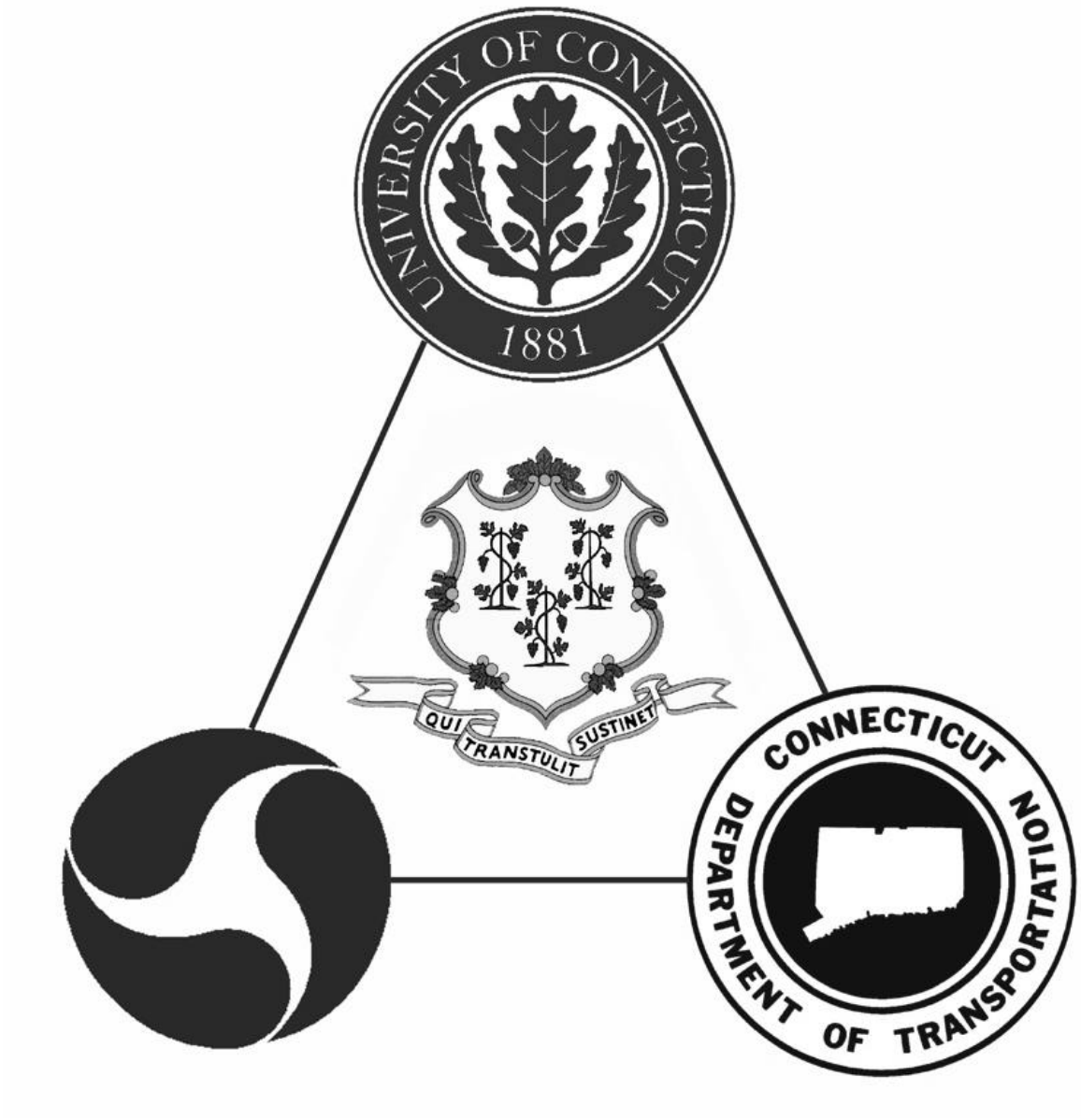
UNIVERSITY OF CONNECTICUT
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CONNECTICUT
DEPARTMENT OF TRANSPORTATION

"Use of Dynamic Modulus (E*) in the Design of Hot-Mix Asphalt (HMA) Pavement"

for Presentation @

Pavement Evaluation Workshop

Newington, Connecticut

September 10, 2002

An FHWA Pooled Funds Project

Lead Agency

Connecticut Department of Transportatio

Why is E* Important?

The new 2002 design guide for pavements is based on mechanistic principles. It requires a modulus, analogous to E for to compute stresses and stains in the HM pavement. E* has been selected for this purpose

Definition of E*

E* is the modulus of a visco-elastic material. It is computed by dividing the maximum (peak to peak) stress by recoverable (peak to peak) axial strain a test sample subjected, to a sinusoidal load at various test temperatures.

Why this Project?

- The 1986 AASHTO pavement design guide contained resilient modulus (M_R) to characterize HMA mixes. M_R didn't work and it took FHWA and others millions of dollars to recognize this flaw.
- Our project is designed to look at the protocol for determining E* and provide state DOTs recommendations for the application of the protocol in their operations.

Project Objectives

- Determine the applicability of E* to characterize HMA mixes
- Determine the practical range of the protocol
- Determine any variation in E* values

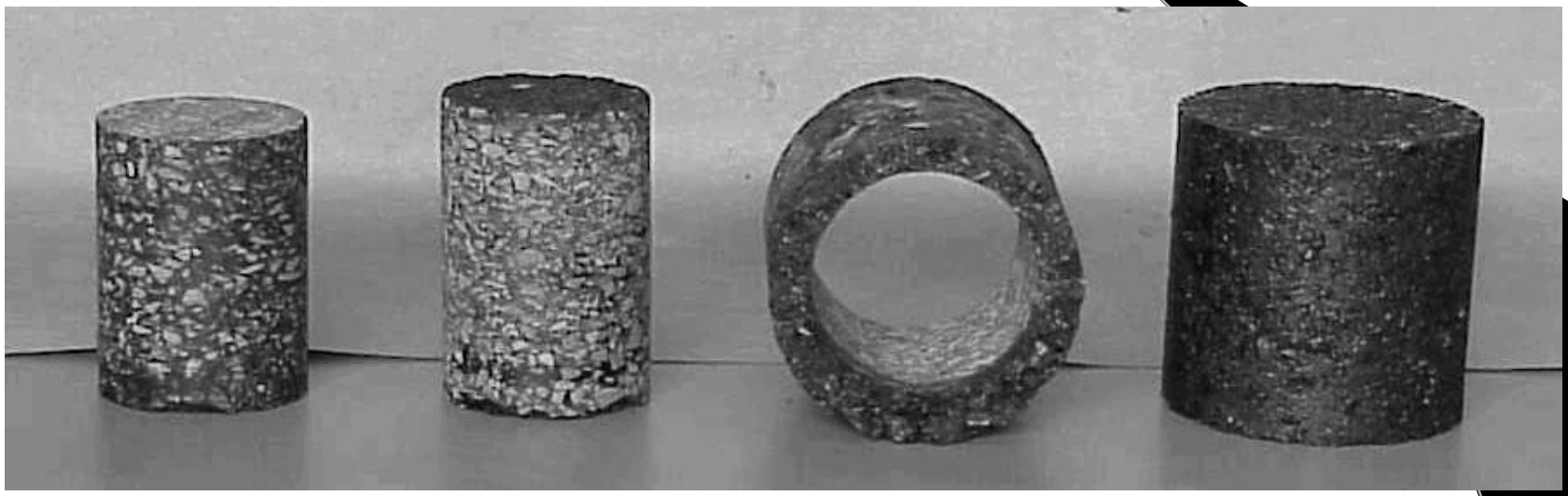
Evaluate the determination of E* for use in operational DOTs

- Using existing commercially available equipment

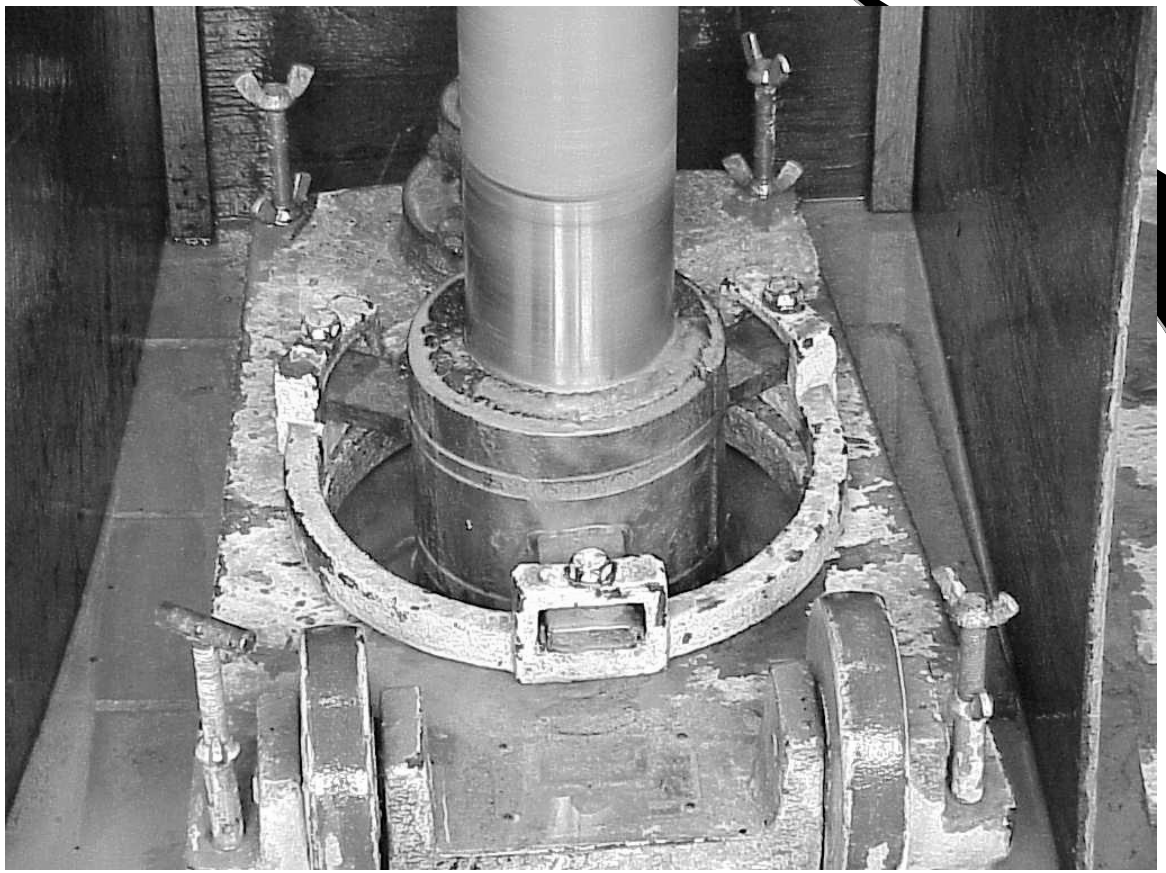
E* Protocol - Overview

- Test 4” diameter – 6” high sampl
- 5 Test temperatures
- 6 Load frequencies / temperature

Test Specimen



Coring Apparatus



End Sawing

Table 2. Recommended Number of Specimens

LVDTs per Specimen	Number of Specimens	Estimated Limit of Accuracy
2	**2**	**18.0**
2	**3**	**15.0**
2	**4**	**13.4**
3	**2**	**13.1**
3	**3**	**12.0**
3	**4**	**11.5**

Load-Test Frame & Environmental Chamber

Table 3. Recommended Equilibrium Times.

Specimen Temperature, ^{0}C (^{0}F)	Time from room temperature, hrs 25 °C (77 °F)	Time from previous test temperature, hrs
-10 (14)	overnight	-
4.4 (40)	overnight	4 hrs or overnight
21.1 (70)	1	3
37.8 (100)	2	2
54.4 (130)	2	1

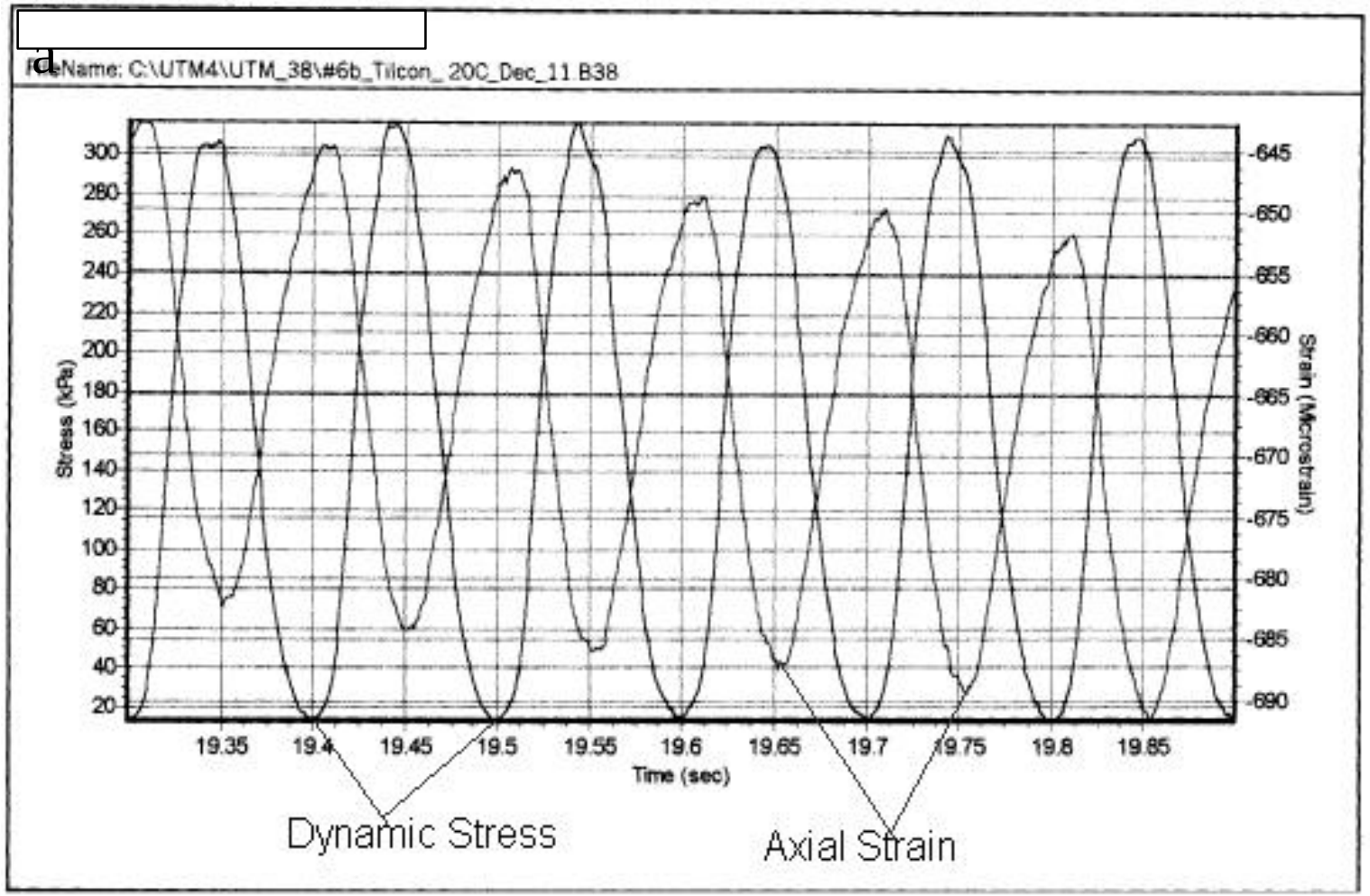
** Note that the temperature equilibrium times may vary depending on the type of environmental chamber in use. Some testing laboratories reported as much as 6 hours to reach the equilibrium temperature.*

Table 4. Typical Dynamic Stress Levels

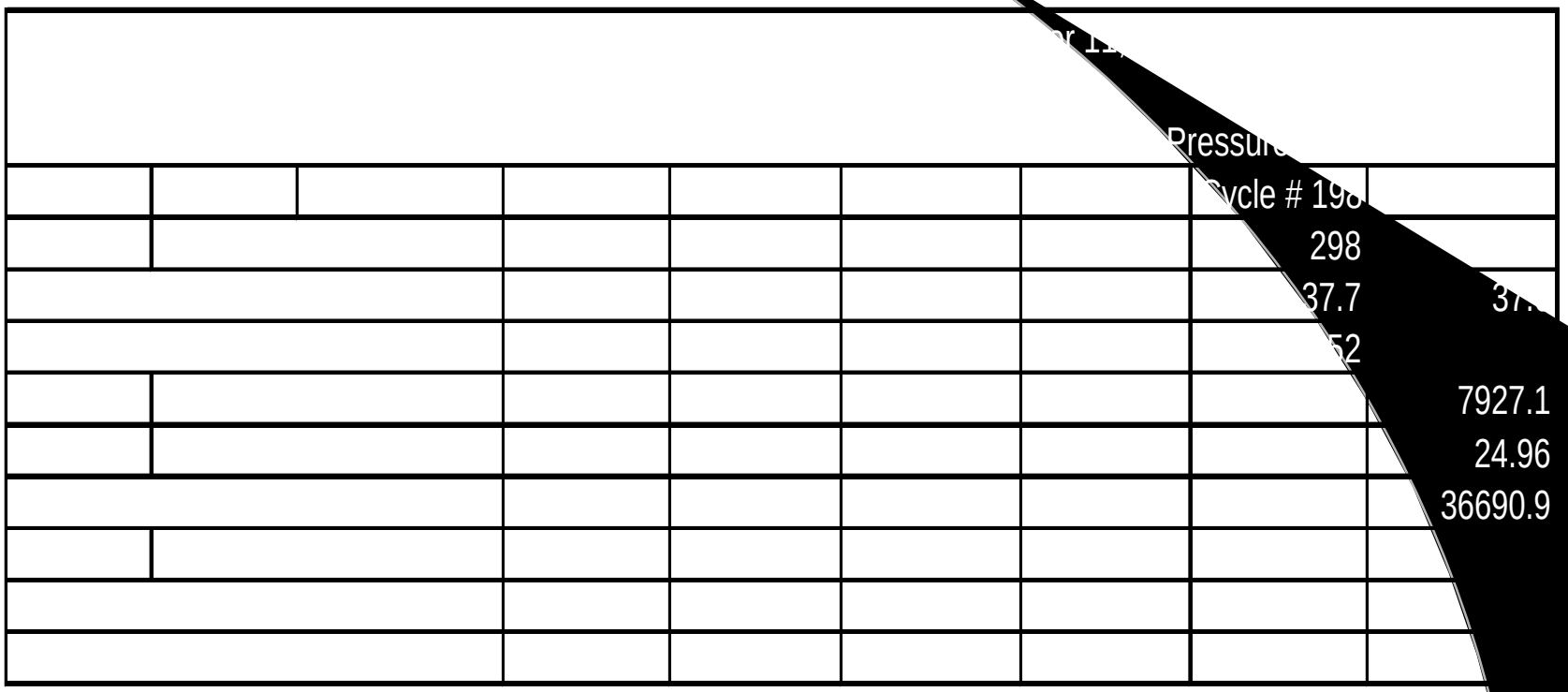
Temperature, ^{0}C (^{0}F)	Range, kPa	Range, psi
-10 (14)	1400 - 2800	200 - 400
4.4 (40)	700 - 1400	100 - 200
21.1 (70)	350 - 700	50 - 100
37.8 (100)	140 - 250	20 - 50
54.4 (130)	35 - 70	5 - 10

Note: Axial strain limited to 50 to 150 microstrain

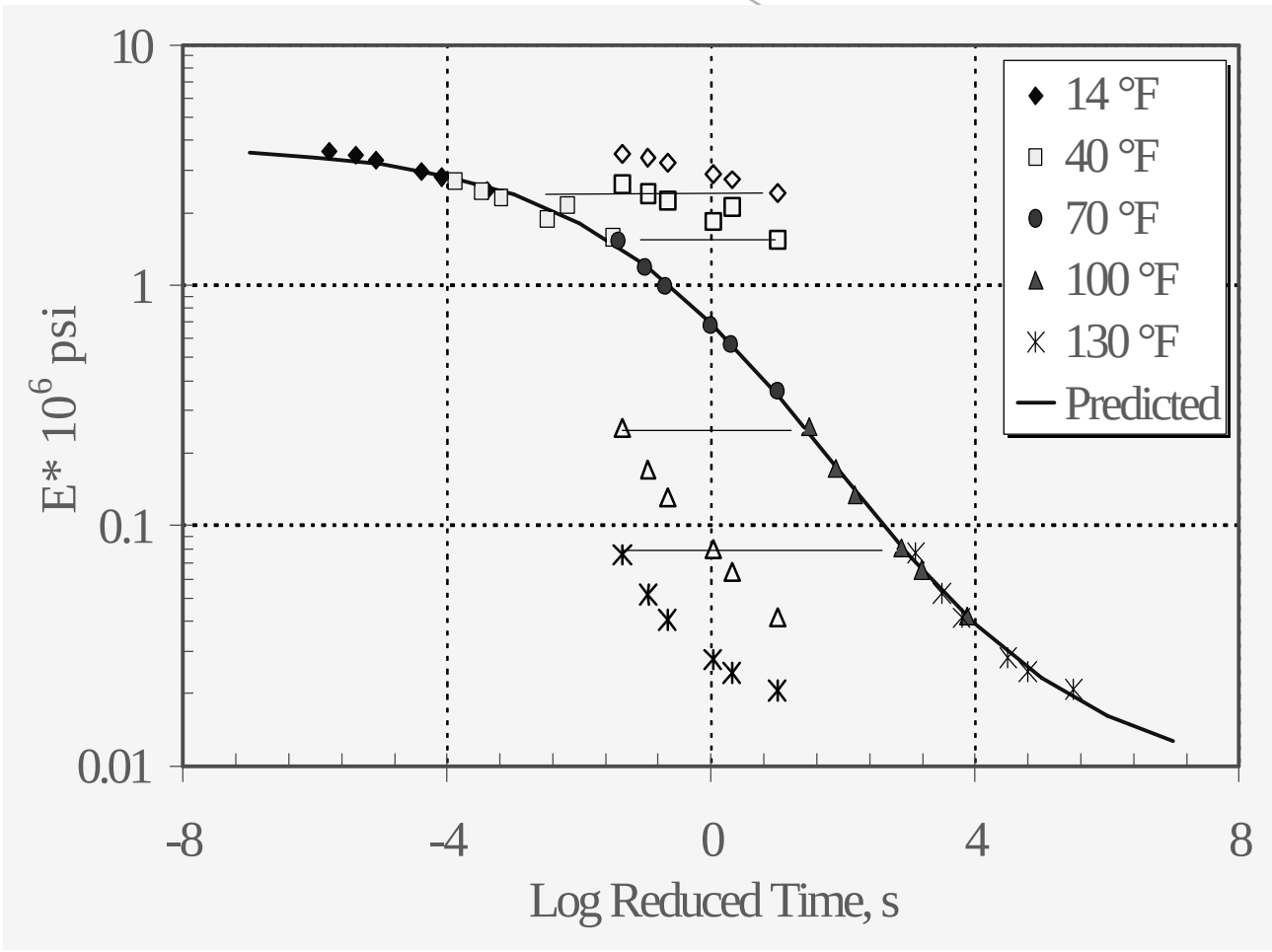
Sample E* Output



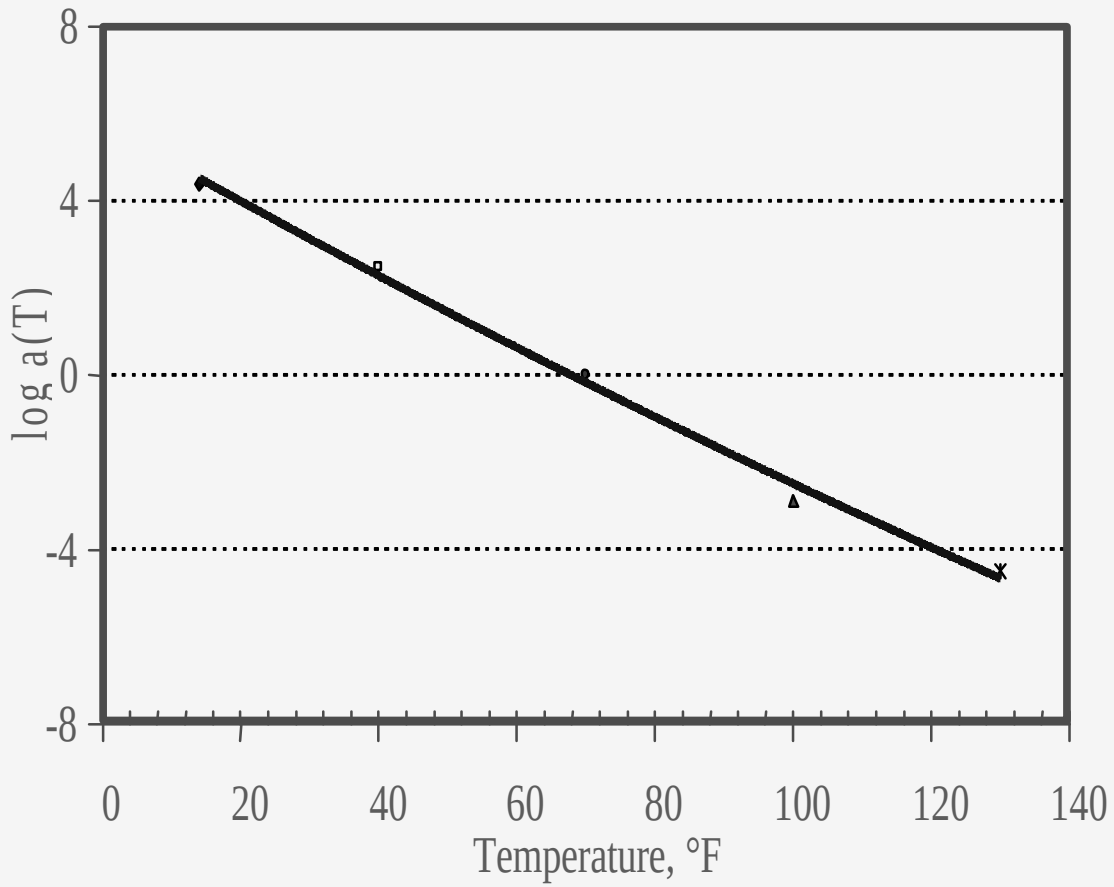
Computer Printout



Constructed Master Curve



Shift Factor



What have we learned to date?

- As stated previously, we hope to encounter and overcome any problems with the E* protocol. In other words, we would be in a position to advise DOT personnel on the pitfalls and problems in using this protocol. We have indeed had some problems.

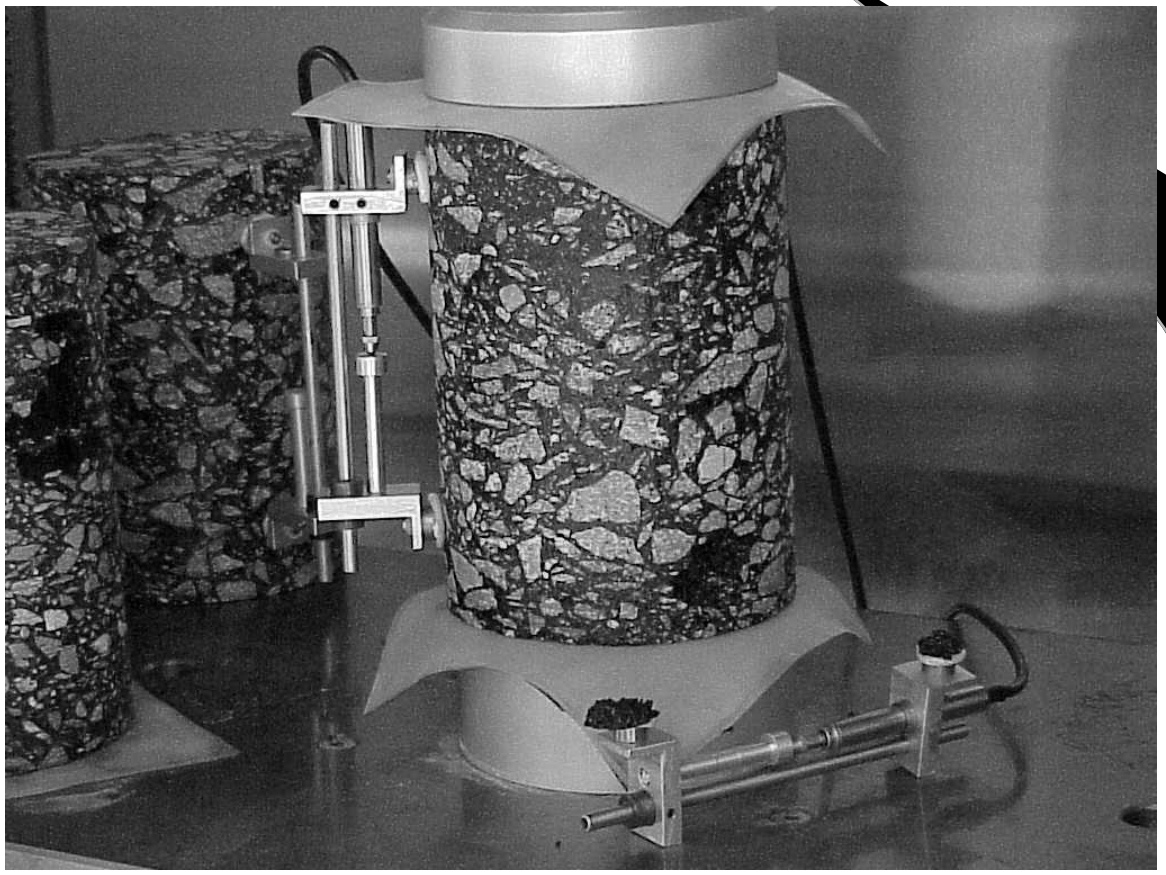
Protocol Changes

- Compaction of 7" high - 6" diameter sample was a problem. We finally wound up with a 6.7" high sample which would fit in our Superpave gyratory compactor. An e amount was sawn from each end to obta 6” sample. The tendency for the saw to i corners was over come by wrapping two turns of electrical plastic tape around the cu site before sawing.

Compaction & Specimen Tolerances

- It turns out that there were several versions of the protocol floating around the United States between 1999 and 2002. On 4/[illegible]02 there was a meeting to consolidate changes and provide a revised protocol for subsequent evaluation. This process was concluded in June 2002 and the resultant protocol used in remainder of the project.

Ruined Sample



Specimen Instrumentation

A template was developed and held in place with rubber bands to overcome alignment problems as gage plugs were glued onto sides of the test specimen

Instrumenting Test Specimen

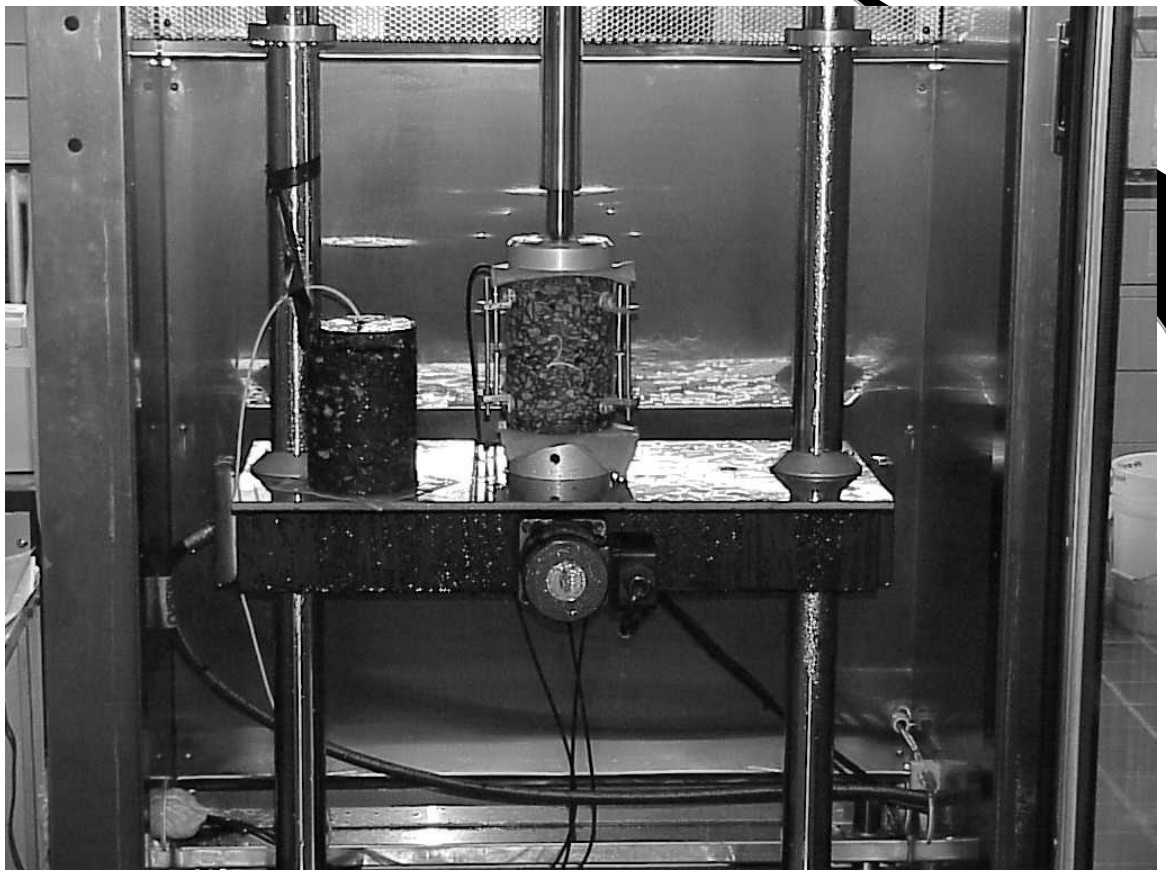
Fabrication & Test Timeframe

- Mix & Compact
- Instrument
- Test
- Construct Master Curve for Mix

Problems with test system

Based on the time to fabricate, prepare, instrument and test the specimens at five temperatures and six frequencies, a single test with two or more specimens will take well over seven full working days to complete. This is a very long time to complete one test. Conditioning the specimen to the test temperature is a big issue. We've also had difficulty in maintaining proper temperature and humidity in the test chamber.

Condensation



Icing Problem

The next slide contains an embedded Microsoft movie. Some older systems may not be able to play this movie.

If viewing these slides as a Powerpoint slide show the movie should start with one mouse click on the movie.

If viewing this in a Powerpoint editing mode then double click on the image.

The movie file is included on this CD. If you are unable to start the movie in Powerpoint then using Windows Media Player the movie should start.

If you need assistance getting the movie to play contact Jim Mahoney at (860) 486-5956

Possible result of Icing

(click image for movie - there is a short pause)

What we've learned to date

- Use clamps for coring & sawing
- Use jig to set gage points
- Base temperature on thermal couple in dummy specimens
- Set load for each frequency & temperature
- Test -10C only when humidity is low

E* Round Robin

- NCAT, Western SuperPave Center, FHWA, Applied Asphalt Technology
- 6 Universities
  - Arizona State
  - Connecticut
  - Maryland
  - North Carolina State
  - Perdue
  - Washington State

E* Tests of State Mixes

- California
- Connecticut
- Illinois
- Montana
- Nebraska
- Nevada
- North Carolina

Project Completion Date
April, 2003

Thank you for your interest and attention

LIGHTS on PLEASE