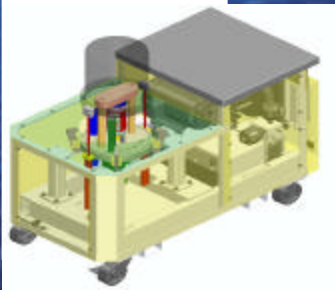


# The Future of Asphalt Pavement Structural & Mixture Design **Complex Modulus, $E^*$**



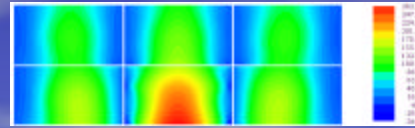
**Thomas Harman**

Asphalt Pavement Team Leader, R&D  
Federal Highway Administration

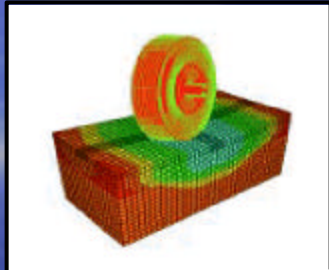
[www.TFHRC.gov](http://www.TFHRC.gov)



# Future



Structural

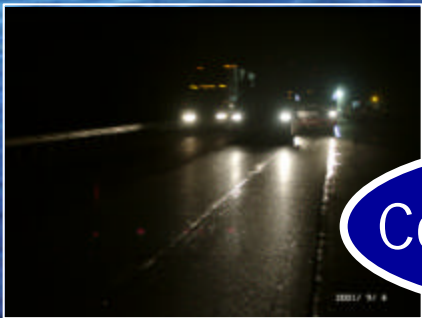


2002 Guide



Construction

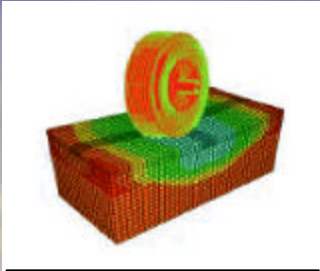
Materials



PRS / Warranty



Superpave II



**2002 Guide**

# The Players



## **NCHRP 1-37A**

- Recommend Test(s)

## **SPR-0003(84)**

- E\* Pooled Fund
- Evaluate Test Procedures

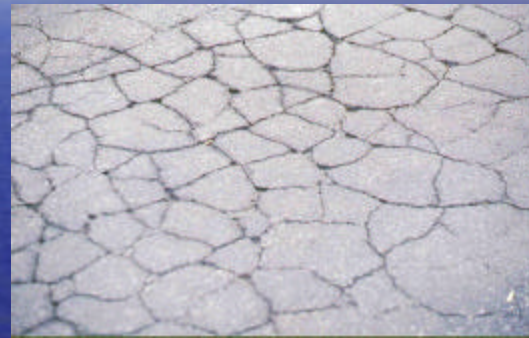
## **NCHRP 9-19**

- Recommend Test(s)

## **NCHRP 9-29**

- Equipment Specs
- First Articles Eval
- Revise Specs

# Simple Performance Test for Superpave Mix Design



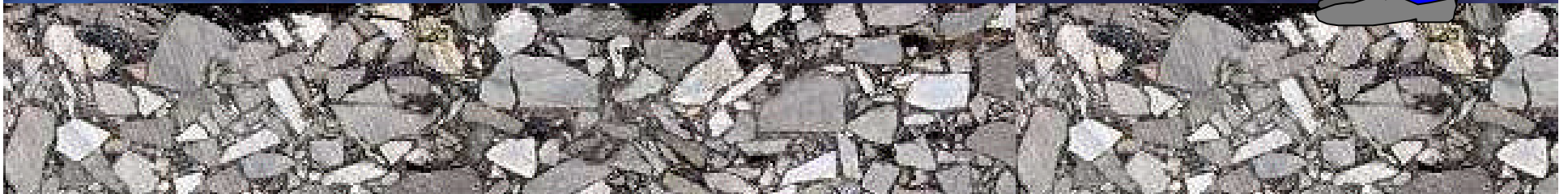
Advanced Asphalt Technologies, LLC

*"Engineering Services for the Asphalt Industry"*

# SPT What Is It?

Test(s) that indicates how mix will perform

- Rutting
- Cracking



# SPT Requirements

- Absolute Requirements of Test
  - Compliment Superpave Volumetric Design
  - Use Gyratory Specimens
  - High Correlation to Rutting/Fracture
  - Identify Inferior Mixes
- Preferred Requirements of Test
  - Tied to Structural Design
  - Adaptable to QC/QA



# Project 9-19

## Candidate Tests



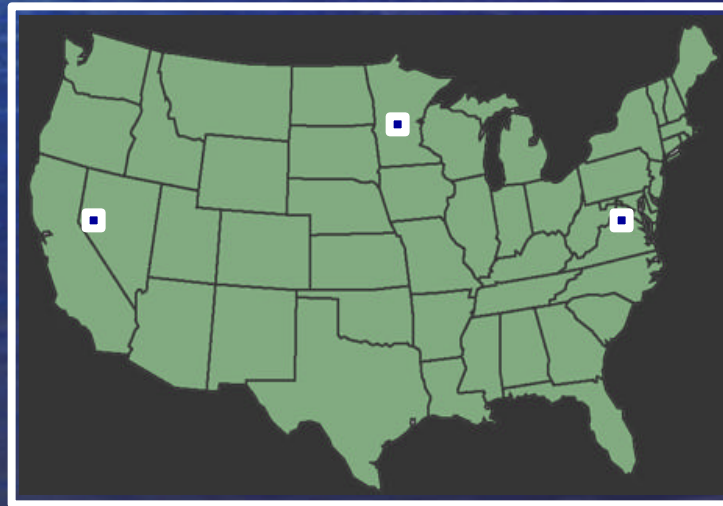
- Complex Modulus,  $|E^*|$ 
  - Rutting
  - Cracking
- Creep Test, FT
  - Rutting
- Repeated Load Test, FN
  - Rutting

# Project 9-19 Correlation Study



MnRoad

WesTrack

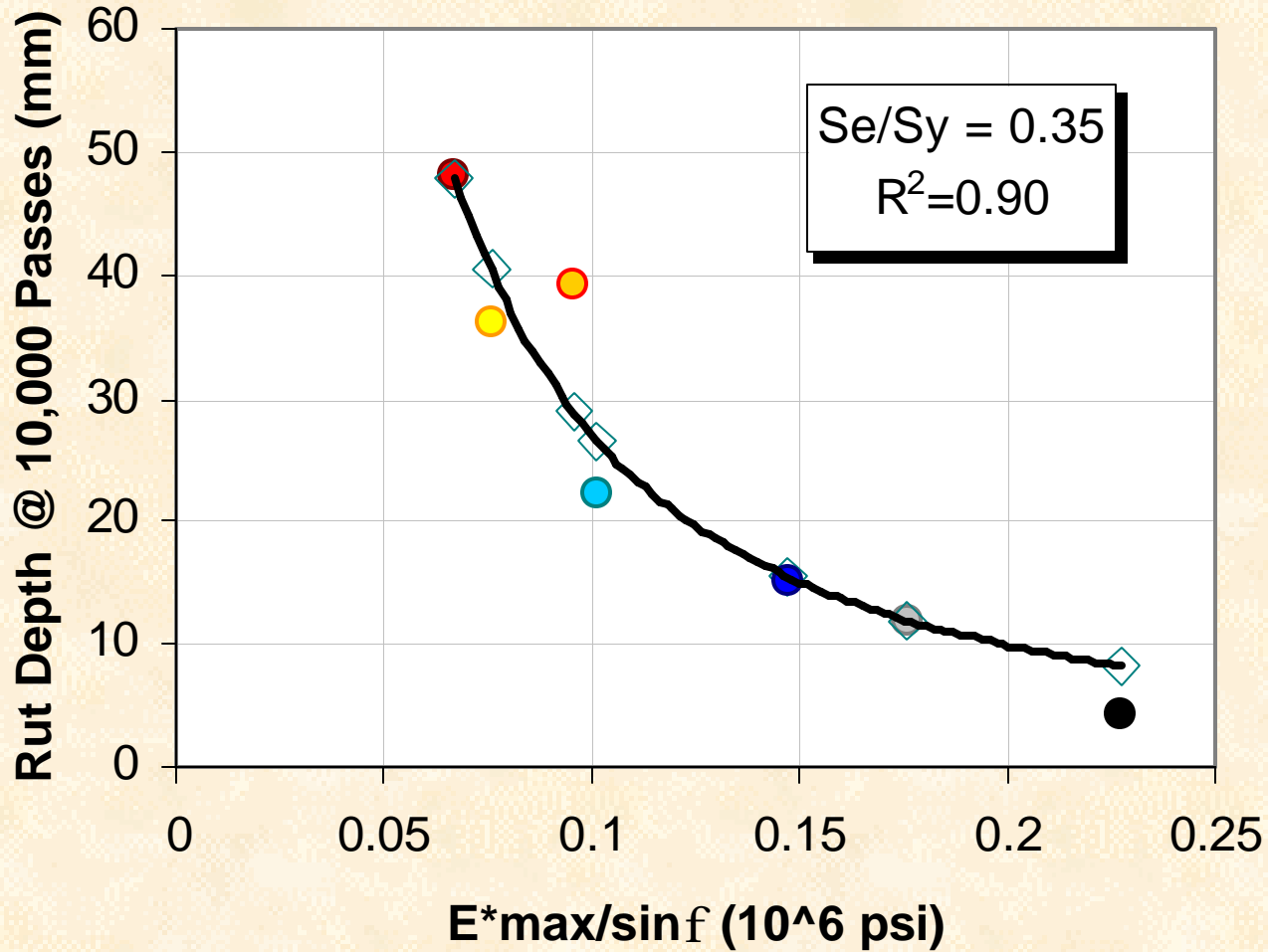


FHWA-ALF





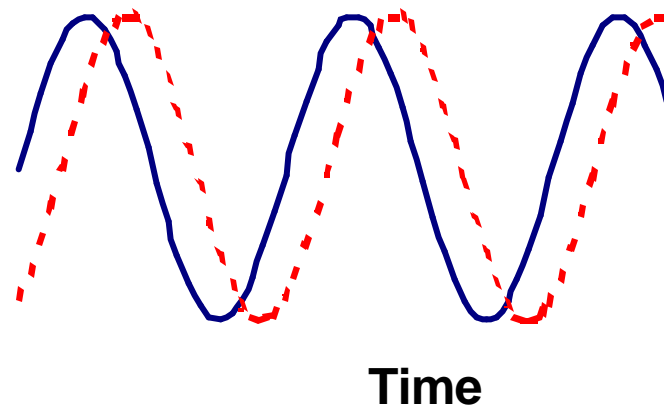
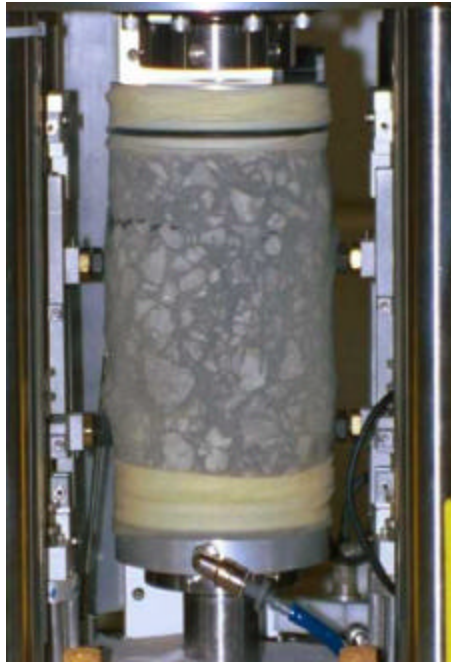
## ALF: Rut Depth vs. $E^*_{max}/\sin f$ @ 130 °F (54.4 °C) Unconfined -- Linear Range



- 5 - AC-10
- 7 - Styrelf
- 8 - Novophalt
- 9 - AC-5
- 10 - AC-20
- 11 - Base AC-5
- 12 - Base AC-20



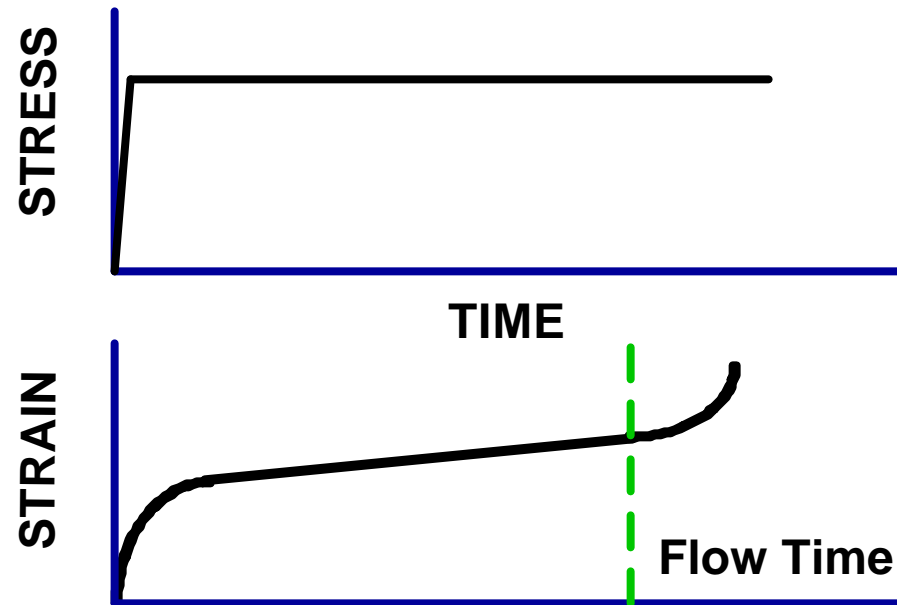
# Complex Modulus, $|E^*|$



$$|E^*| = \frac{s_0}{e_0}$$

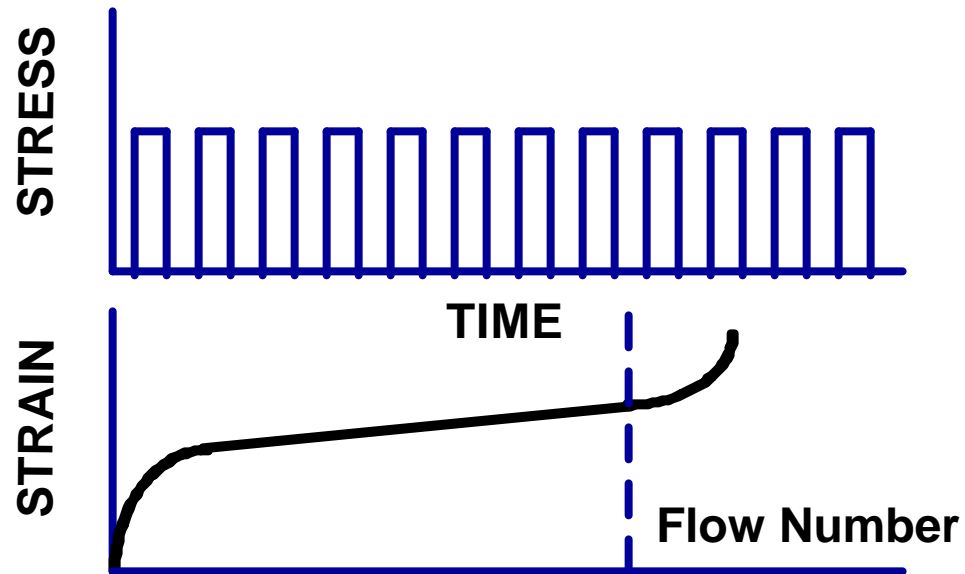
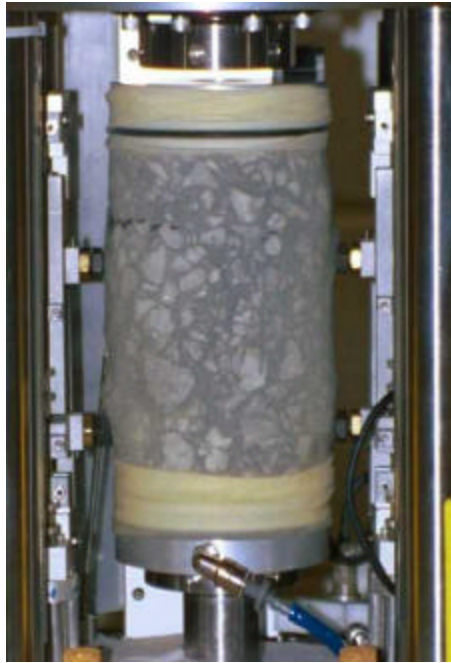
- Rutting
  - Min  $|E^*|$  at High Temp
- Fatigue Cracking
  - Max  $|E^*|$  at Intermediate Temp

# Creep Flow Time, FT



- Rutting
  - Min FT at High Temp

# Repeated Load Permanent Deformation Test, Flow Number



- Rutting
  - Min FN at High Temp



# Advantages

- Complex Modulus,  $/E^*/$ 
  - Used for Structural Design in 2002 PDG
  - Addresses Rutting and Cracking
- Creep, FT
  - Simple Test Equipment
  - Minimal Training
- Repeated Load, FN
  - Potentially Best Simulation of Actual Loading

# Disadvantage



- Specimen Size
  - 1:1.5 D/H Ratio required to ensure fundamental properties
  - 100 mm Diameter by 150 mm High
  - Smooth Parallel Ends (Sawed)
- Sawed and Cored From Over-Height Gyratory Specimens
  - Not all SGC can produced Specimens

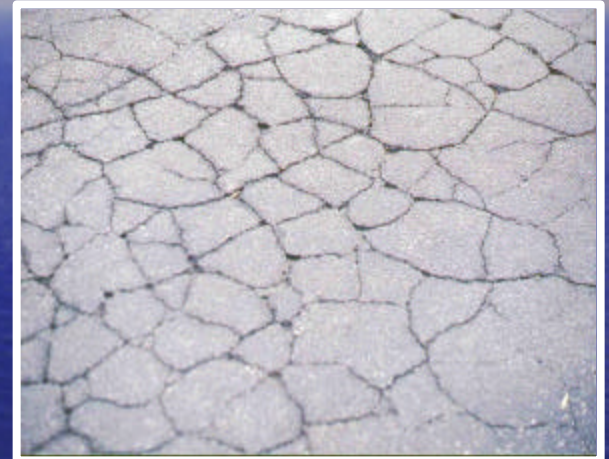
# Project 9-19

## SPT Criteria Development

- Use Models proposed in 1-37A, account for:
  - Climate
  - Traffic Level
  - Structure
- Test at Effective Pavement Temperature
  - Minimum or Maximum Values
    - Traffic Level
    - Pavement Structure
- Completed in Fall 2002

# Project 9-19 Validation

- Criteria Will Be Validated
  - Not the tests
- In-Service Pavement Data
  - 50+ LTPP and Other Test Sections
- Completed in 2002





# Project 9-29

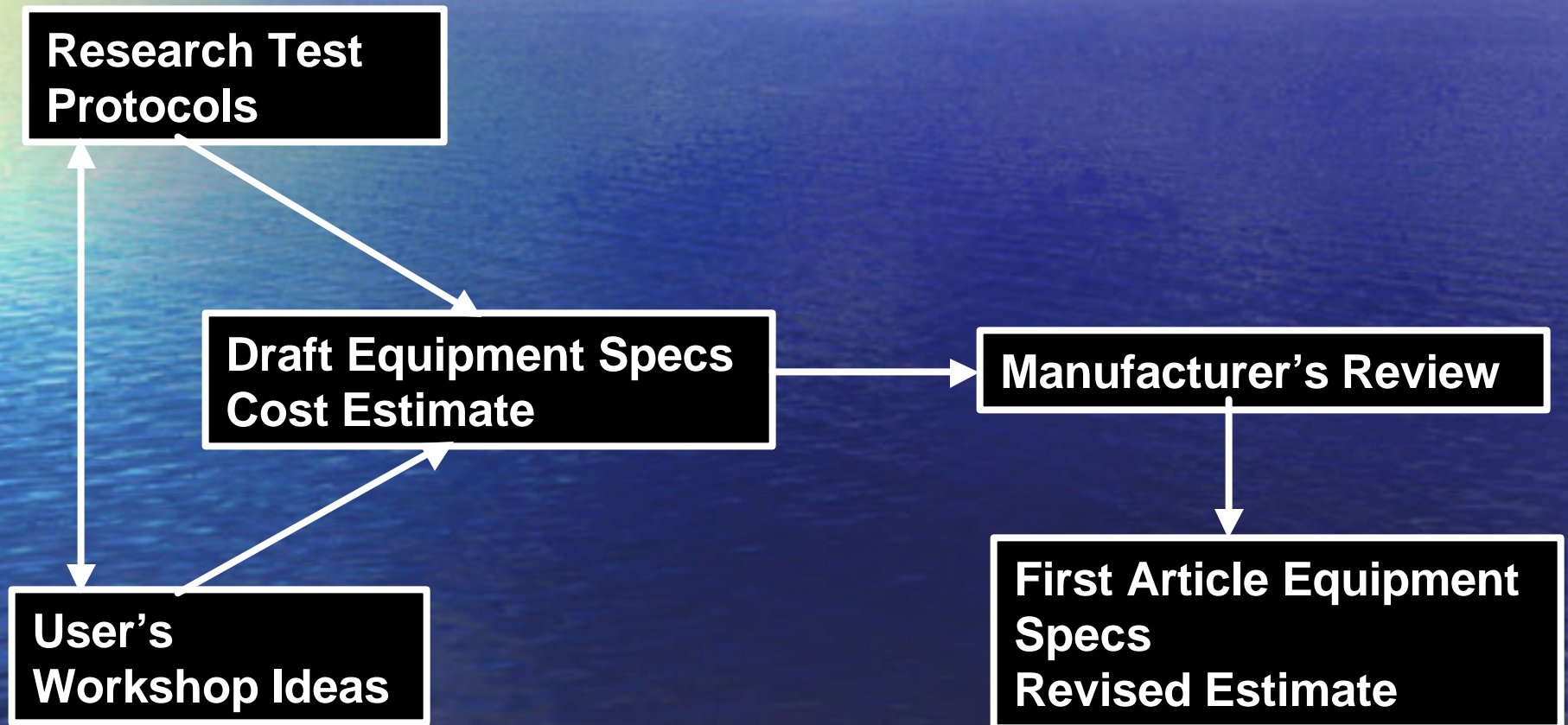
## Equipment Specifications

- Simple Performance Test System
  - All 3 Tests
- Automated Specimen Fabrication Equipment...
- Encourage Innovation by Manufacturers
  - User Friendliness
  - Reliability
  - Cost



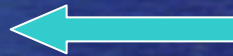
# Project 9-29

## Specification Development



# First Article SPT Procurement

- EnduraTec
- Instron
- Interlaken
- Shedworks



- **Specifications**
- **Advantages**
- **Cost**
- **Past Performance**

# First Article SPT Systems

- Tests
  - Complex Modulus
  - Flow Time
  - Flow Number
- Temperature Range
  - 20 to 60 °C
- Confining Pressure Range
  - 0 to 210 kPa



# First Article Simple Performance Test Systems



**SHEDWORKS**

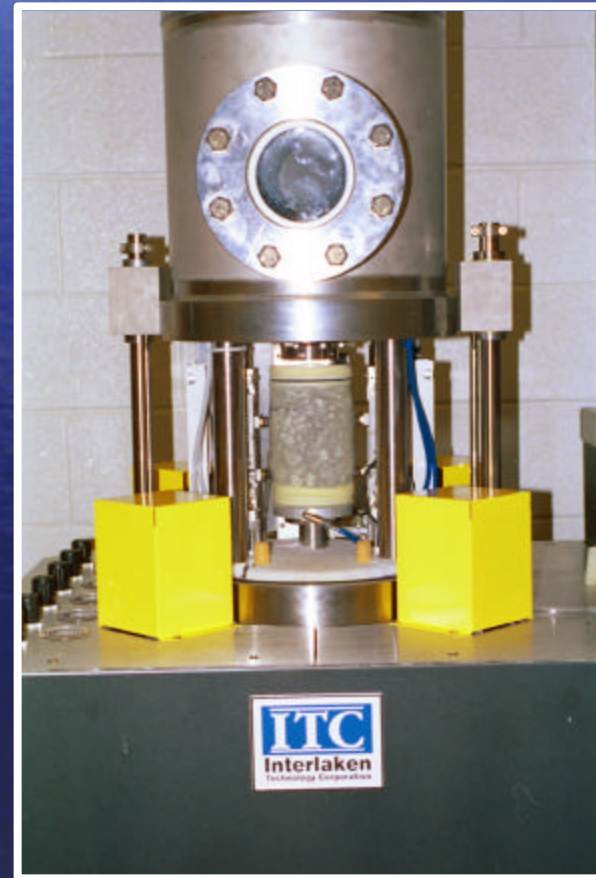
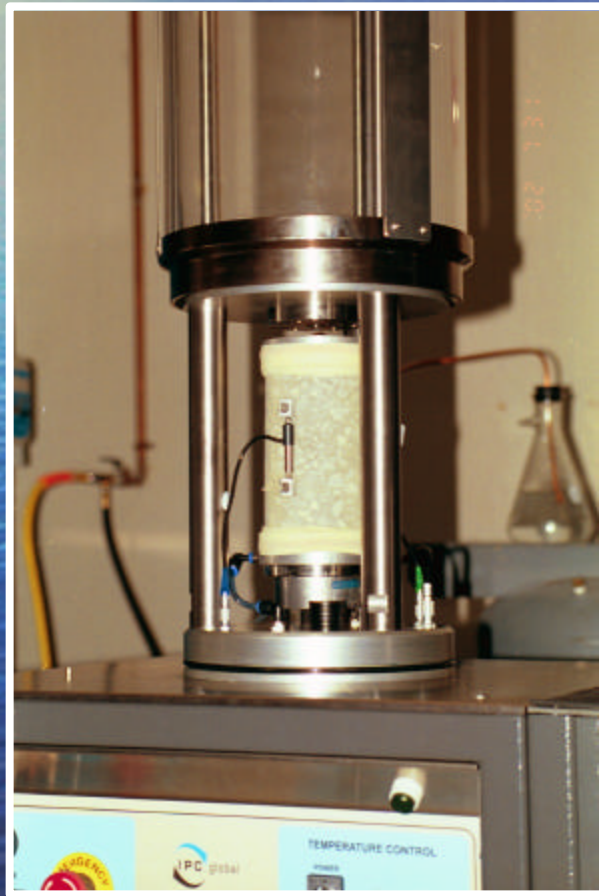


**INTERLAKEN**

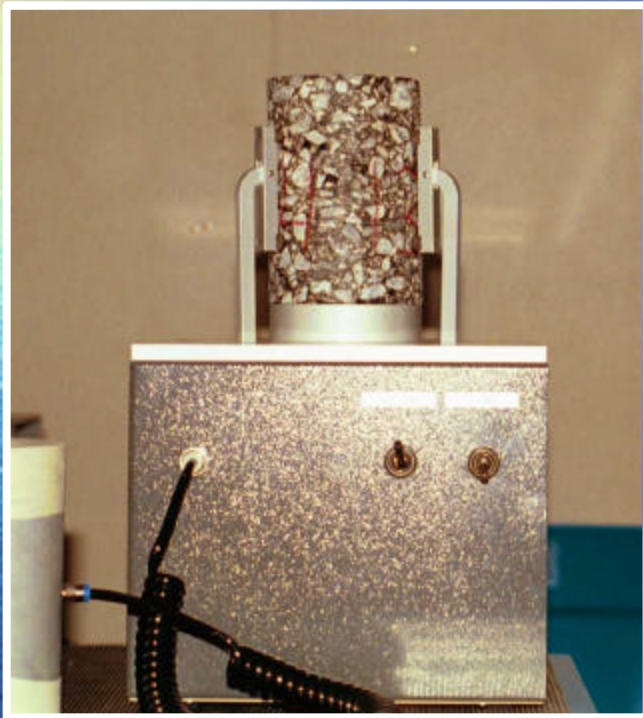


# Instrumentation

## LVDT's



# Shedworks



# Interlaken





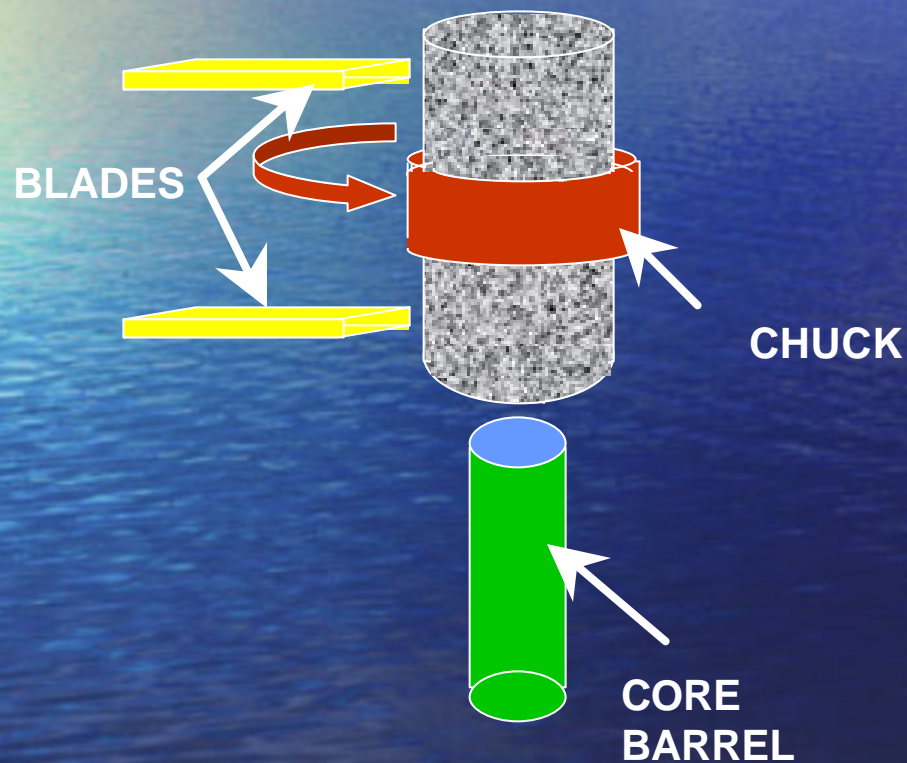
# Specimen Fabrication System

- Pine
- Shedworks 
- **Specifications**
- **Automated**
- **Cost**

# First Article Specimen Fabrication System



# First Article Specimen Fabrication Equipment



# Summary- Simple Performance Test Work Completed

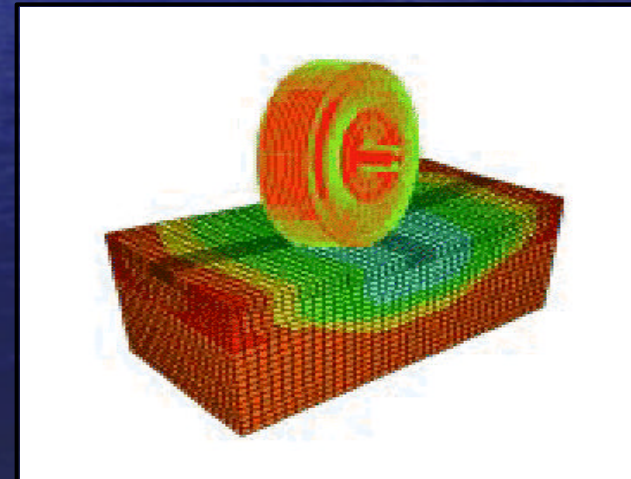
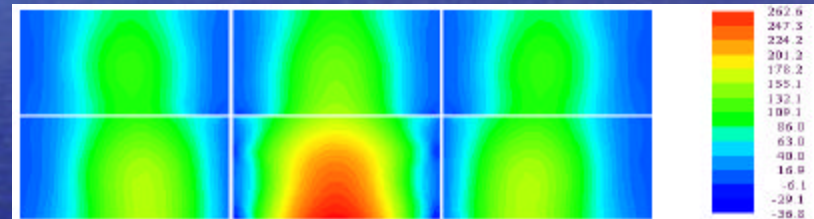
- Three Candidate Tests
- Detailed Draft Protocols
- Detailed Equipment Specifications
- First Article Devices
  - Simple Performance Test System  
(\$25 k to \$45 k)
  - Automated Specimen Fabrication System  
(\$12 k)



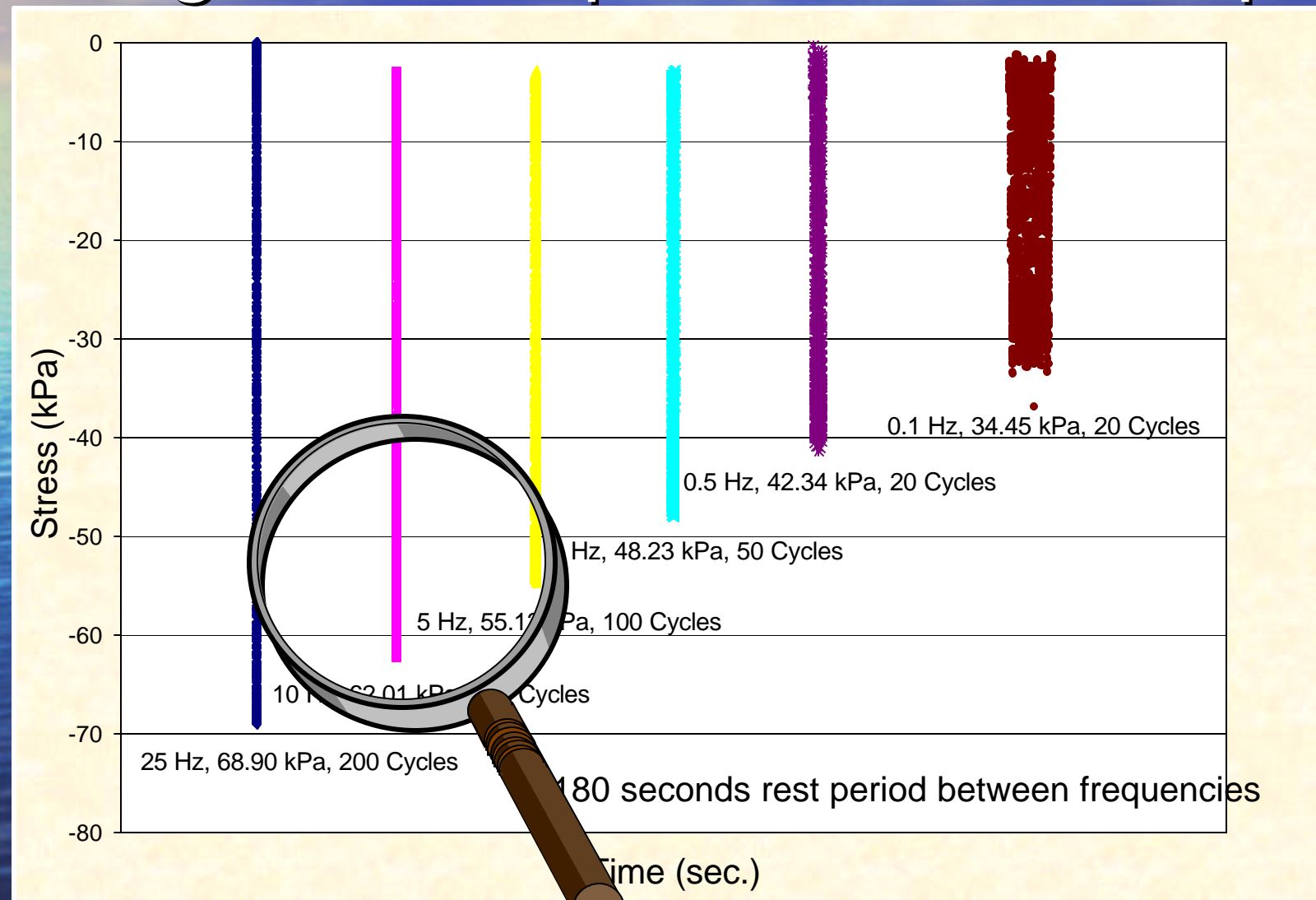
# NCHRP 9-29 Timeline

- Criteria Development
  - Early Fall 2002
- Criteria Validation
  - End of 2002
- First Article Evaluation
  - Early 2003

# Complex Modulus, $|E^*|$ for Structural Design

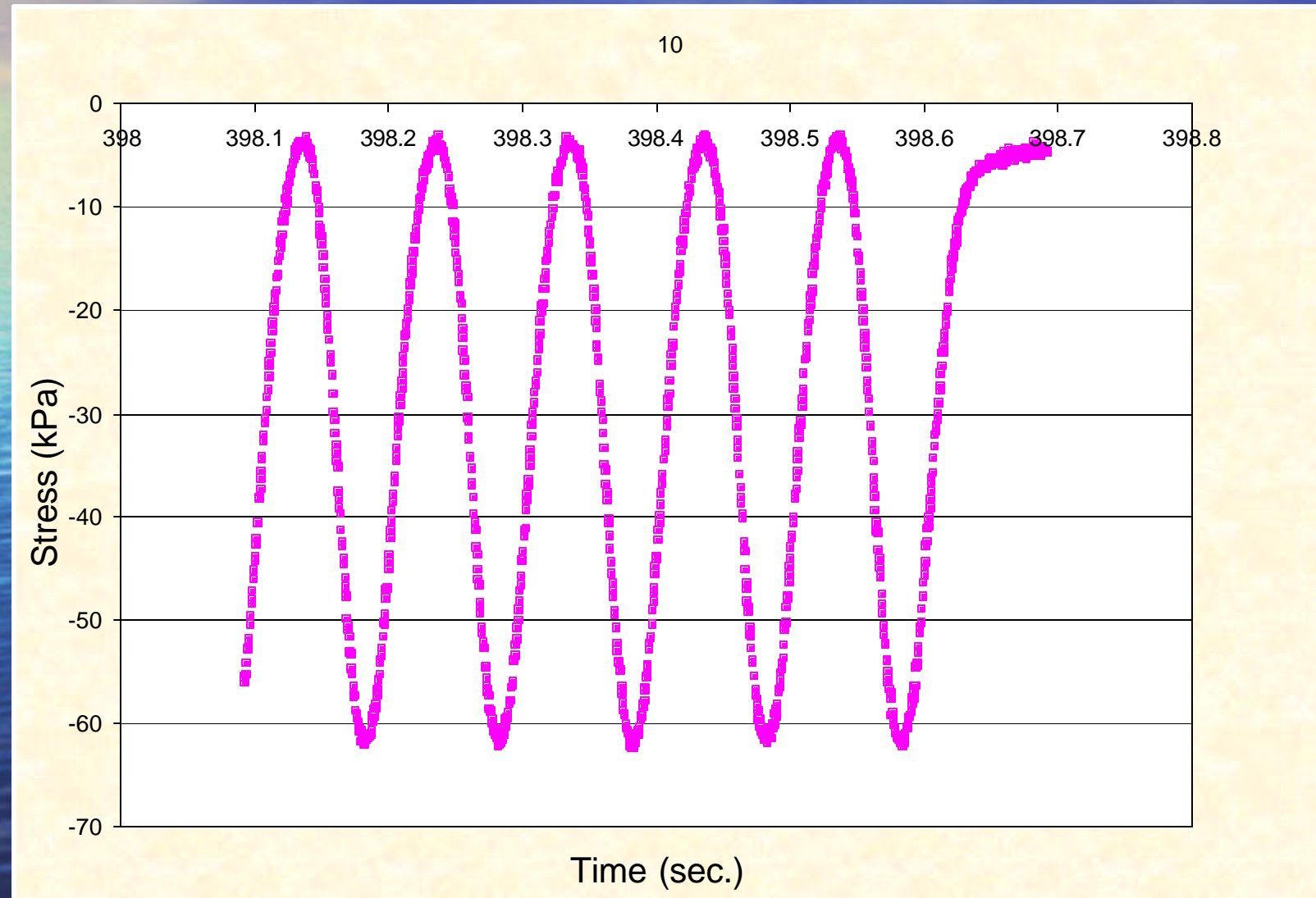


# 2002 PDG Requires a Range of Frequencies & Temp.'s



# Example

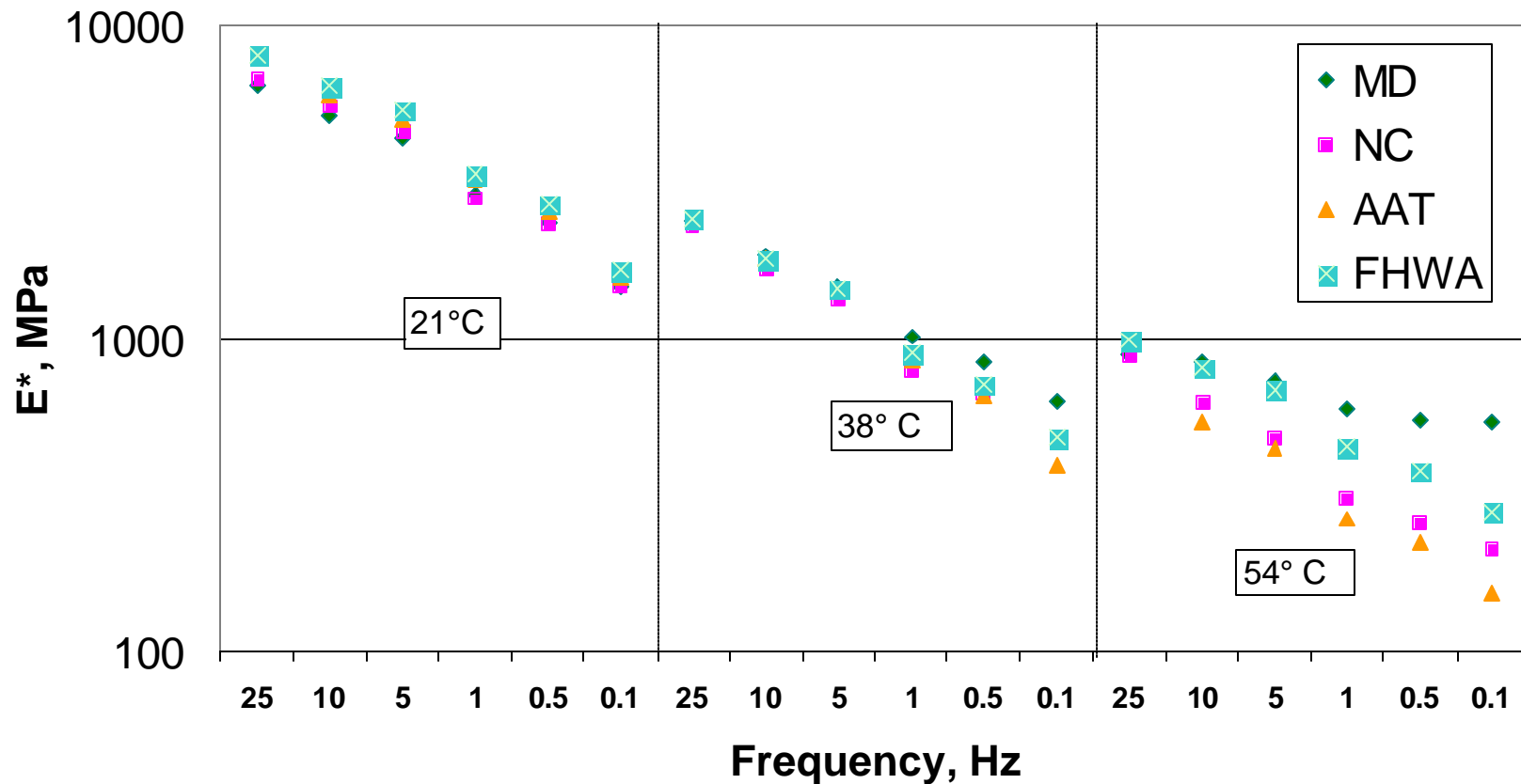
## 10 Hz and 62 kPa





# /E\*/ Pooled Fund Study – UConn (2002 PDG)...

## Perliminary Result of Round Robin Study



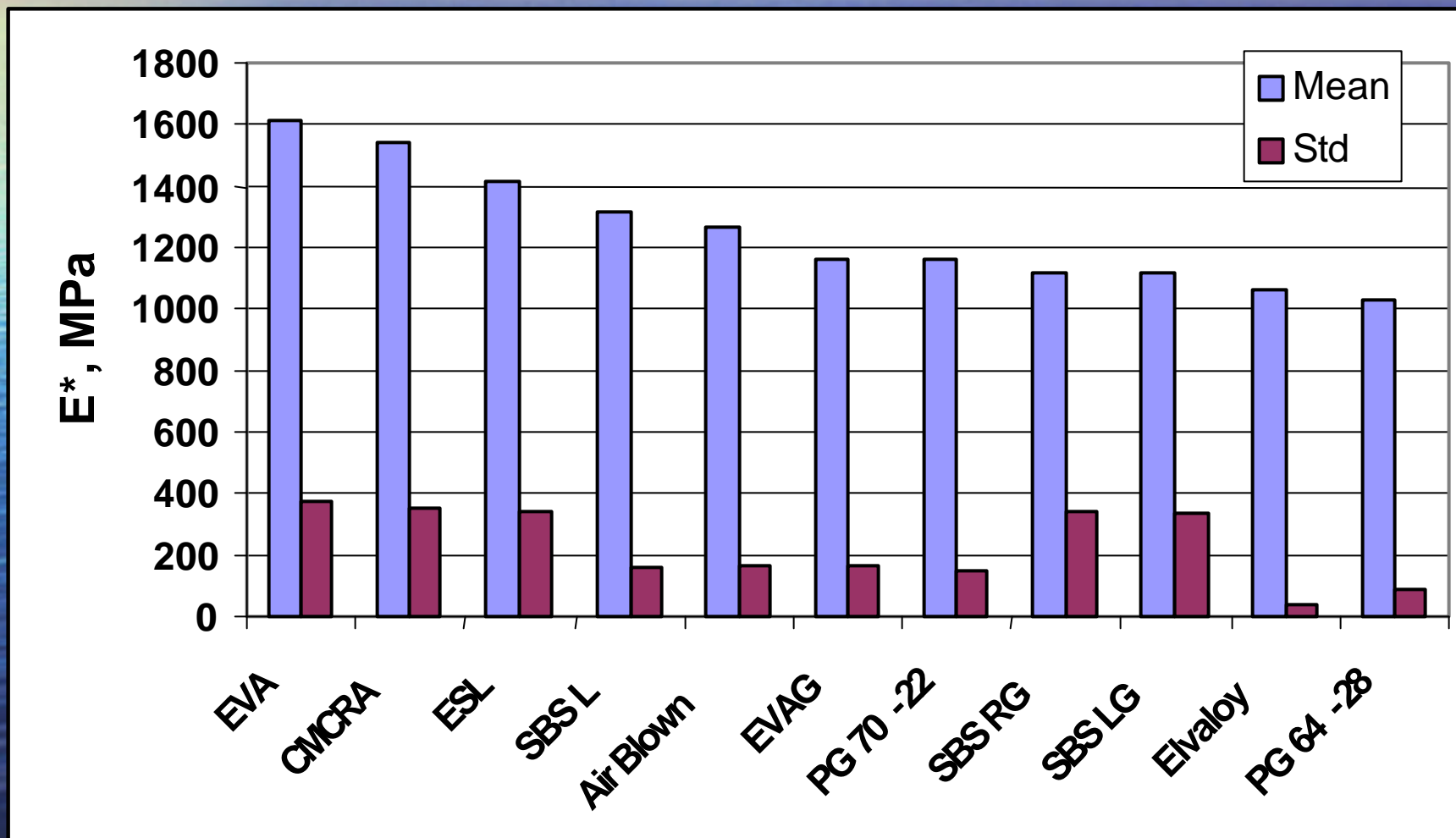
# Understanding Modified Binders

NCHRP 90-07, TPF 5(019)



# FHWA-ALF

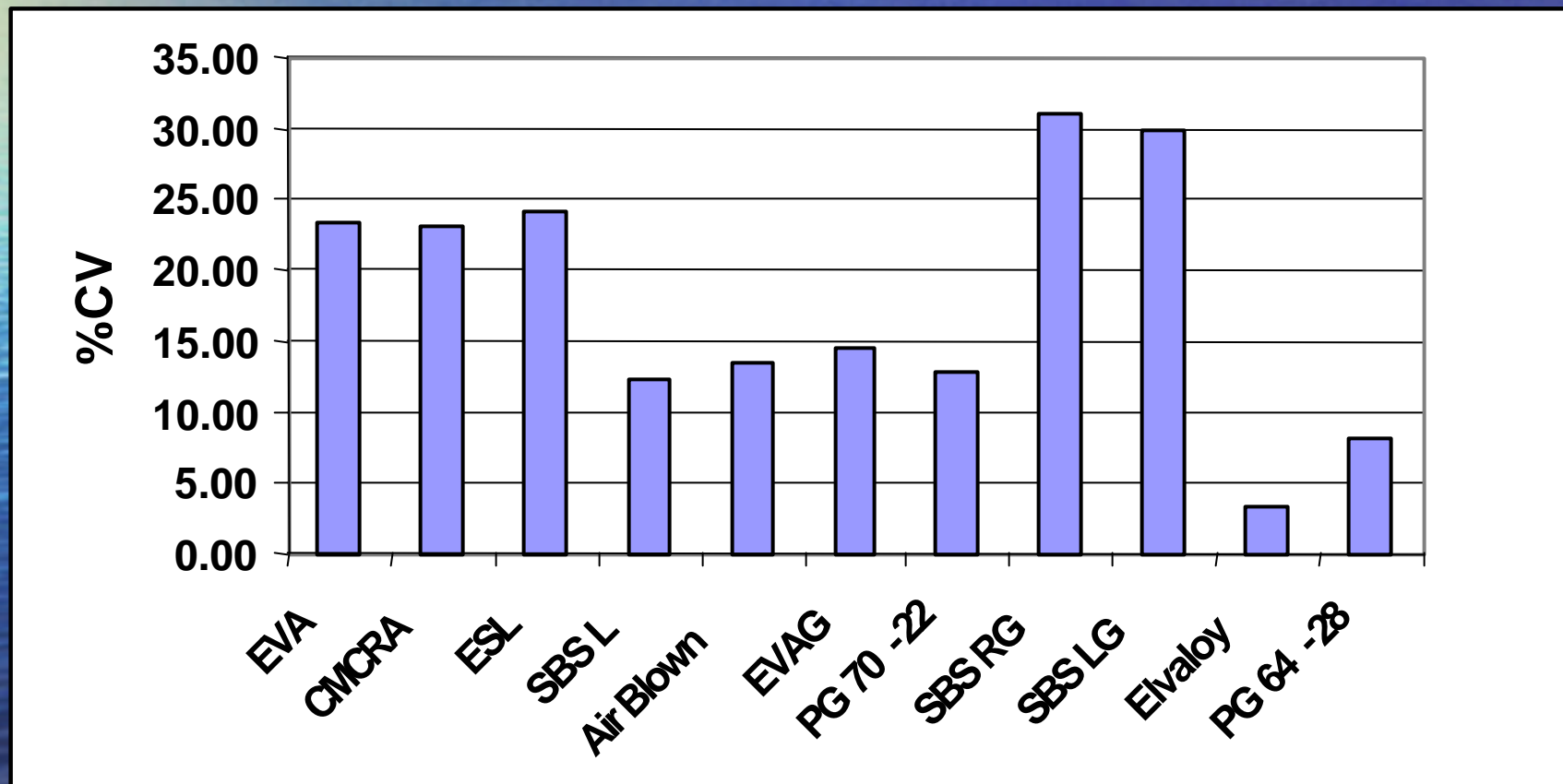
Mean and Standard Deviation of  $E^*$   
(3 Replicates, 50°C, 10 Hz)



# FHWA-ALF

## Coefficient of Variation of $/E^*/$

(3 Replicates, 50°C, 10 Hz)



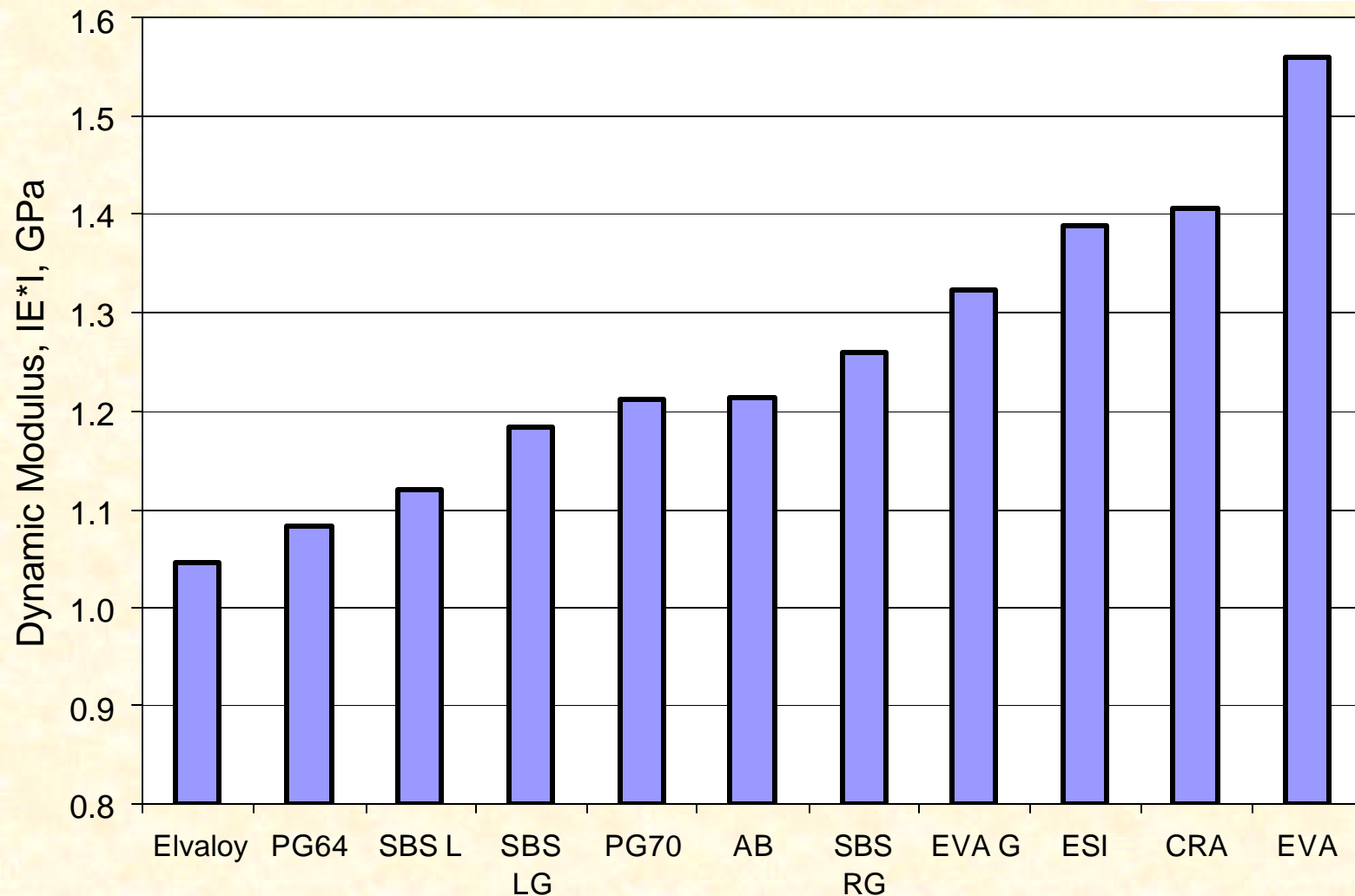
# TRB Superpave Binder Expert Task Group

✓ /E\*/ Concern

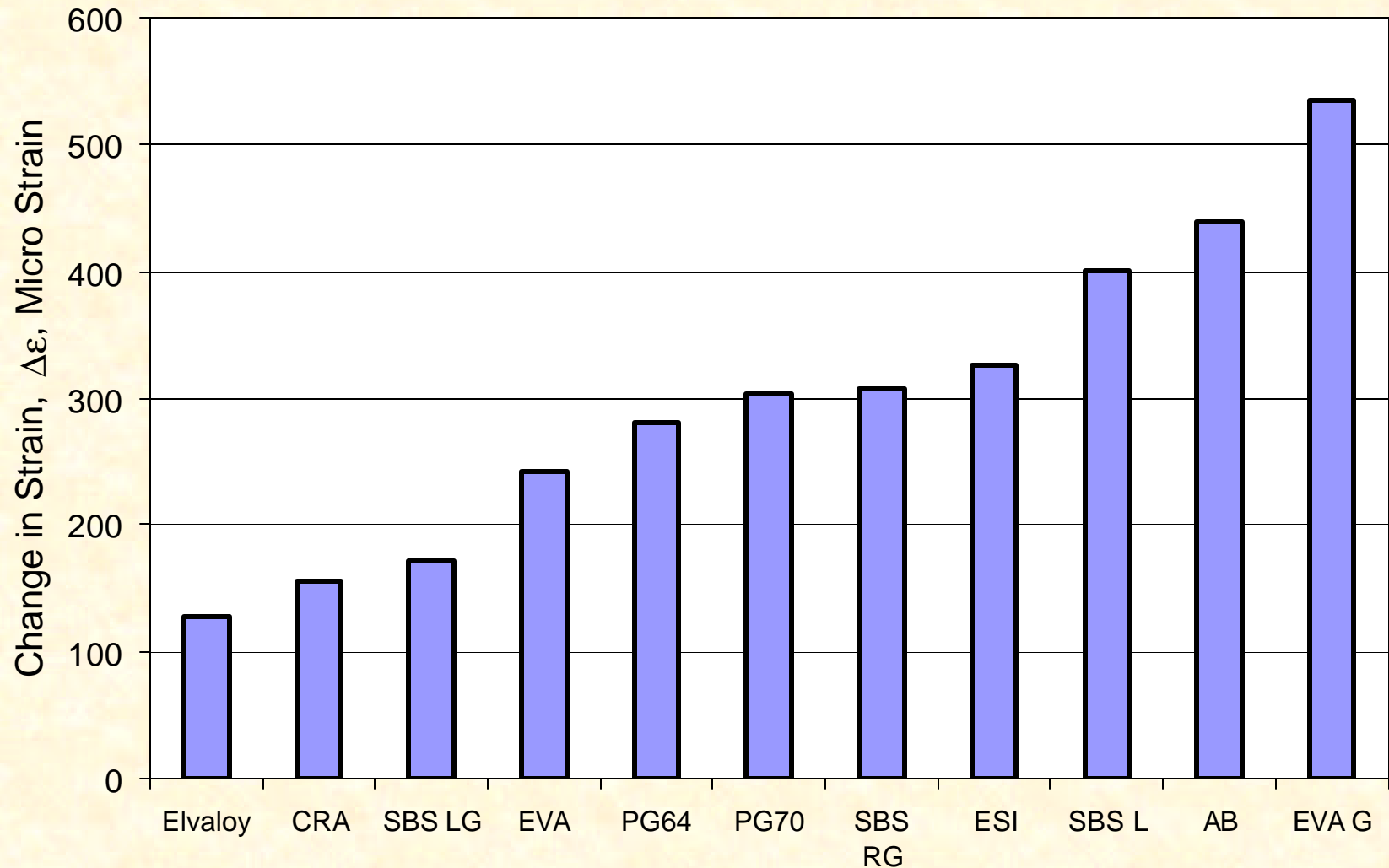


AASHTO / TRB / NCHRP / FHWA

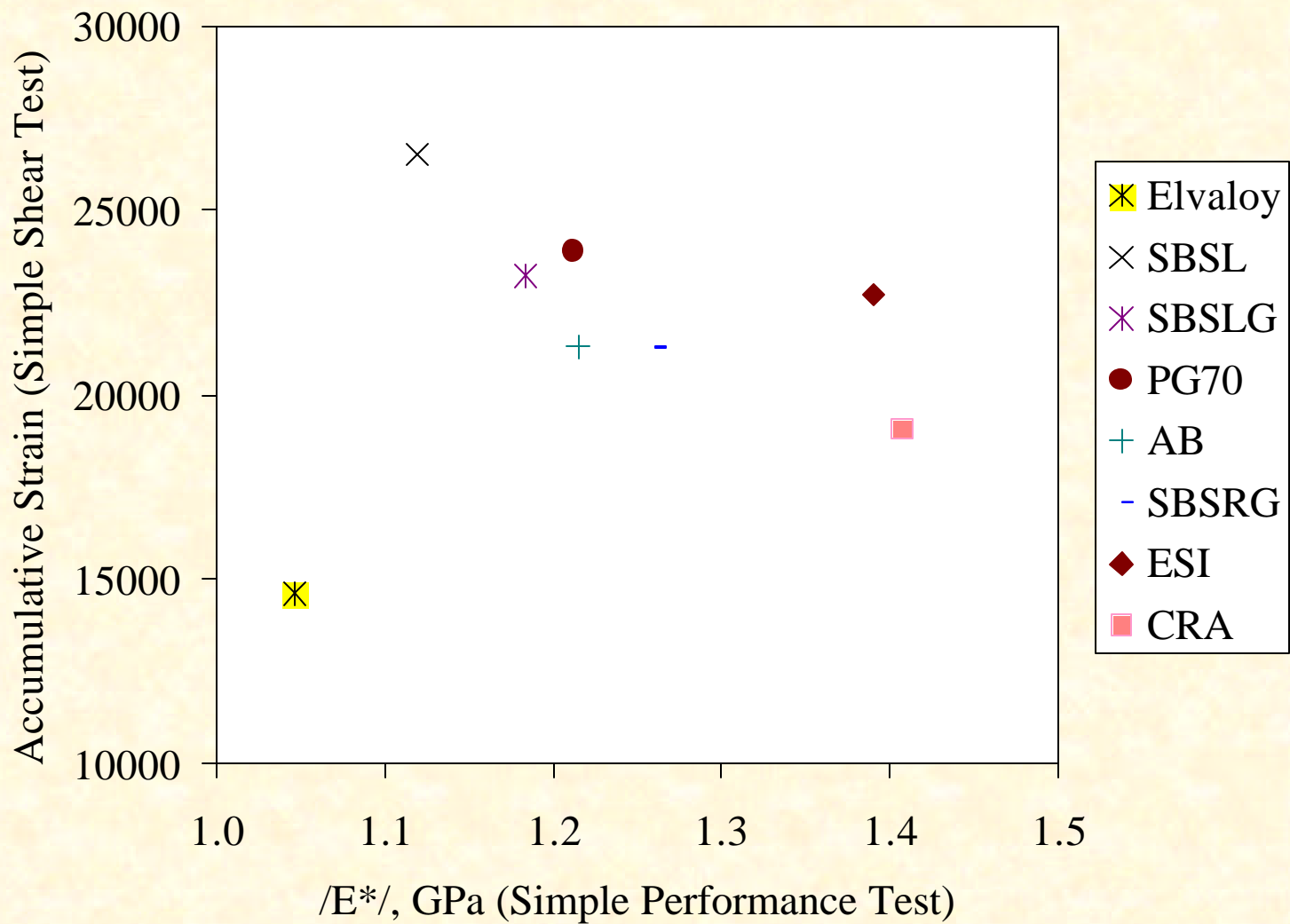
# Lab Mix – Similar PG Grade /E\*/ at 10 Hz



# Permanent Strain 25 to 0.1 Hz

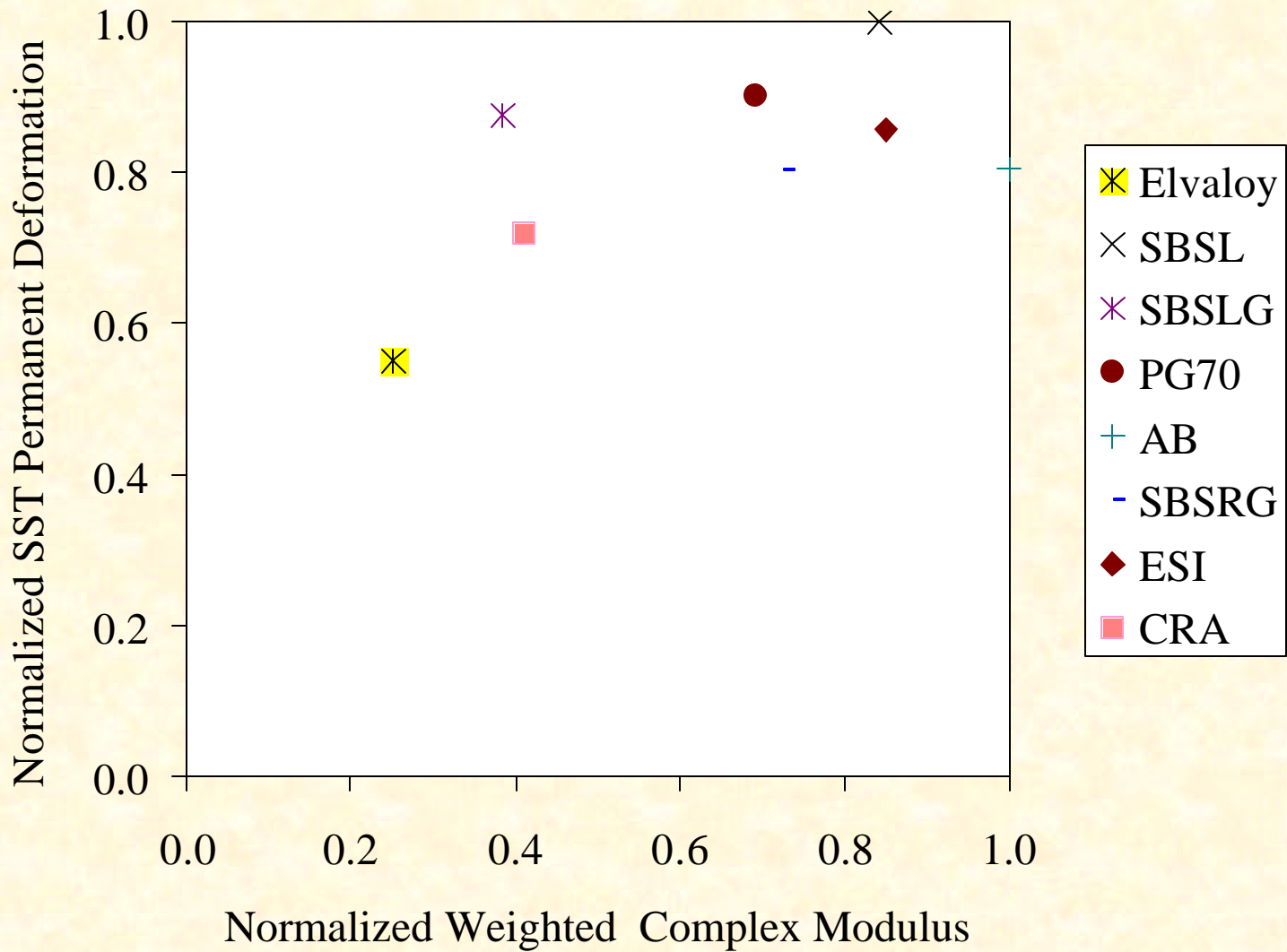


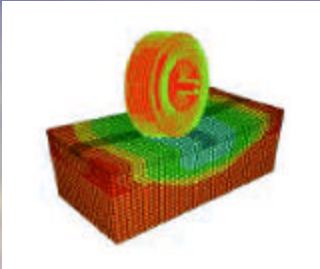
# SST vs $/E^*/$





$$|E^*| \times (\frac{?}{?}_{max} / ??)$$





**2002 Guide**

# Summary



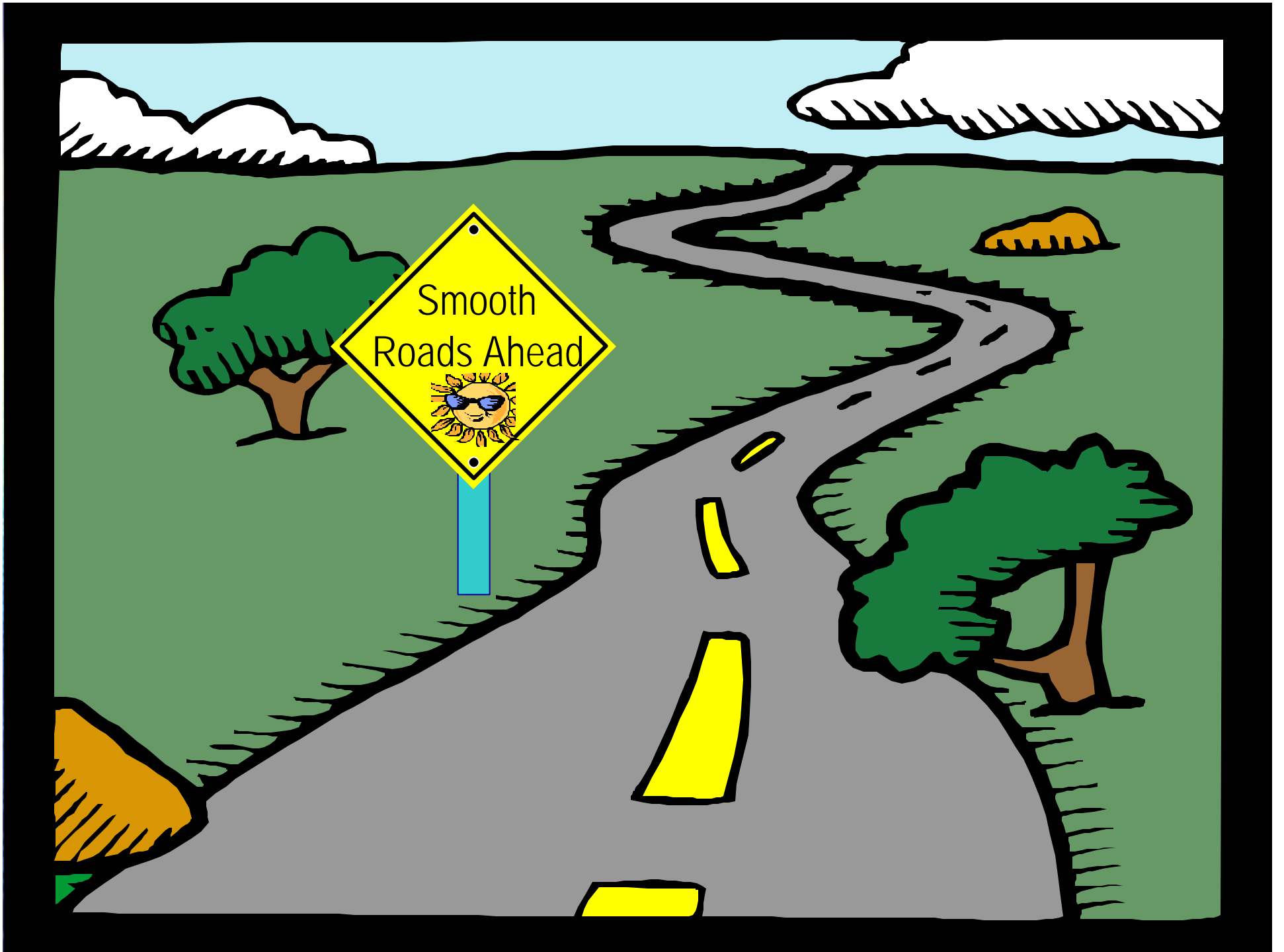
## **NCHRP 1-37A**

- Complex Modulus,  $/E^*/$
- Issues of repeatability
- Concern with modifiers

## **NCHRP 9-19/29**

- Links Mix Design to Structural Design





Smooth  
Roads Ahead

