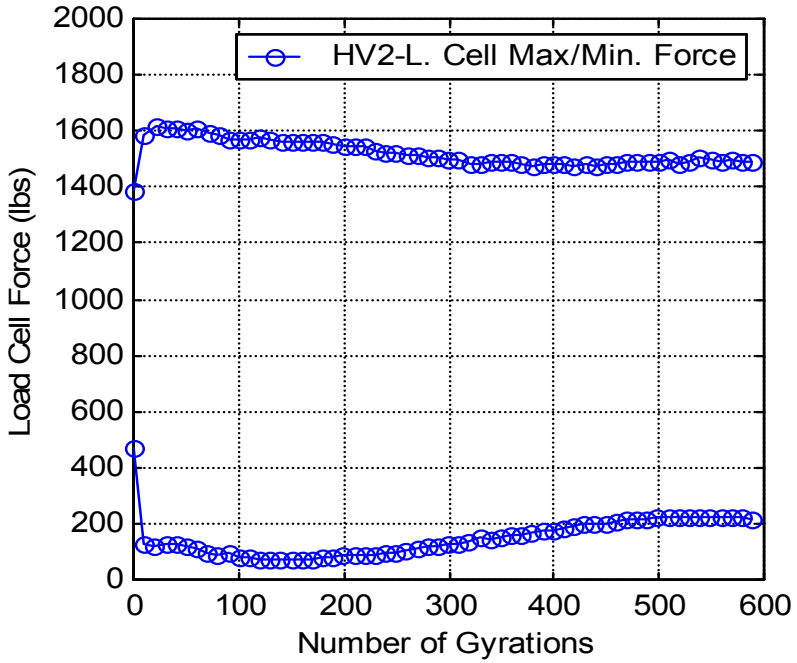
3D Plots for HV2, HV5 (at 6.5% asp. content

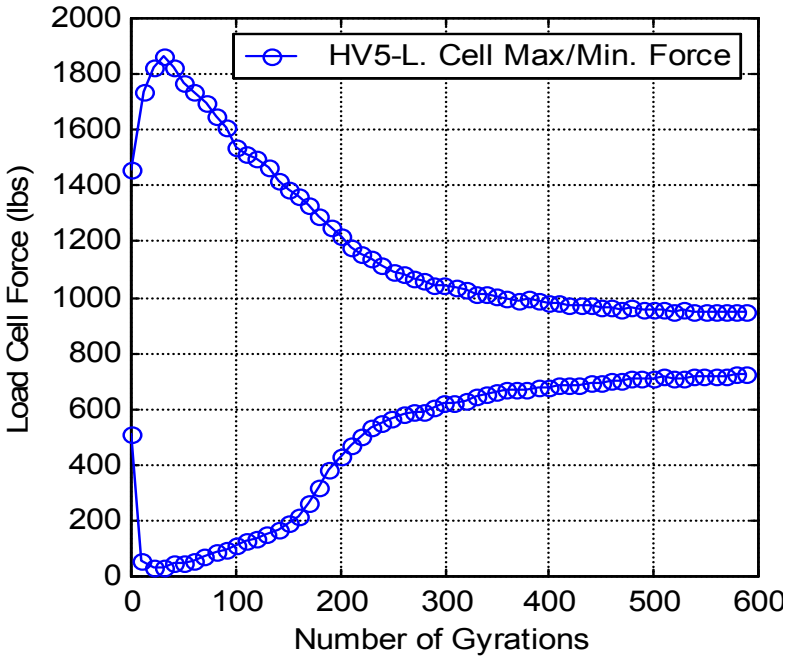




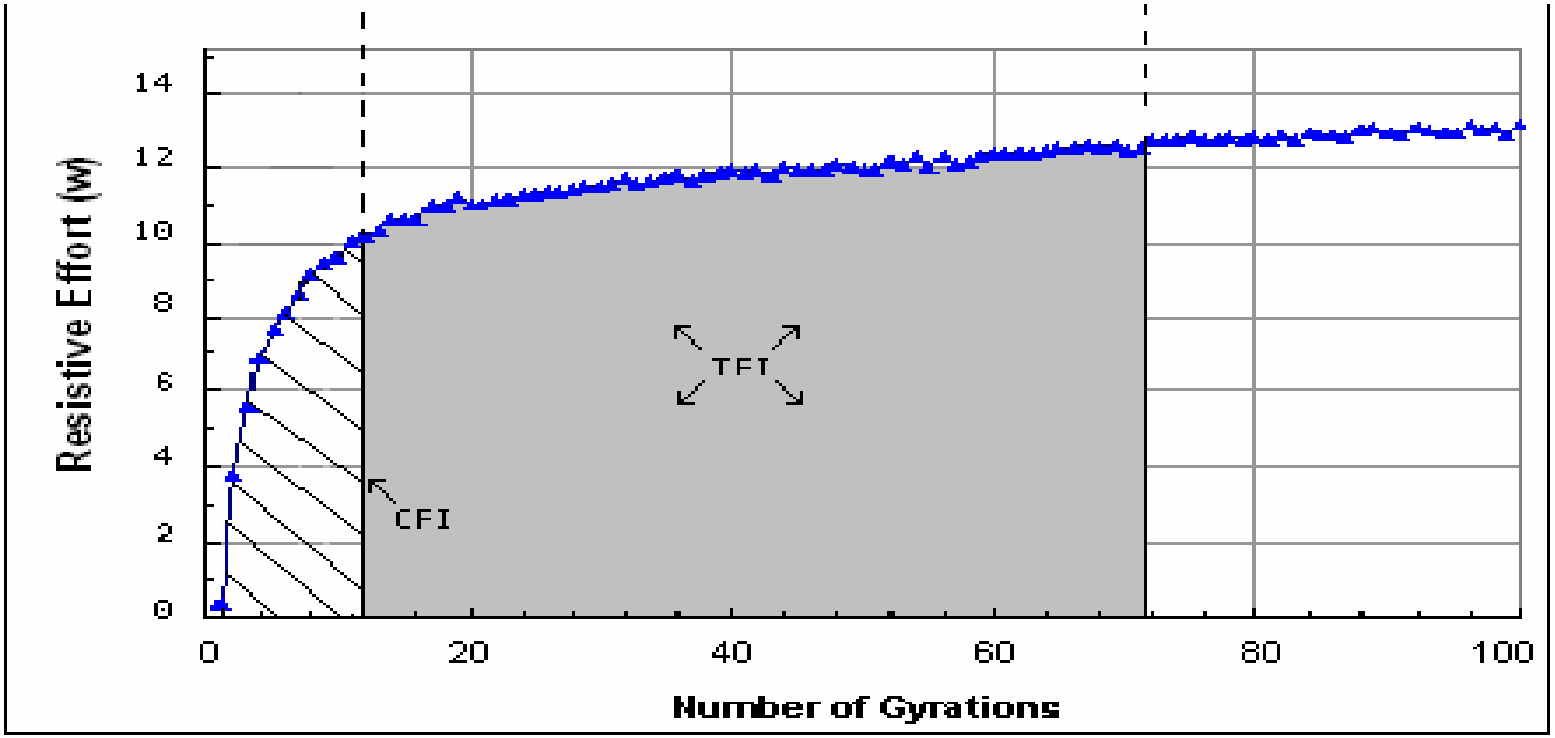
Sample of Collected Data and Typical Analysis (continued)

Load Cell force distributions versus number of gyrations for HV2 and HV5 mixtures





Sample of Collected Data and Typical Analysis (continued)



Combine force measurements and volumetrics to calculate workability and stability indices.

The Resistive Effort (ω)

$$w = \frac{4eP\theta}{Ah}$$

- Where
  - w: the resistive effort (kPa)
  - e: the eccentricity of resultant force (m)
  - P: the magnitude of resultant force (kN)
  - θ: the angle of tilting (1.16°)
  - A: the area of specimen (m^2)
  - h: the height of specimen at any given gyration (m)

Stress Analysis: Masad et al

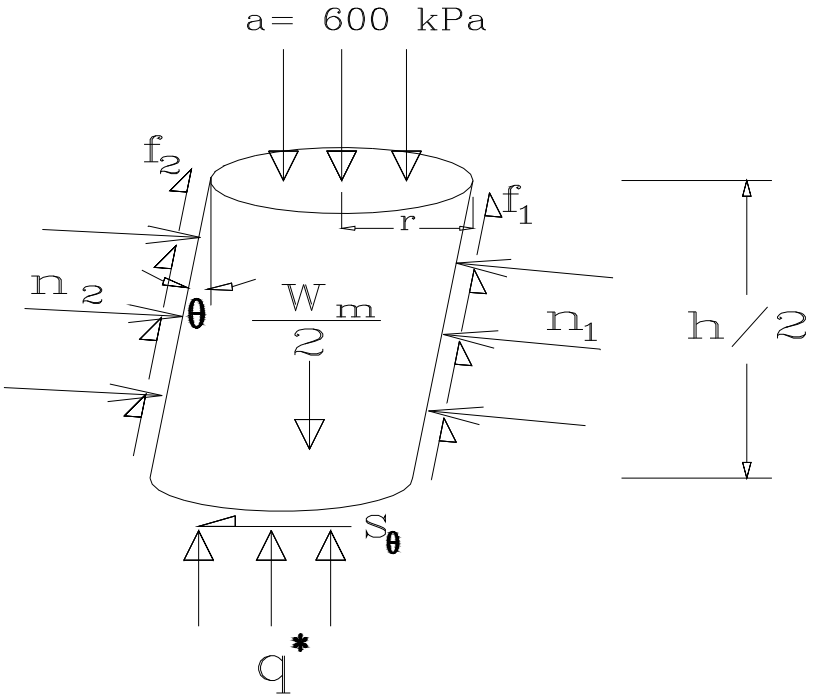
$$S_\theta = (N_2 - N_1)\cos\theta + \frac{1}{2}(P_{av} - W_d)\tan\theta$$

$$du = dv + ds$$

dv= volume change energy

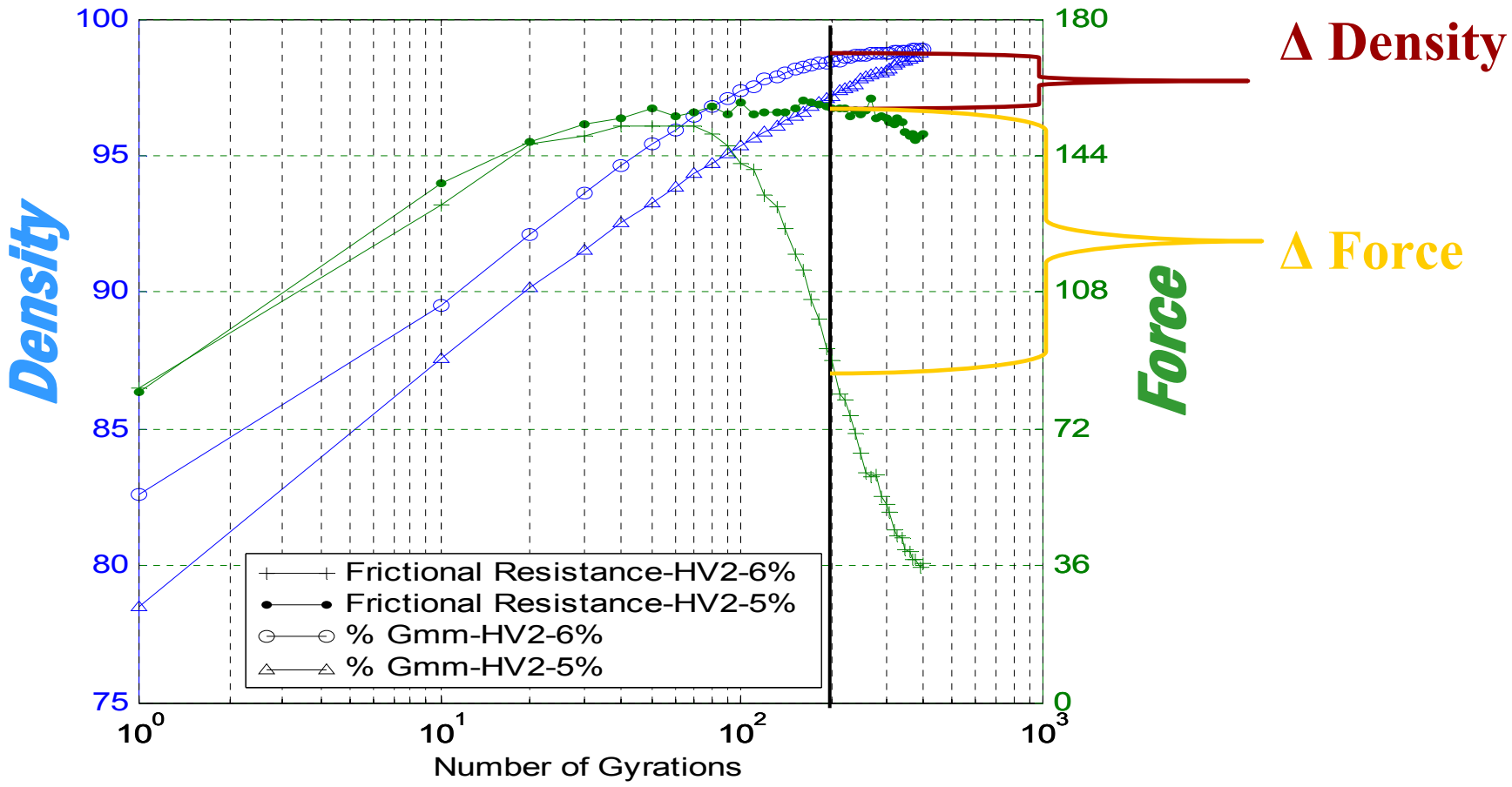
ds= shear change energy

$$CEI = \sum_{N_{G1}}^{N_{G2}} S_{N\theta} d_e$$



Masad, et al. "Quantifying Laboratory Compaction Effects on the Internal Structure of Asphalt Concrete." Transportation Research Record 1681. Transportation Research Board of the National Academies. Washington D.C., pp 179-185, 1999.

Comparing Mixes: Volumetrics vs. GPDA

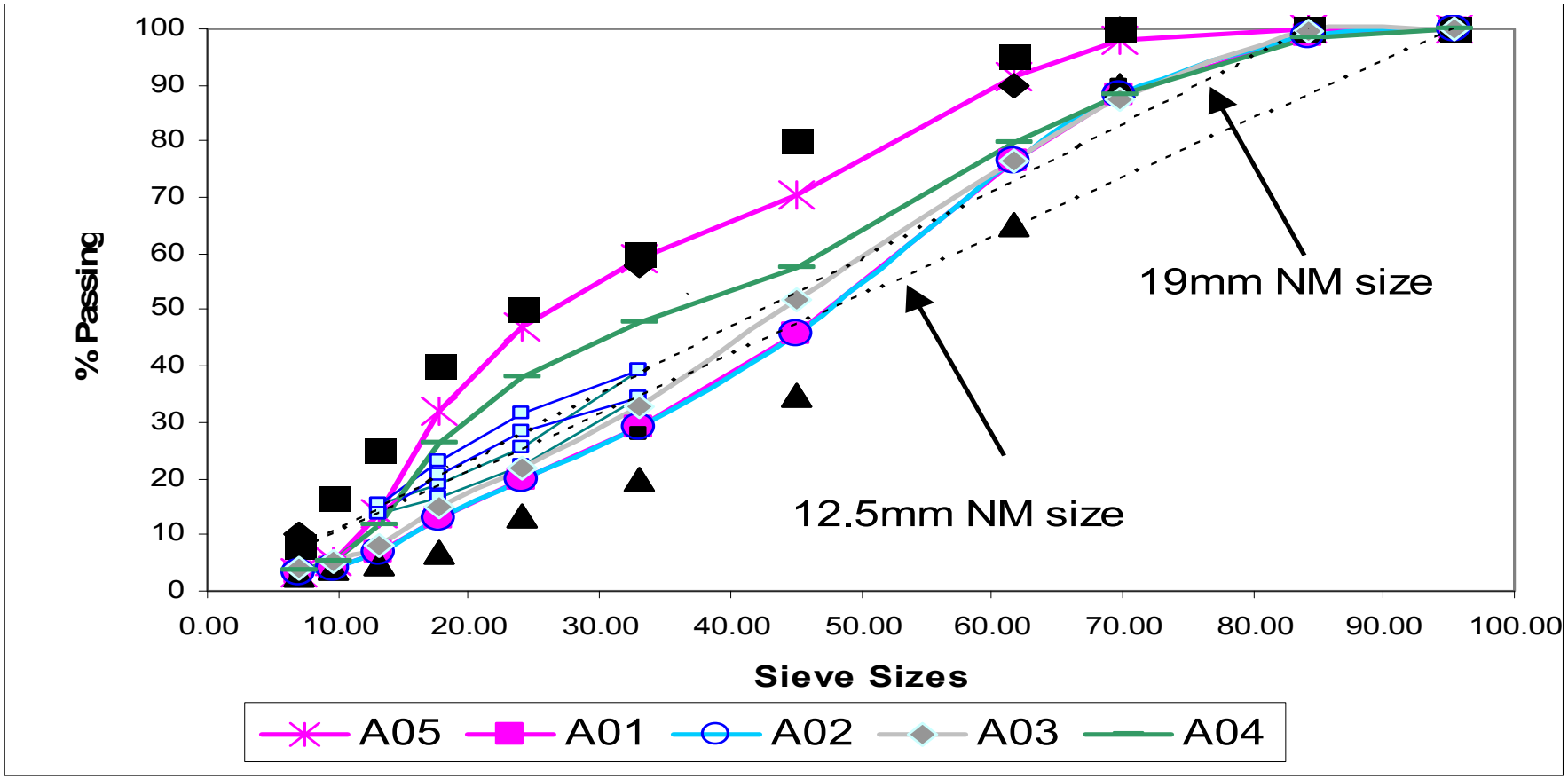


Experimental Program

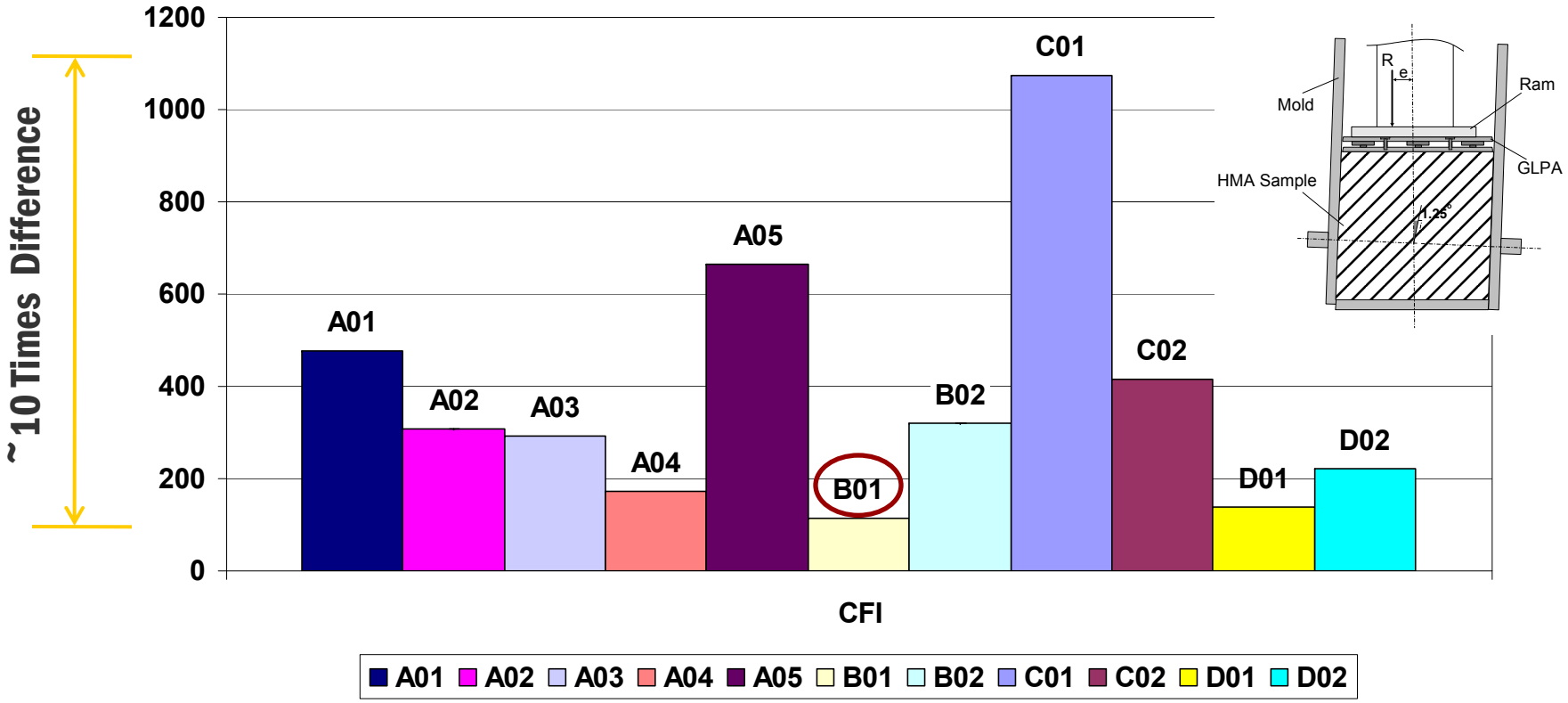
- Four sources of Aggregates
- Two gradations
- Various levels of fine aggregate angularity
- Two PG Grades

- Used PDA to collect shear data

Experimental Plan

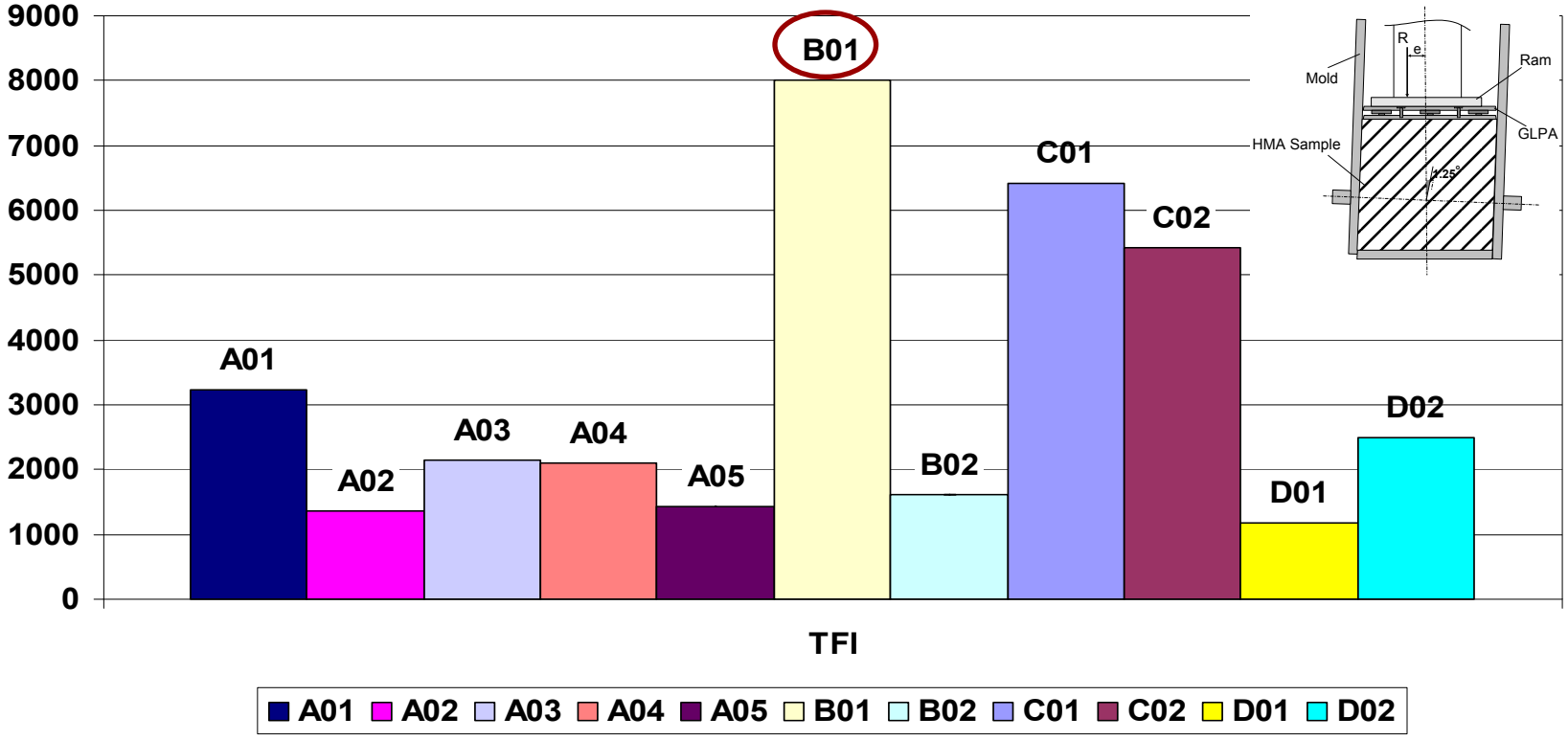


Results- Construction (CFI)



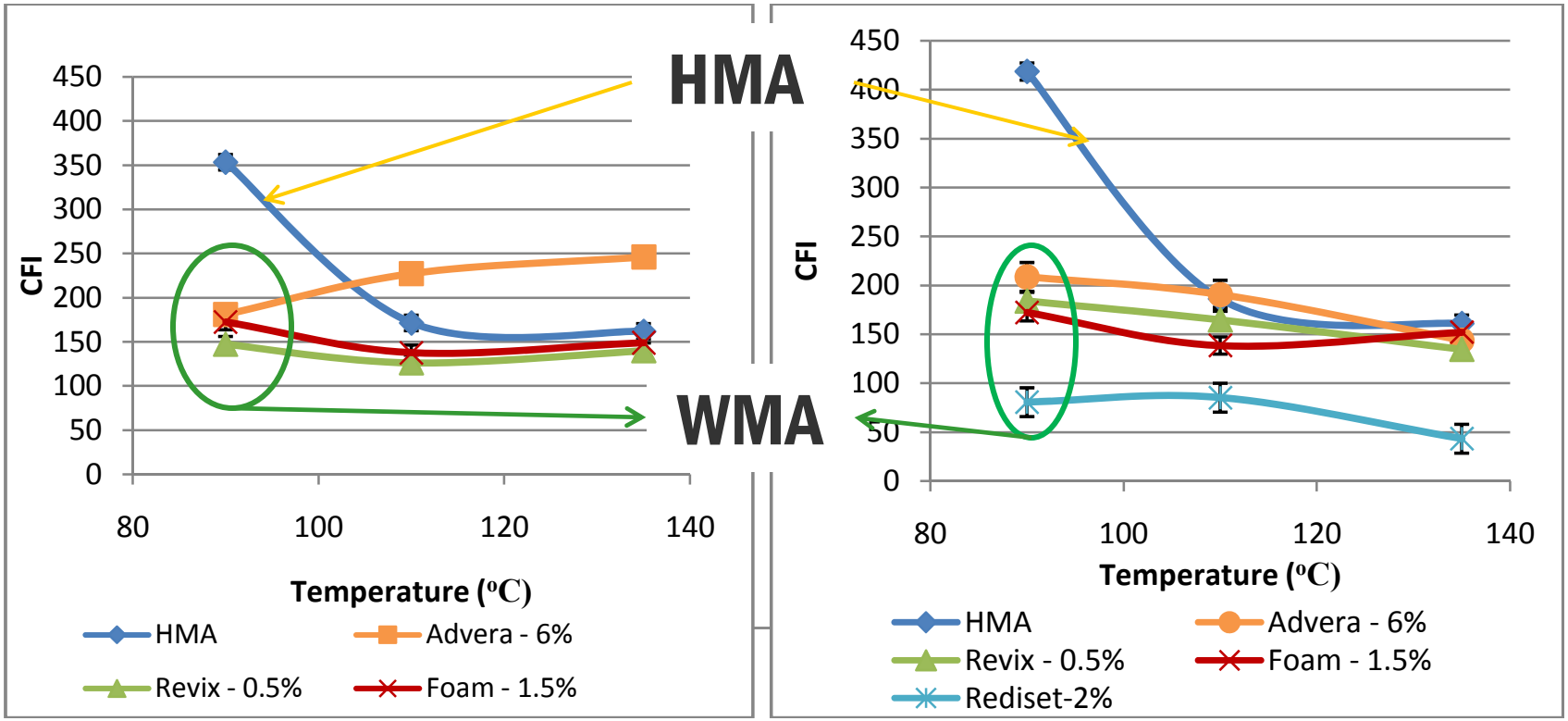
Average CFI values for all mixes

Measuring Traffic Resistance Index (TFI) with the PDA



Average TFI values for all mixes

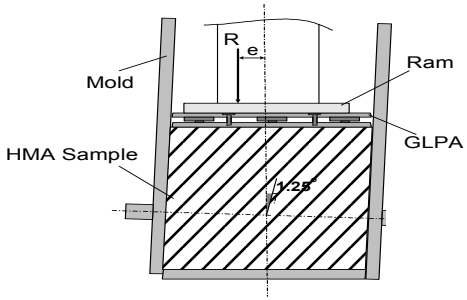
Effects of Warm Mix Additives on Workability (CFI)

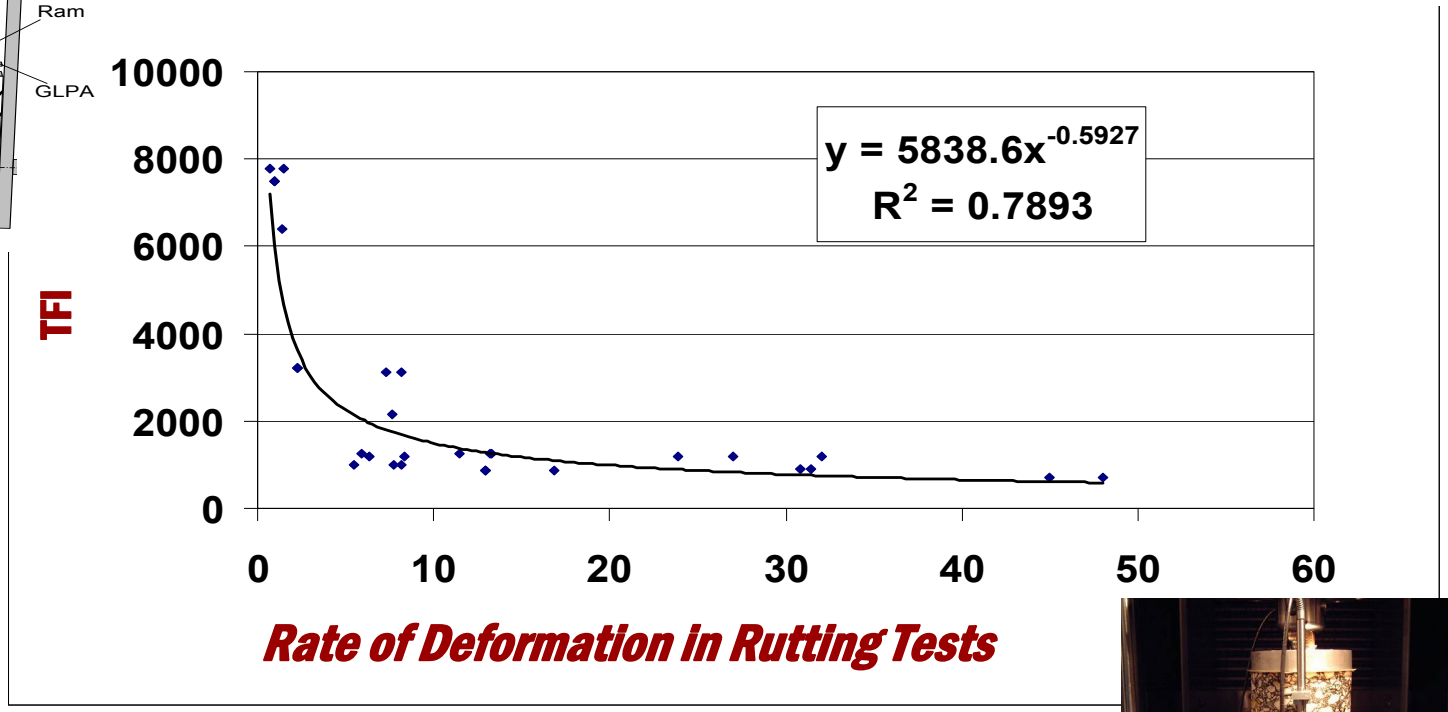


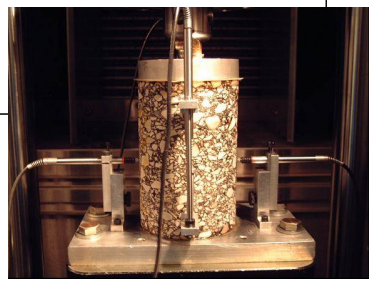
PG 64-22

PG 76-22

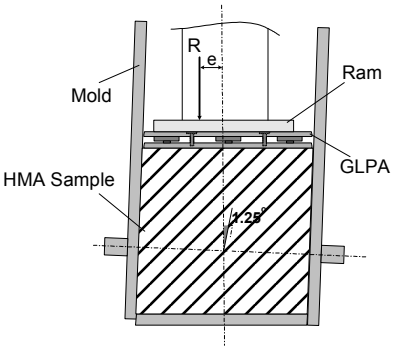
Correlation between GPDA and rutting : *TFI vs. Rate of Deformation*

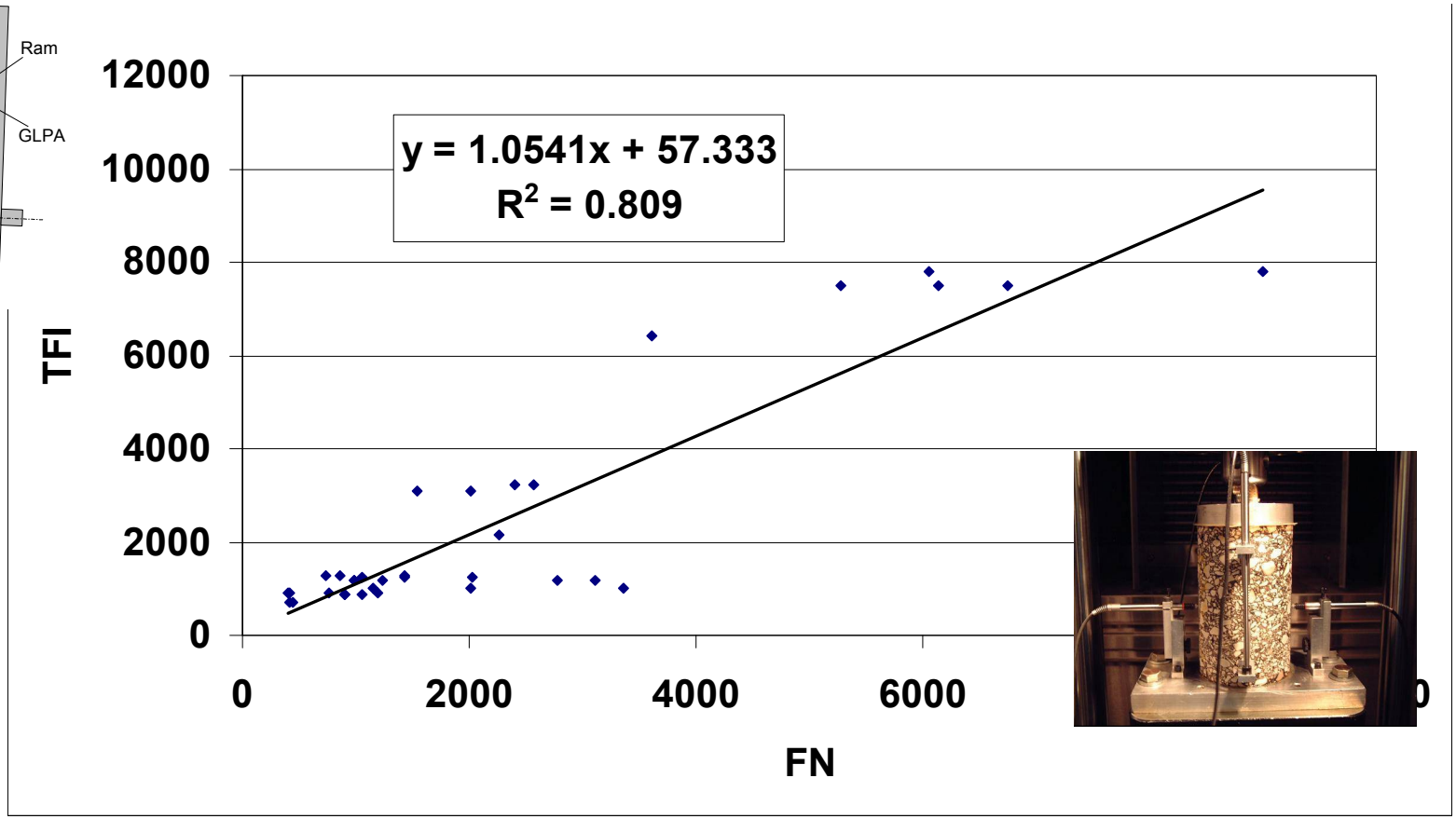






Correlation between GPDA and Rutting:
TFI vs. Flow Number





Proposed Criteria

Workability

Mixture Type	Traffic Level (Million ESALS)	Maximum CFI
E-3	<3	250
E-10	3 to <10	300
E-30	10 to <30	400

Stability

Mixture Type	Traffic Level (Million ESALS)	Minimum TFI
E-3	<3	800
E-10	3 to <10	1000
E-30	10 to <30	1600

Recommendations

- The SGC be used as a tool for mixtures:
  - Evaluate effect of gradation and WMA additives– **Workability**
  - Estimate rutting resistance - **Stability**
- It is recommended that
  - **Workability** and **Stability** be included in evaluation of mix designs to allow for optimum materials selection.
  - Conduct performance testing when possible.

Concluding Remarks

- There is no substitute for performance testing of asphalt mixtures
- We can, however, reduce possible combinations of mixture variables using the SGC and GPDA measurements.
- GPDA results can be better used to study
  - Workability – **Warm Mix**
  - Stability – **Modification/Gradation**