Additives in Asphalt

By

R. Gary Hicks

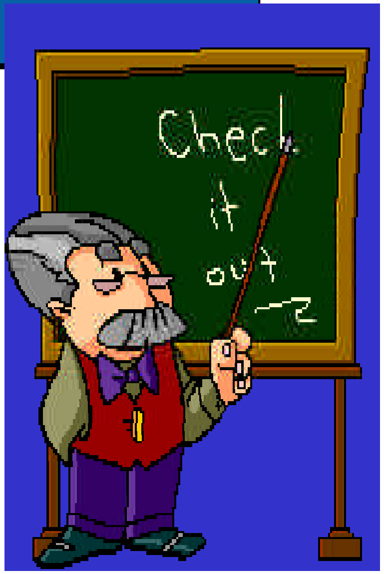
MACTEC E & C

For

2003 Pavement Summit

December 11, 2003

Additives in Asphalt - Topics



- ***Why modify ?***
- ***Types of additives***
- ***Selection & verification***
- ***Superpave Implications***
- ***Summary***

Why modify?

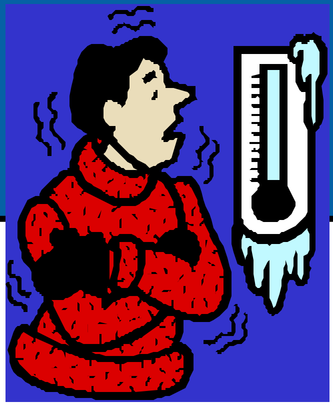
Improve pavement durability

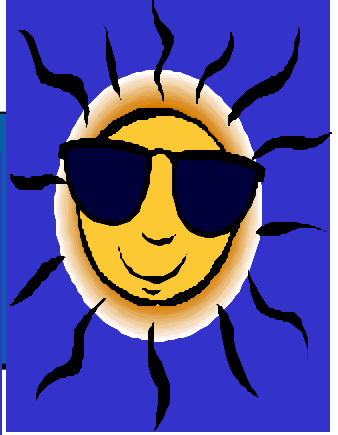
and

Lower life cycle costs

.

Why Modify?



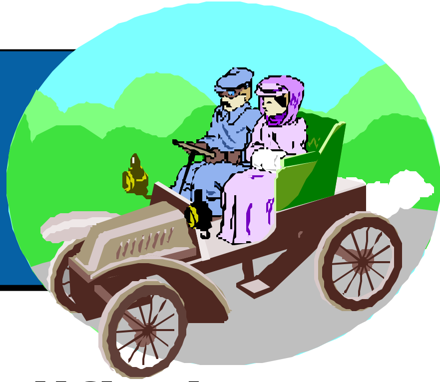


- Increase serviceable temperature range
  - Stiffen at high temperature
  - Soften at low temperature
  - Improve flexibility at all temperatures

Why Modify?

- Improve asphalt - aggregate bond
- Improve asphalt film thickness
- Reduce:
  - permanent deformation
  - cracking
  - draindown
  - pavement thickness
  - raveling
  - stripping
  - fatigue damage
  - life cycle costs

History



- ***1843 - British patent - polymer modified AC***
- ***1930's - Test projects in Europe***
- ***1950's - Neoprene Latex in U.S. & Canada***
- ***1970's - Wide use of polymers in Europe***
- ***1980's - Modified binders increase in U.S.***
- ***1990's - SHRP PG specs increase demand***

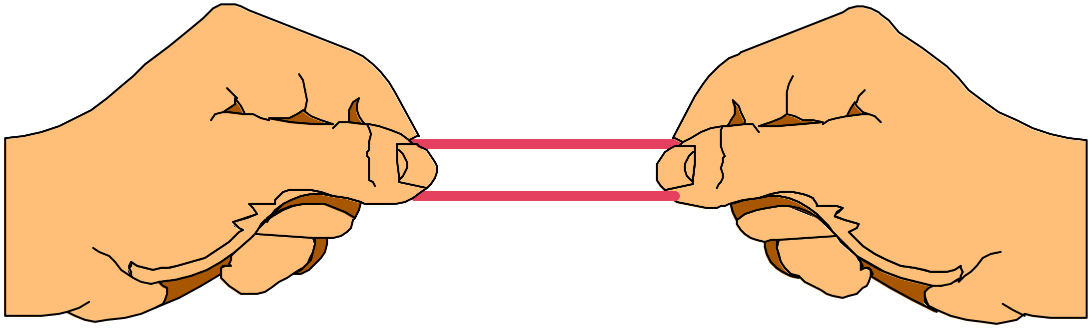
Modifiers

- Polymers
- Asphalt Rubber
- Chemical modifiers
- Fibers & Fillers
- Modification through processing

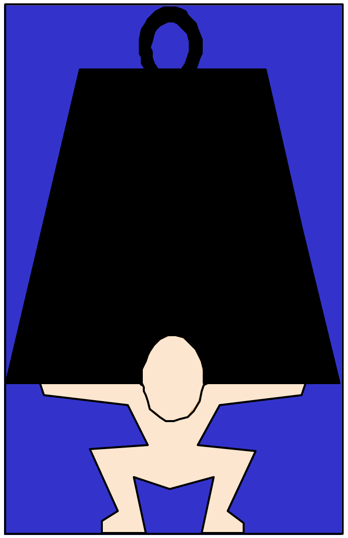
Polymers

Types of polymers

- Elastomers (or rubbers)



- Plastomers (or plastics)



Polymers

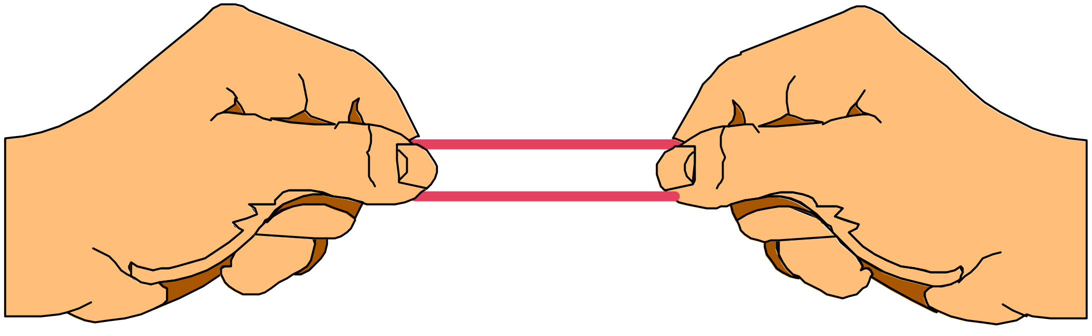
- *Elastomers*
  - *Block co-polymers, random polymers, natural & synthetic latex*
  - *Pre-blended or blended at HMA plant*
  - *Used in cold & hot AC paving applications*

Common Elastomers

- ***Styrene-butadiene block Copolymers (SB, SBS)***
- ***Styrene-butadiene rubber latex (SBR)***
- ***Natural rubber latex***

Elastomeric Polymers - Why?

- Temperature Susceptibility
- Strain Recovery
- Tensile Strength at high strains
- Cohesion
- Adhesion



Polymers

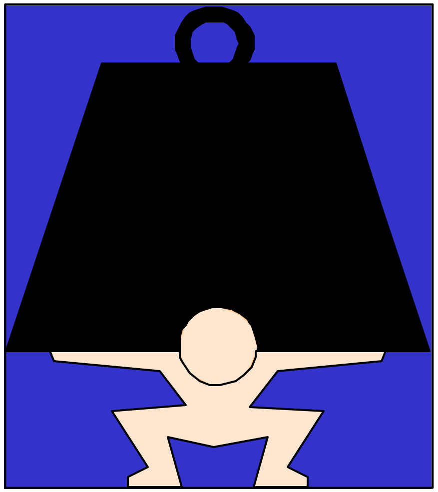
- Plastomers
  - Polyethylene & Ethylene Copolymers
  - Preblended or blended at hot mix plant
  - HMA paving applications

Typical Plastomers

- ***Ethyl vinyl acetate (EVA)***
- ***Polyethylene***
- ***Polypropylene***
- ***Polyolefins***

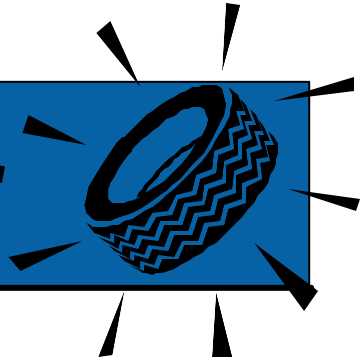
Plastomeric Polymers - Why?

- Temperature Susceptibility
- High modulus
- Tensile strength at low strains



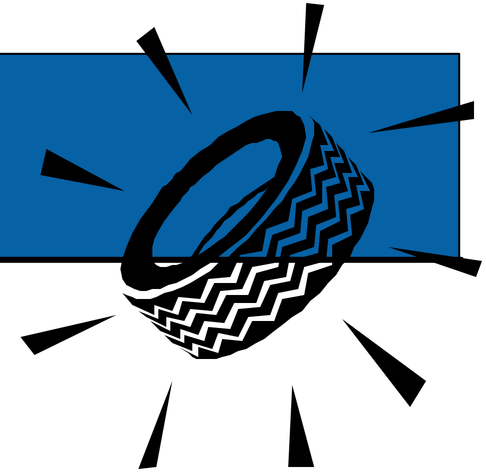
Asphalt Rubber

Asphalt Rubber



- ***Wet process***
  - ***Natural or Synthetic (SBR) rubber***
  - ***Pre-blended or added at HMA plant***
  - ***HMA / OGFC, Chip Seals, SAMI's***
- ***Dry process***
  - ***Added in cold feed at HMA plant***
  - ***HMA paving (e.g. Plus Ride)***

Asphalt Rubber



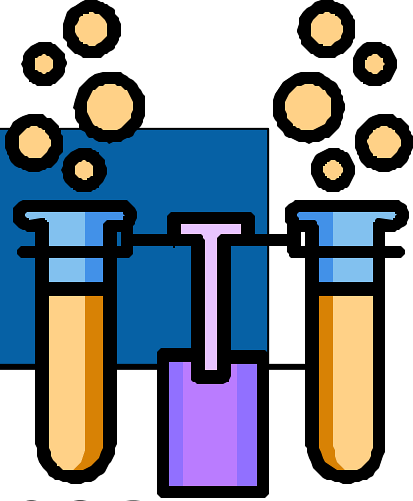
- Performance depends upon
  - process
  - type and size of crumb rubber
  - additives, stabilizers, de-vulcanization
  - application or use- mix/pavement design, climate

Asphalt Rubber - Why?

- Reduced lift thickness
- Temperature Susceptibility
- Elasticity
- Film thickness or durability
- Use of waste material

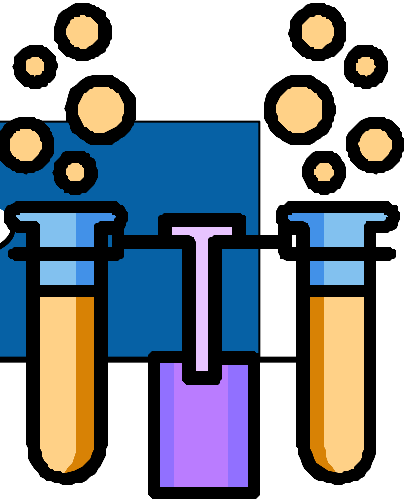
Chemical Modifiers

Chemical Modifiers



- Anti-stripping agents - amines
- Strong Acids / Bases
- Extender Oils
- Asphalt Extenders
  - Sulfur, Gilsonite

Chemical Modifiers - Why?



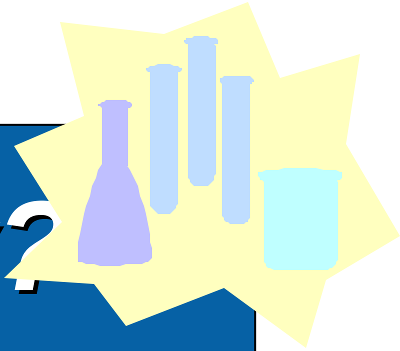
- Reduce moisture damage
- Increase AC film thickness
  - Reduce draindown during construction
- Extend PG Temperature Range (Lower costs)

Fibers & Fillers

Fillers & Fibers

- Lime
- Mineral fines
- Carbon black
- Waste materials
  - Mineral by-products
  - Polyethylene (HDPE)
  - Sawdust
- Trinidad Lake Asphalt
- Cellulose
- Polymeric fibers
- Synthetic mineral fibers

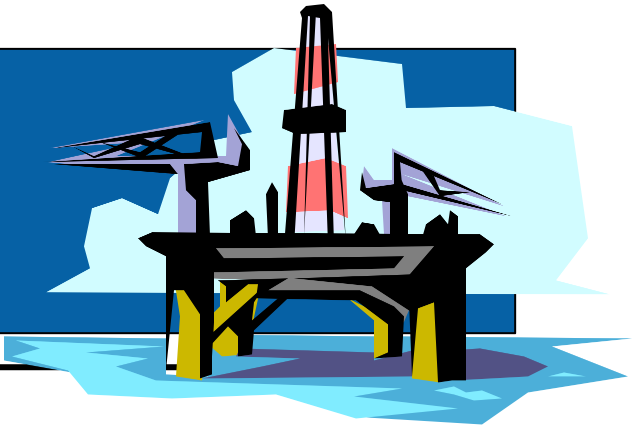
Fillers or Fibers - Why?



- **Fillers**
  - *Stiffen binder - higher mix modulus*
  - *Lime - anti-strip agent , clay flocculent*
- **Fibers**
  - *Increase mixture cohesion*
  - *Prevent draindown during construction for SMA / OGFC*

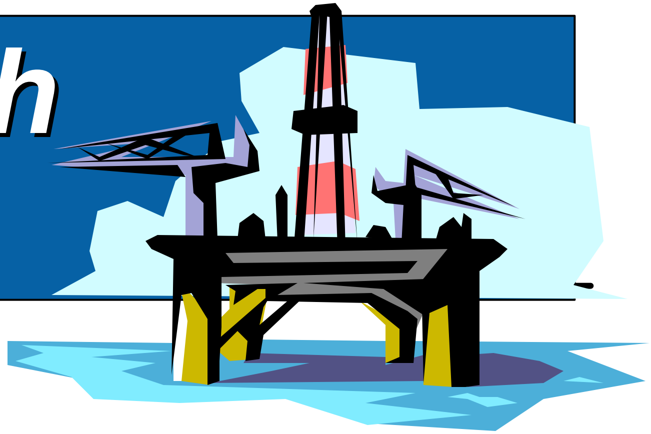
Modification Through Processing

Modification through processing



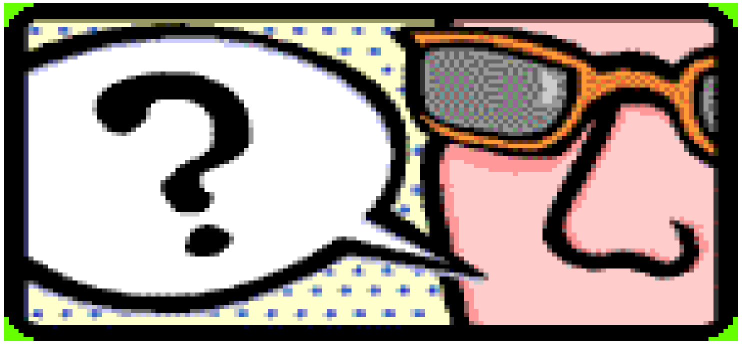
- ***Solvent de-asphalting***
- ***Air blowing / Oxidation***
- ***Vis-breaking***
- ***De-waxing***
- ***Caustic washing***

Modification through processing - Why?



- Roofing Industry
- Oil crisis of 70's - gasoline from heavy crudes
- Superpave
  - Extend PG Temperature Range at lower cost
  - Meet "stretch" PG grades
  - Upgrade low quality asphalts

Binder Selection and Modification

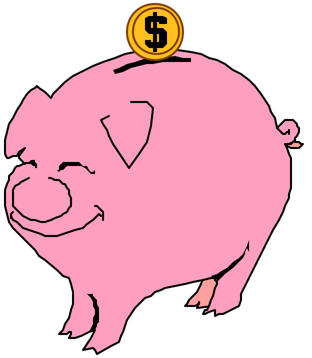


Binder / Modifier Selection & Verification

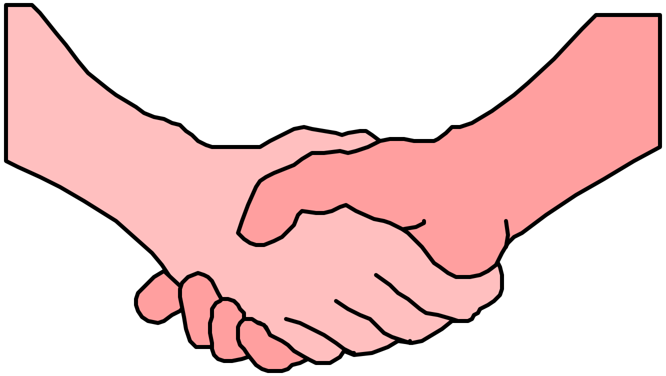
- *Pavement Temperature*
- *Traffic speed & load*
- *Pavement Structure*
- *Application*
- *Performance Testing*

Are the additives effective?

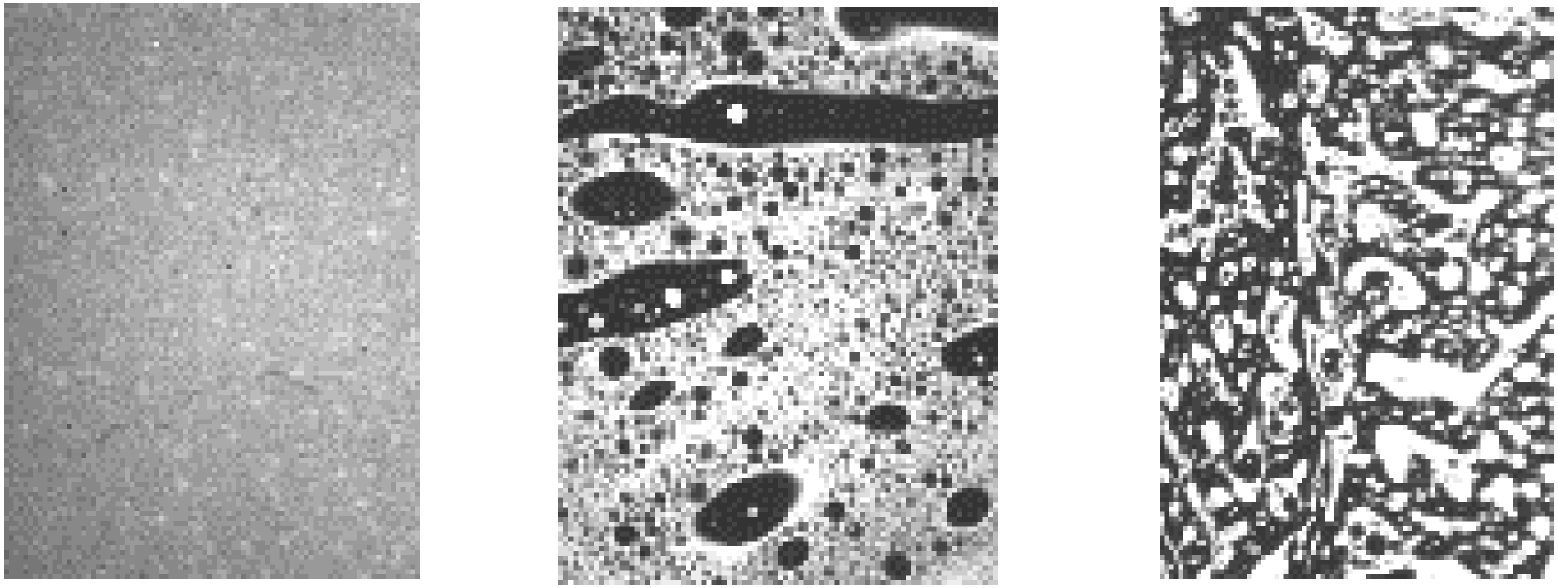
- ***Enhanced Pavement Performance***
  - ***<u>Stability/Compatibility</u> of the modifier in AC***
  - ***<u>Physical properties</u> of modified binders/mixture***



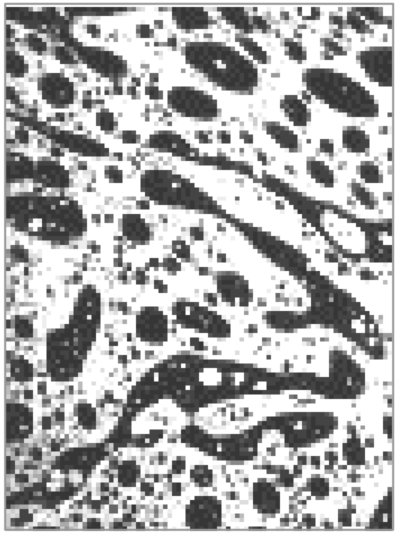
Compatibility



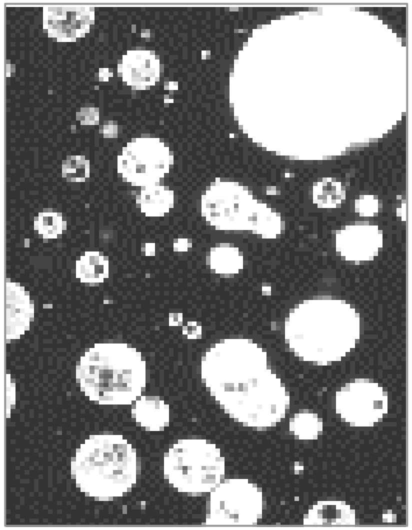
Photomicrographs of the same SBS polymer in 3 different asphalts



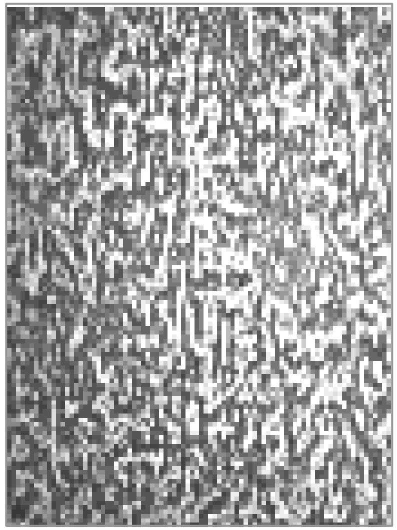
Different SBS polymers in the same asphalt



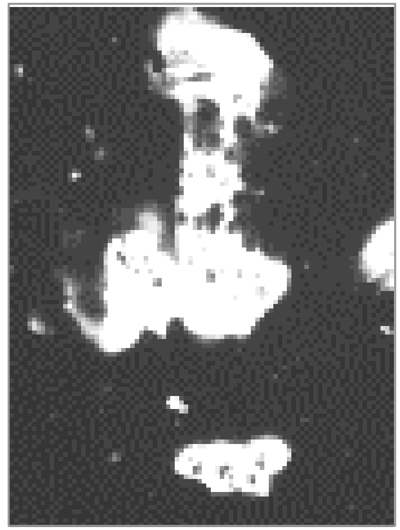
Asphalt A
Polymer A



Asphalt A
Polymer B

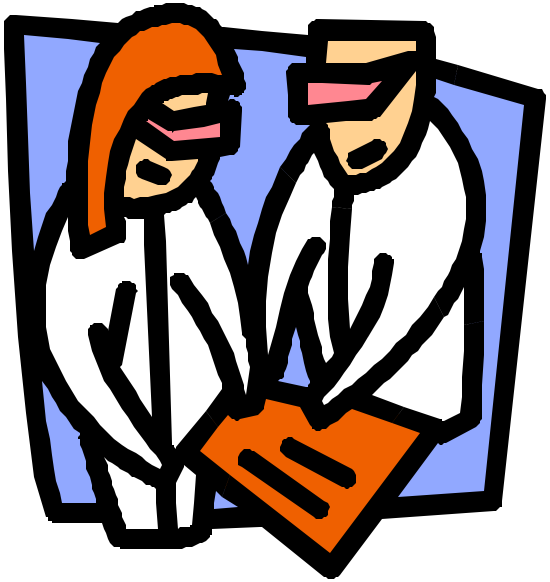


Asphalt B
Polymer A



Asphalt B
Polymer C

Physical property characterization of modified asphalt



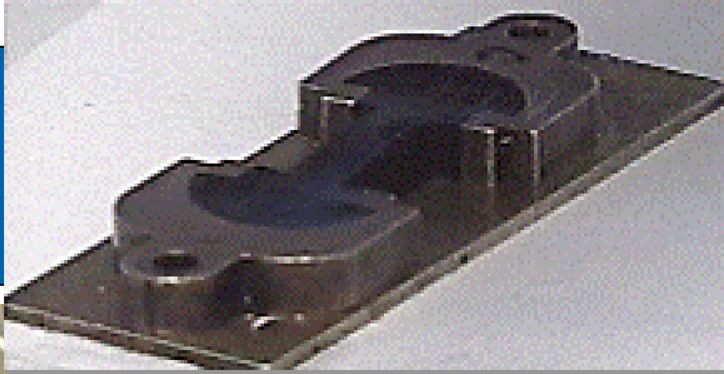
Specifications and Tests for Modified Asphalts

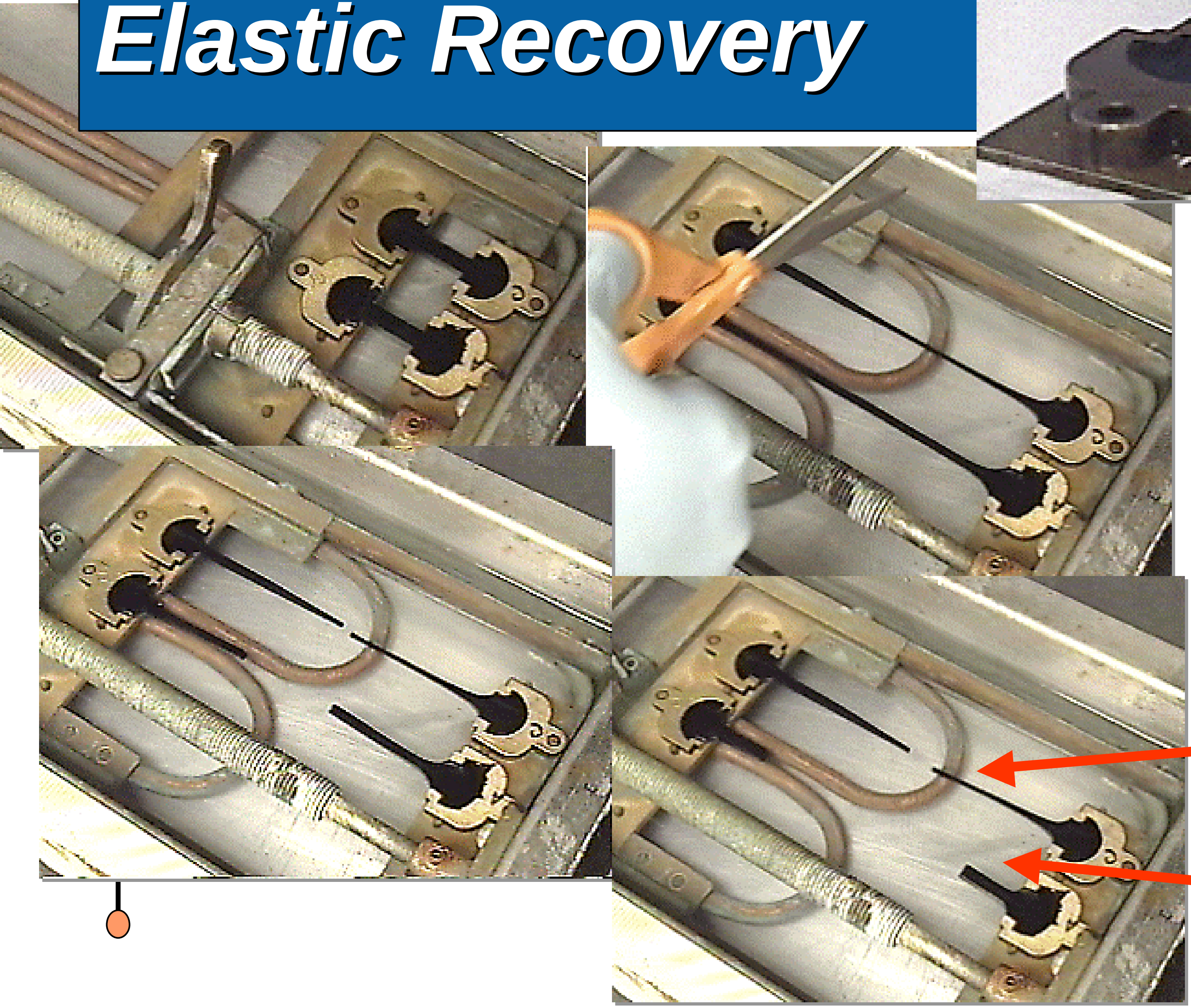
- ***Identify presence of specific modifier***
  - ***Task Force 31 (AASHTO, AGC, ARTBA) specs - Types I (SBS), II (SBR) and III (EVA)***
- ***Performance based - blind to modifier type***
  - ***West Coast PBA***
  - ***SHRP's Superpave PG binder spec***
- ***SHRP+ - PG grade with modifier identifier***
- ***SHRP II? –incorporates tests for modified binders***

Tests for Modified Asphalts - and products they favor (PG +)

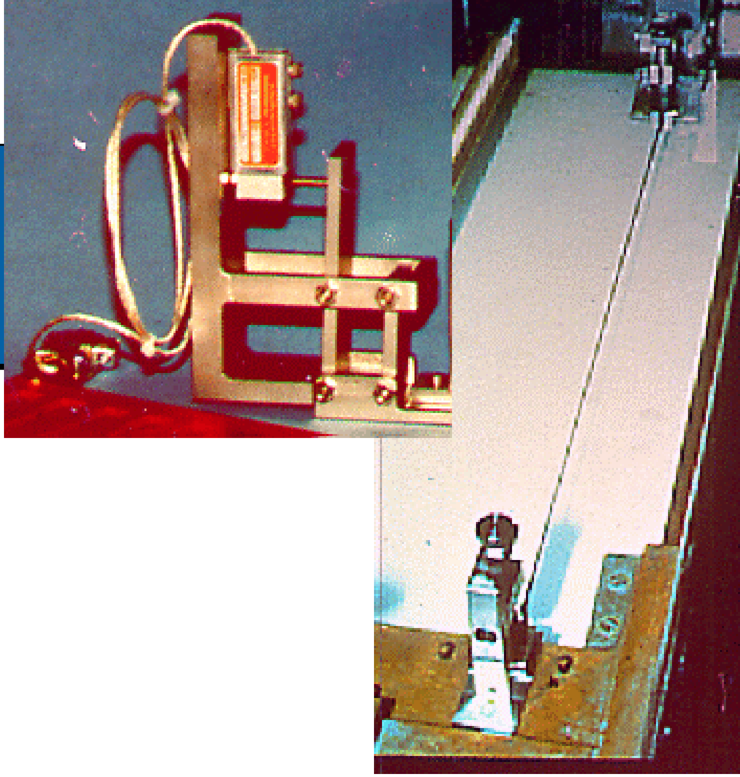
- ***Elastic Recovery -*** *recovery from deformation* ***(SBS)***
- ***Force Ductility -*** *strength at elongation* ***(SBS)***
- ***Toughness & Tenacity-*** *strength measure* *(****SBR, SBS)***
- ***Low temperature ductility-*** *low temperature behavior* ***(SBS)***

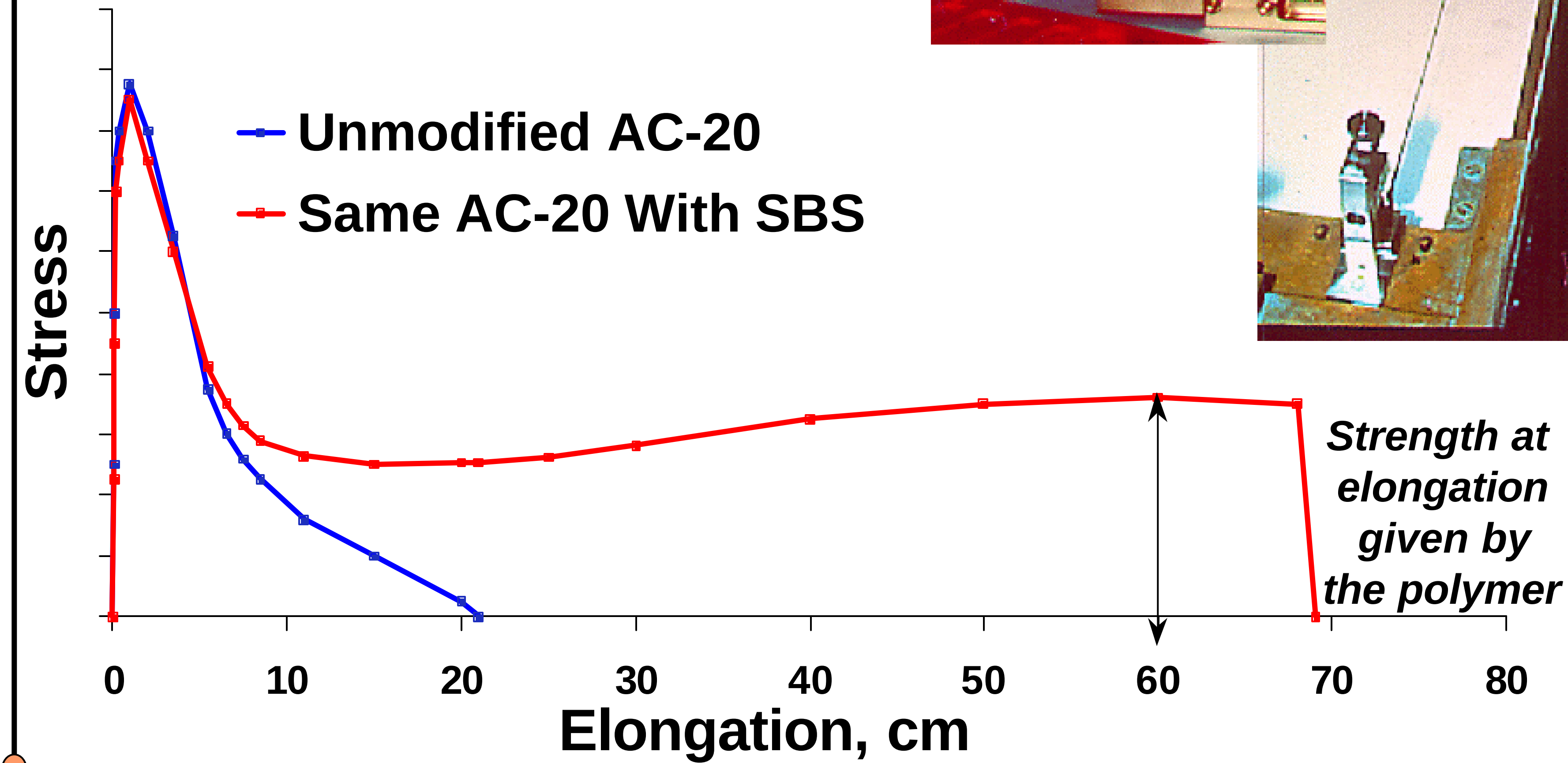
Elastic Recovery



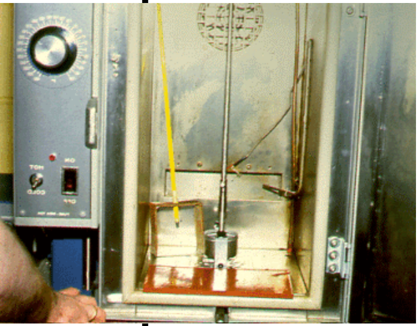


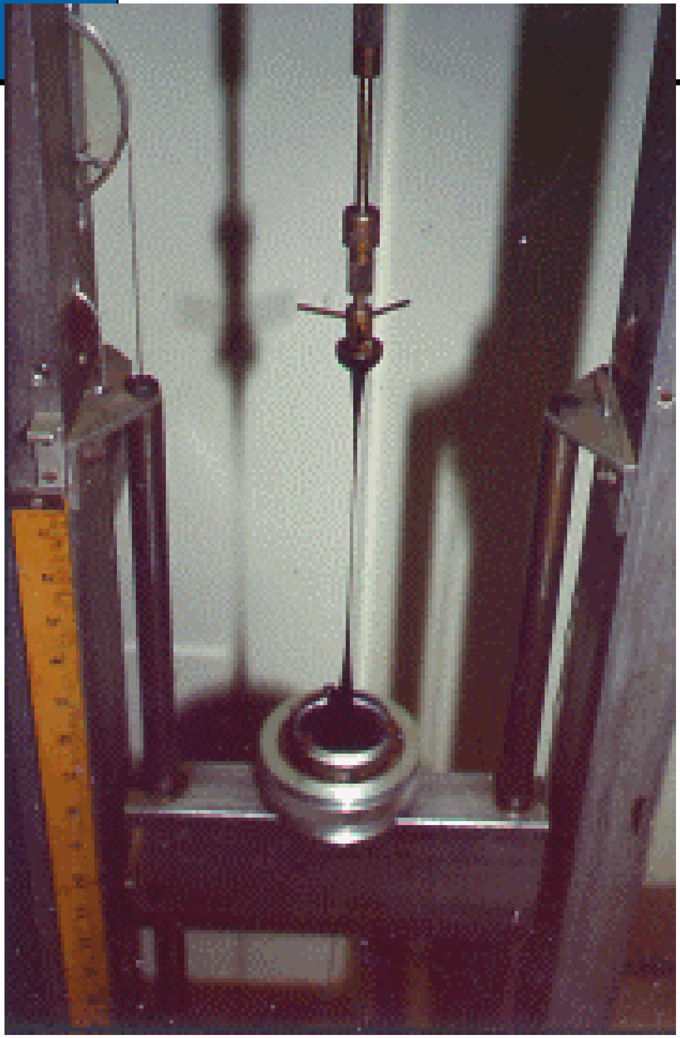
Force Ductility

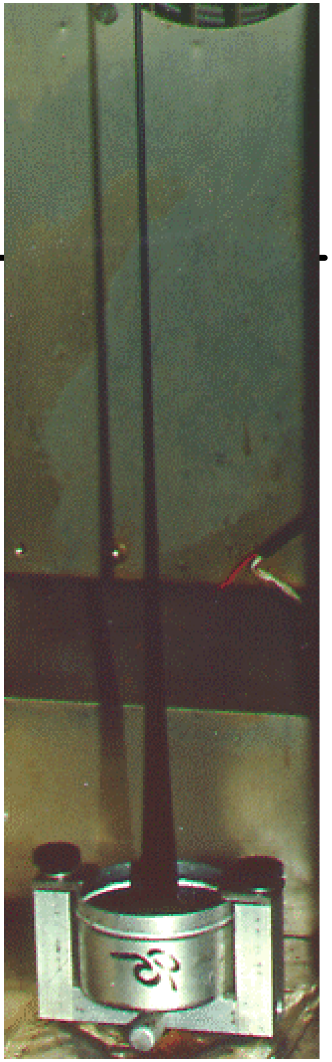




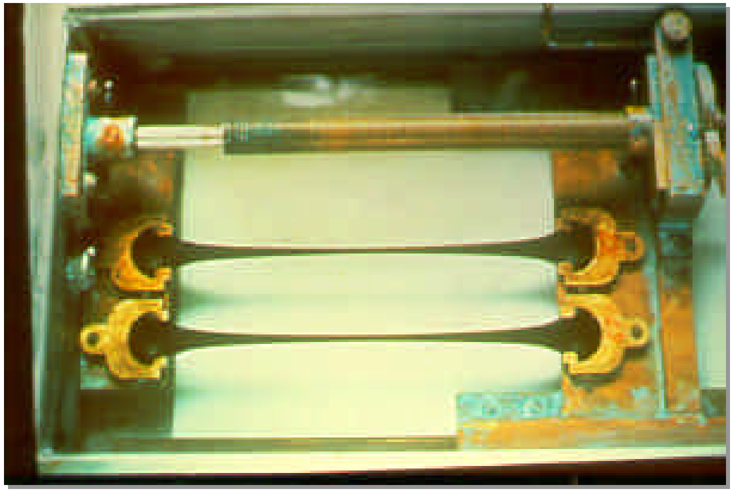
Toughness & Tenacity







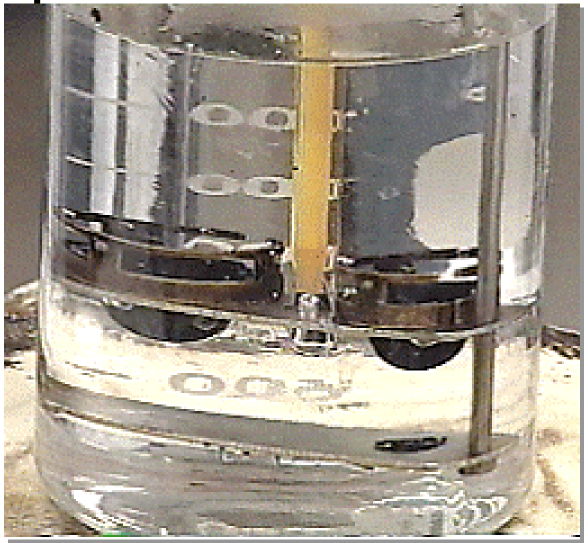
Ductility

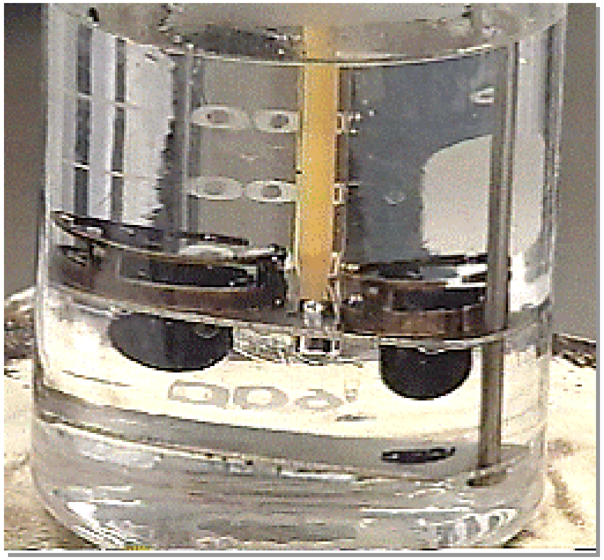


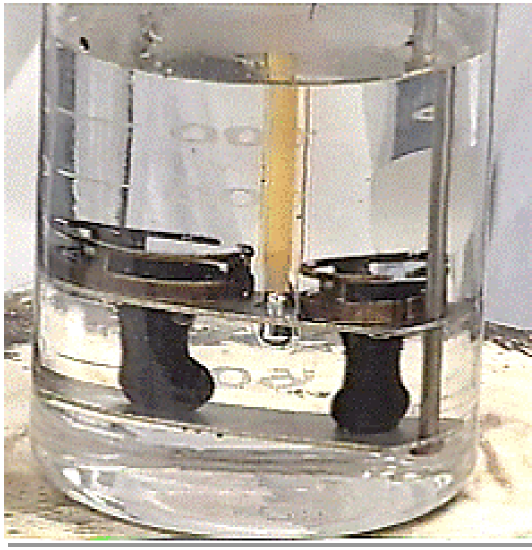
Tests for Modified Asphalts - and products they favor (con't)

- ***Ring and Ball Softening Pt -*** *high temp behavior* ***(gelled asphalt, oxidation, SBS, SBR, EVA)***
- ***% Polymer (e.g. FTIR, Fourier Transform Infrared) - recipe***
- ***Separation –*** *Are the materials homogeneous (compatible materials)?*

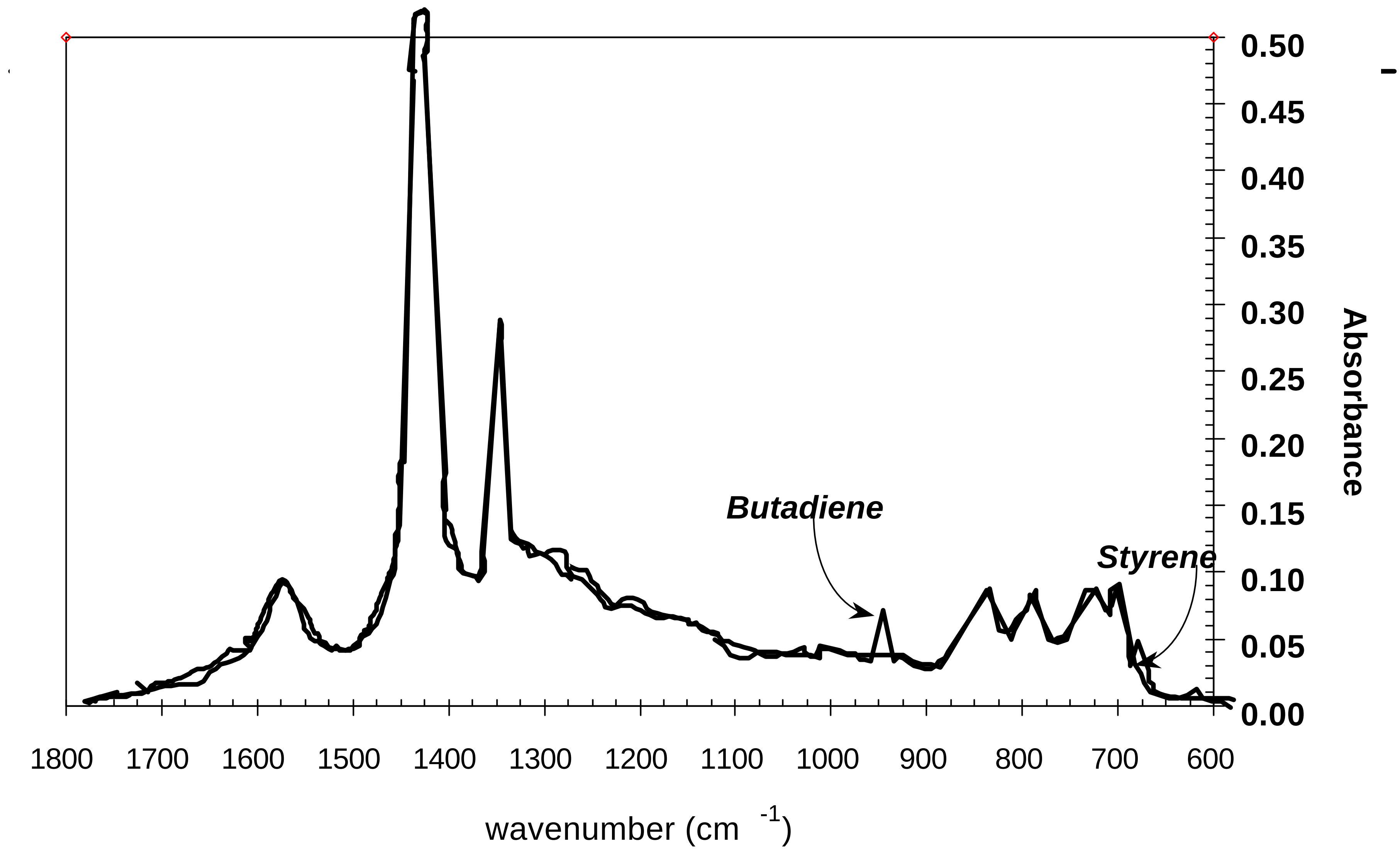
Ring & Ball Softening Point



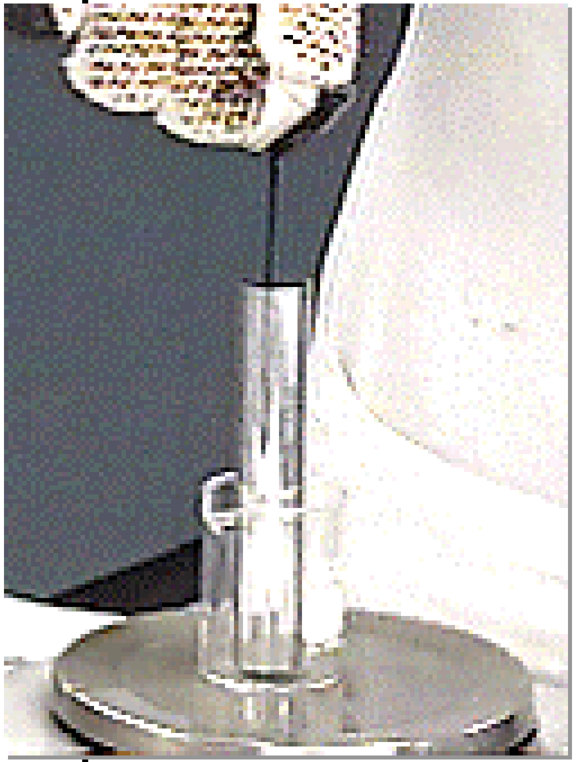


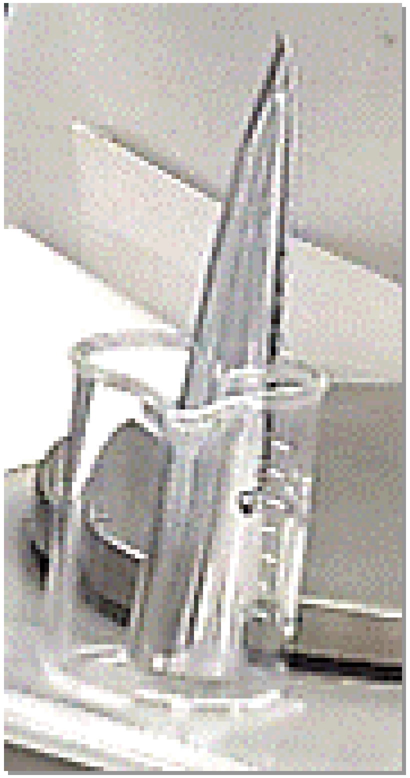


FTIR - SB(S) Modified AC



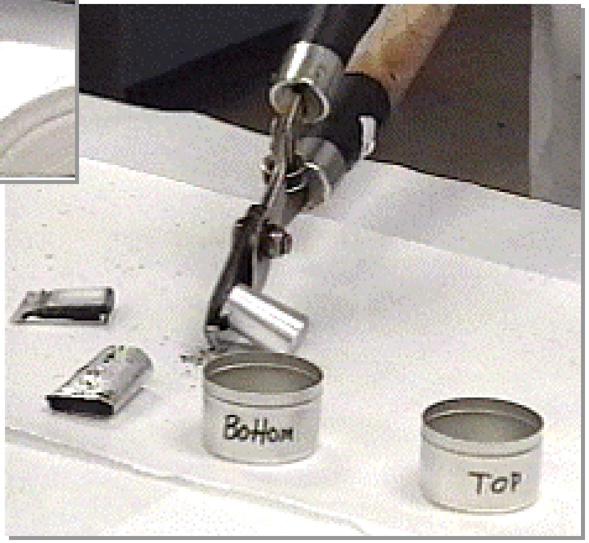
Separation Test

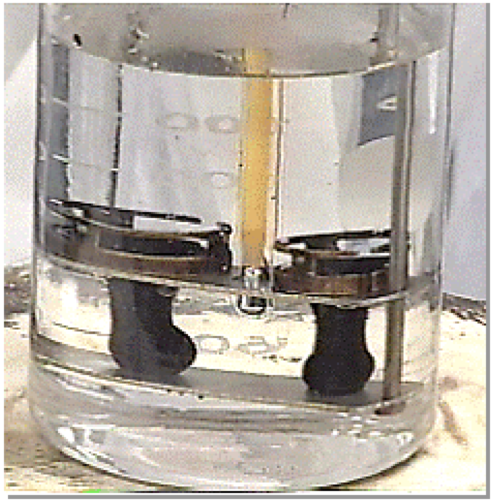




Separation Test

- *Tube cooled*
- *Cut into thirds*
- *Tested top & bottom (here, for ring & ball softening point)*





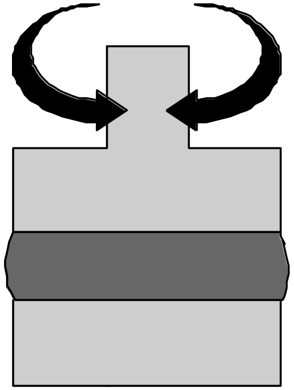
Does your state require additional tests?

PG+ specifications

- 27 states require extra tests (for some grades)
  - Elastic Recovery - 17 states
  - Separation - 6 states
  - Toughness & Tenacity - 5 states
  - Phase Angle - 5 states
  - Ductility - 3 states
  - Force Ductility - 2 states
  - Others: Solubility, Sieve, Viscosity, Spot, Smoke, Softening point, Infrared for polymer, APA

Superpave Performance Based Tests

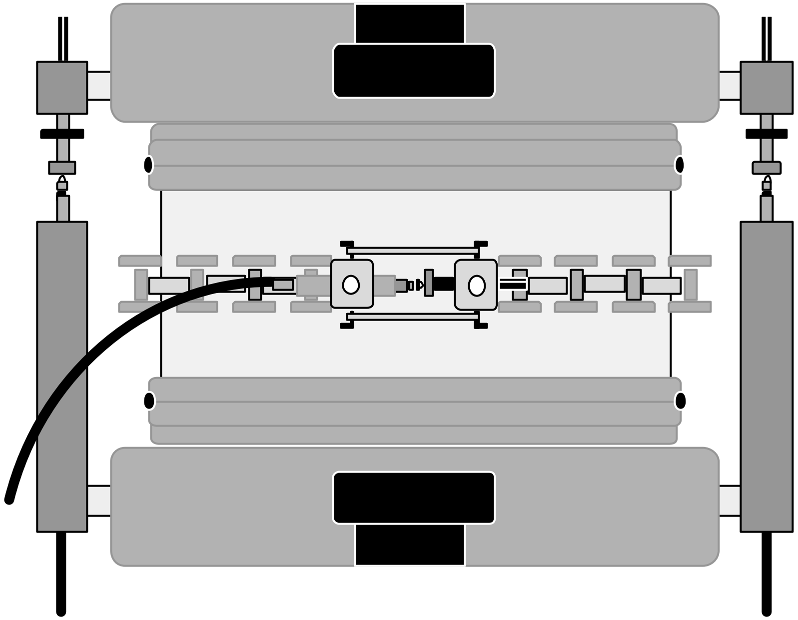
- Developed using unmodified AC's
  - Dynamic Shear Rheometry
  - Bending Beam Rheometry
  - Direct Tensile Test
- NCHRP 9-10
  - Methodology for modified binders



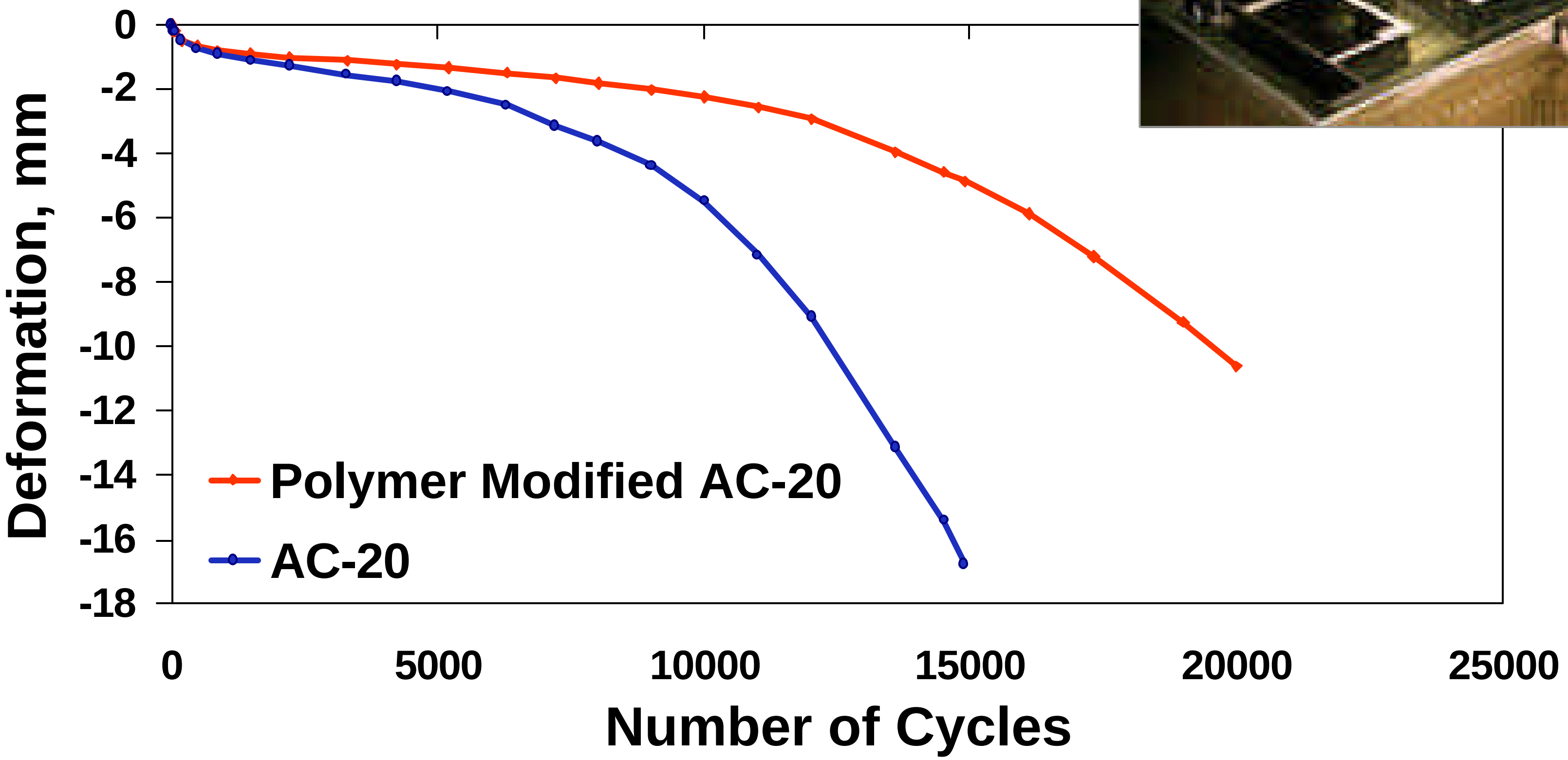
PG binders
Is spec blind to modifiers?

- ***PG for Modified Asphalt (NCHRP 9-10)***
  - ***DSR Fatigue parameter (G* x sin d)***
    - ***No correlation to mixture fatigue***
    - ***Use damage concept based upon dissipated energy ratio (DSR)***
  - ***DSR Rutting parameter (G*/sin d)***
    - ***Prefer repeated creep accumulated strain (DSR)***
  - ***Binder homogeneity/separation - LAST test***
  - ***Mix and compaction temperatures – Zero shear viscosity***

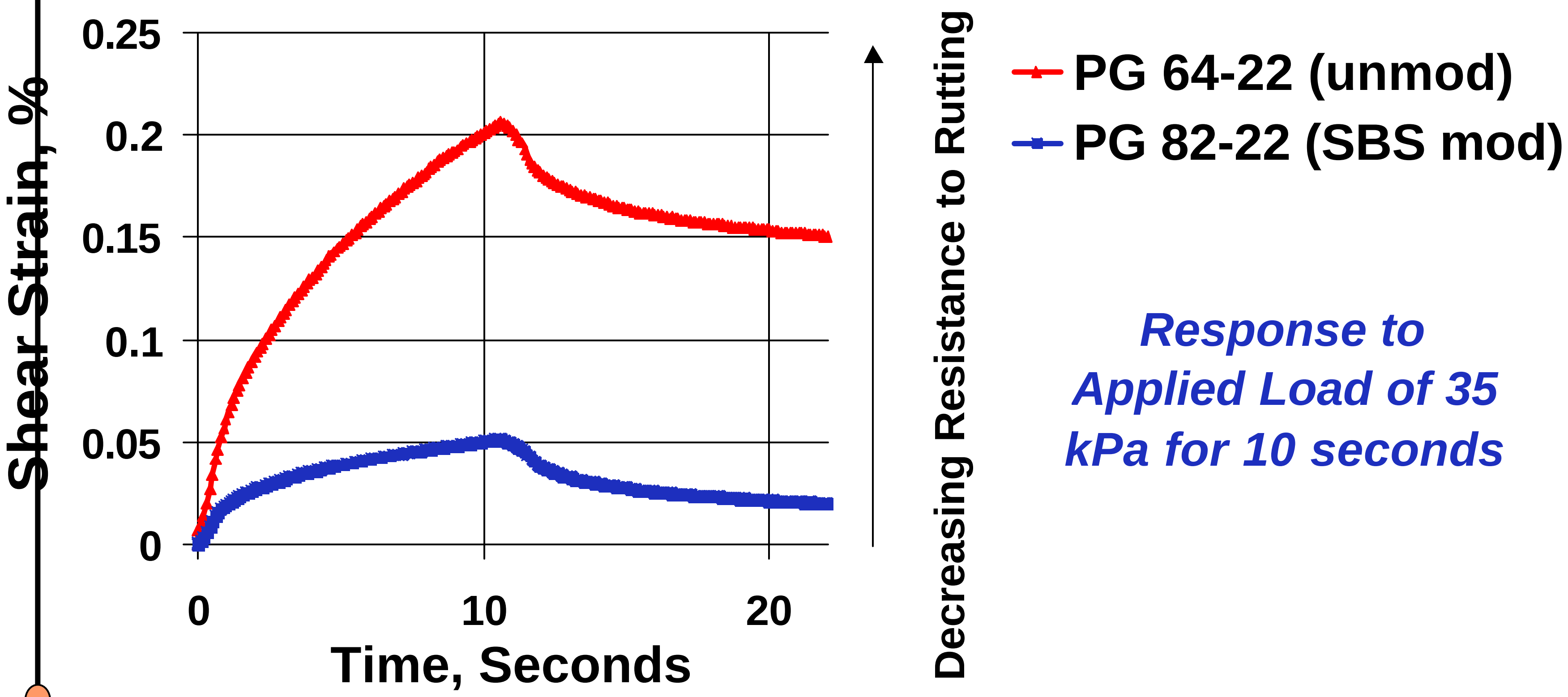
Performance of Modified Mixes



Hamburg Wheeltracking
Same AC-20 unmodified & modified



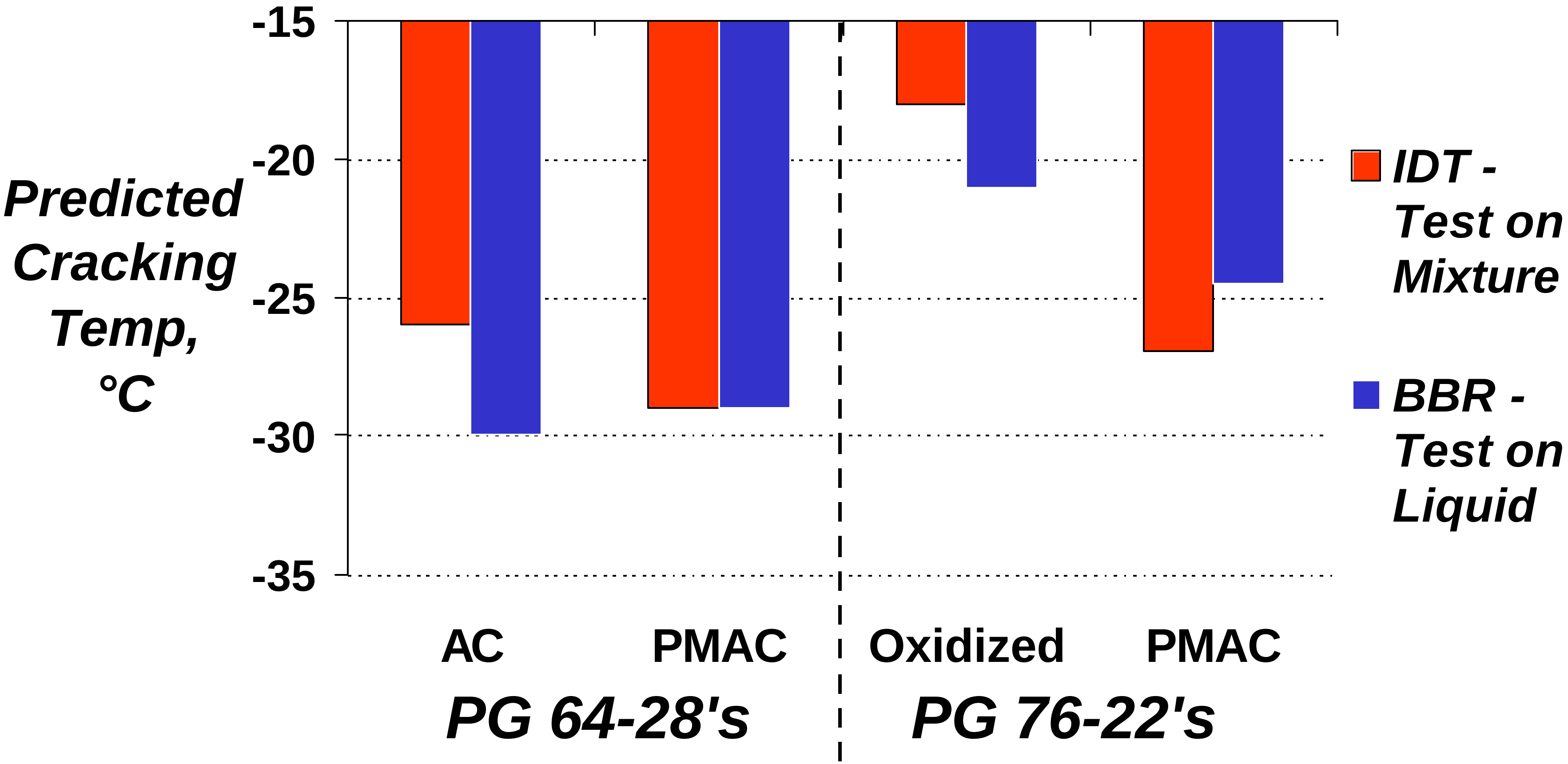
Permanent Deformation
SST Shear Creep Test, 40°C
FHWA ALF Surface Mixture



Response to Applied Load of 35 kPa for 10 seconds

Thermal Cracking

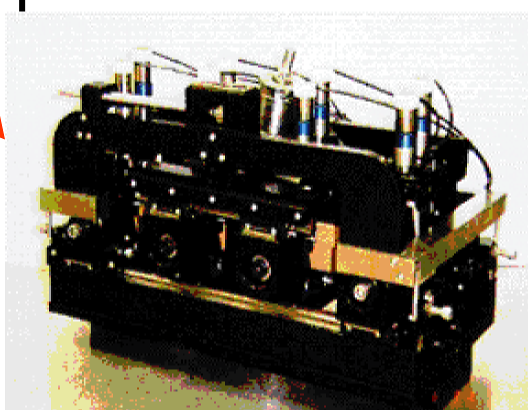
Indirect Tensile & Bending Beam Predictions

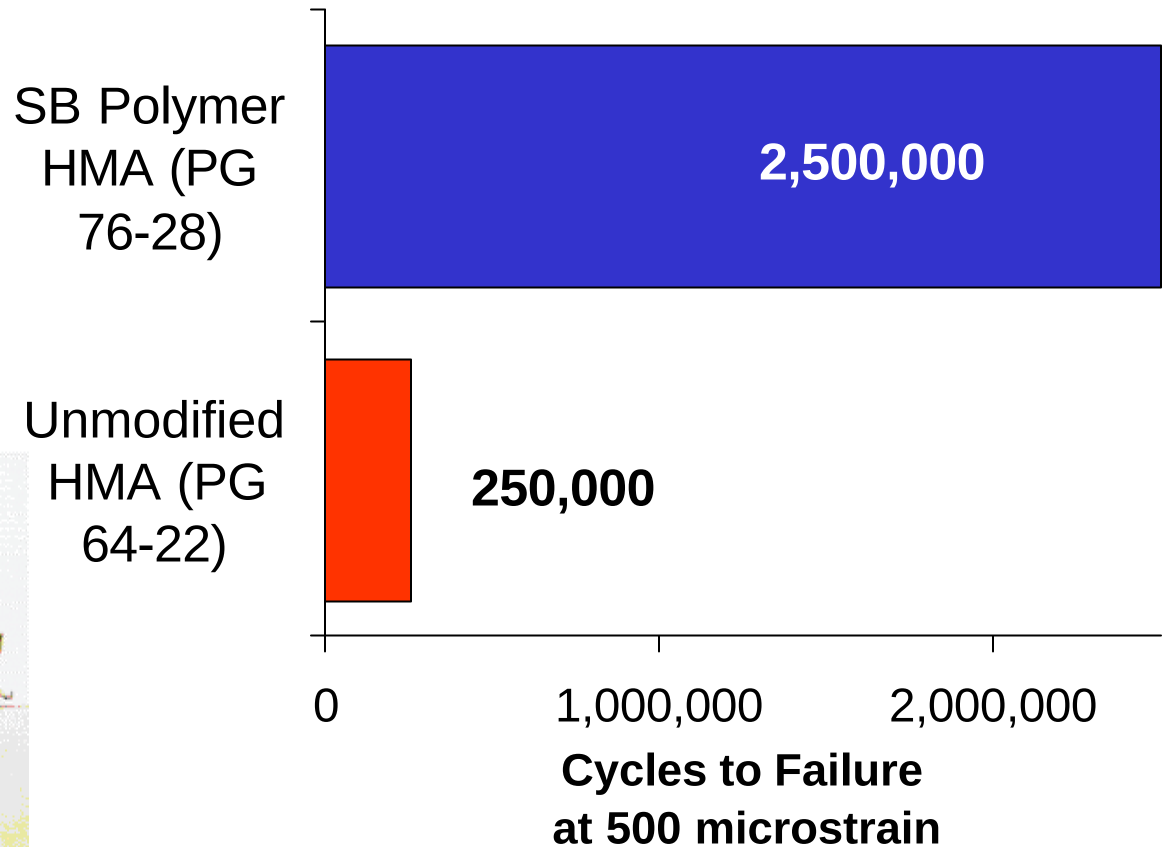


Durability

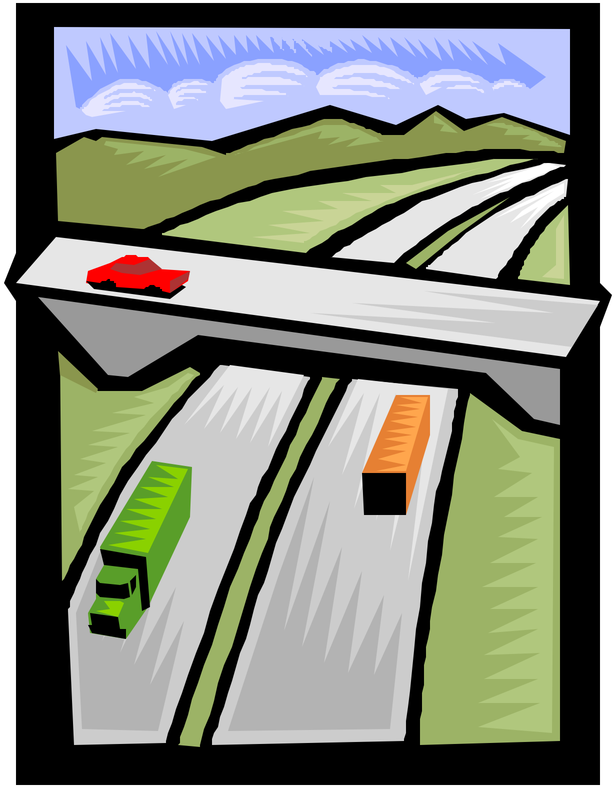
Resistance to Fatigue Cycling

Flexural Beam Fatigue Test, AASHTO TP-8

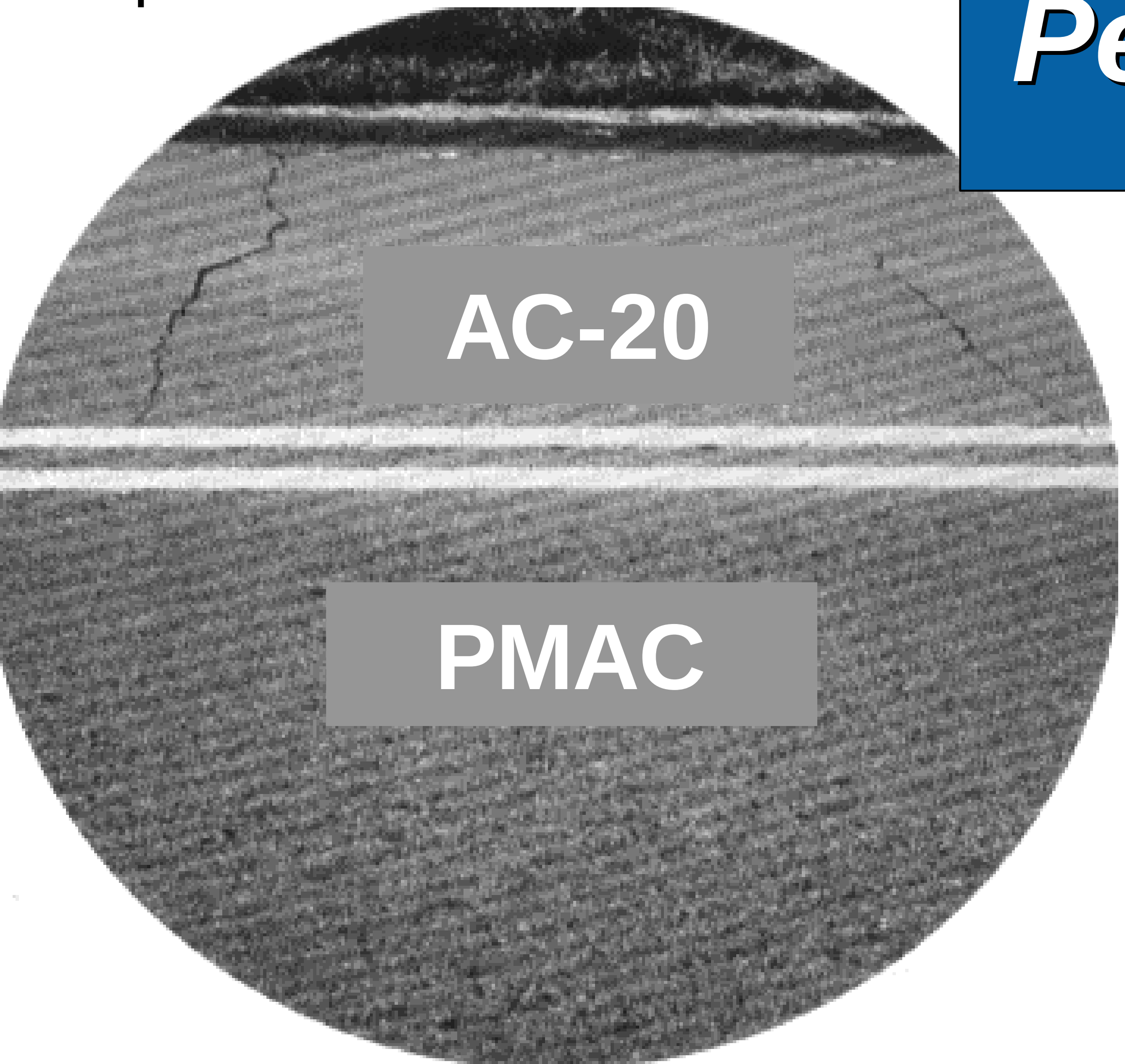




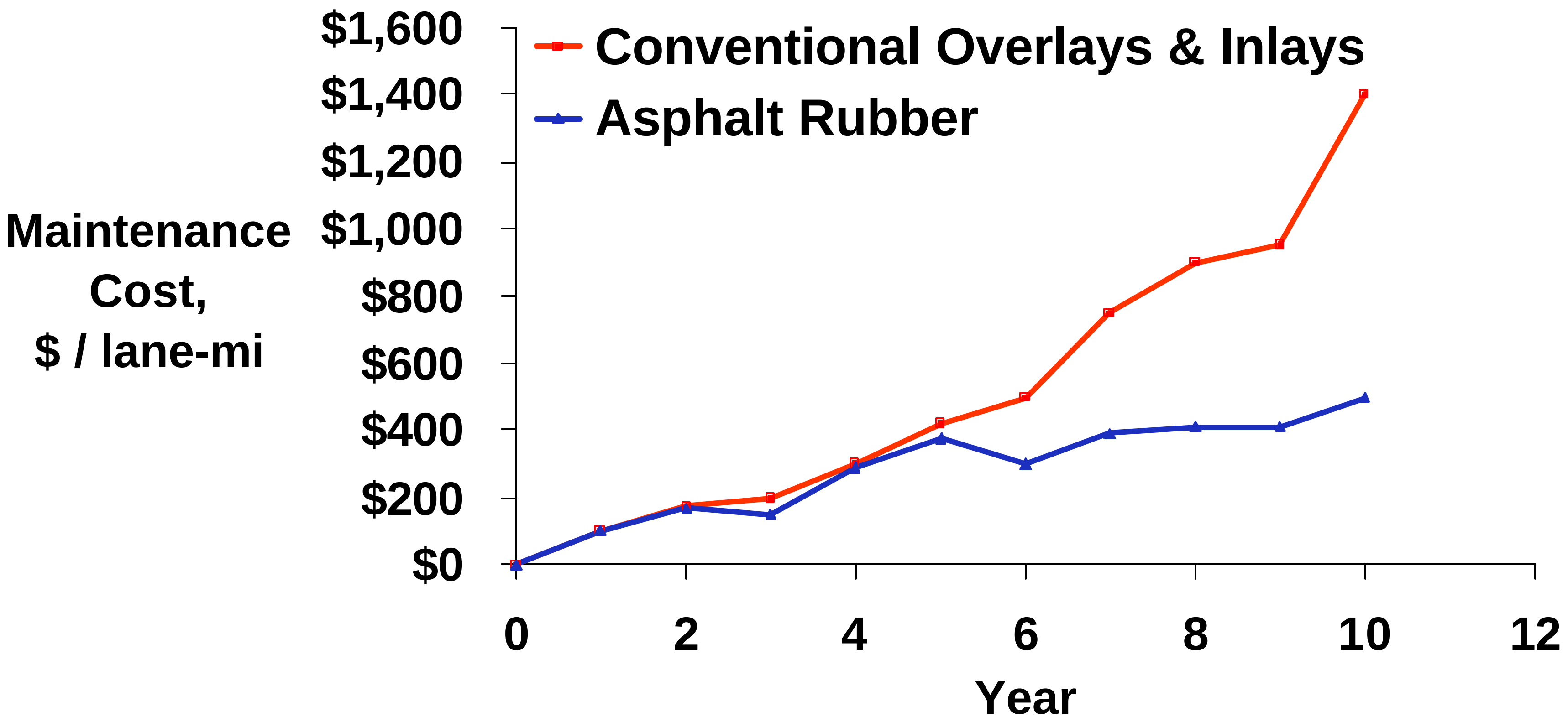
Field Performance



Why Modify? Performance



Arizona Experience with CRM
Reduced maintenance costs



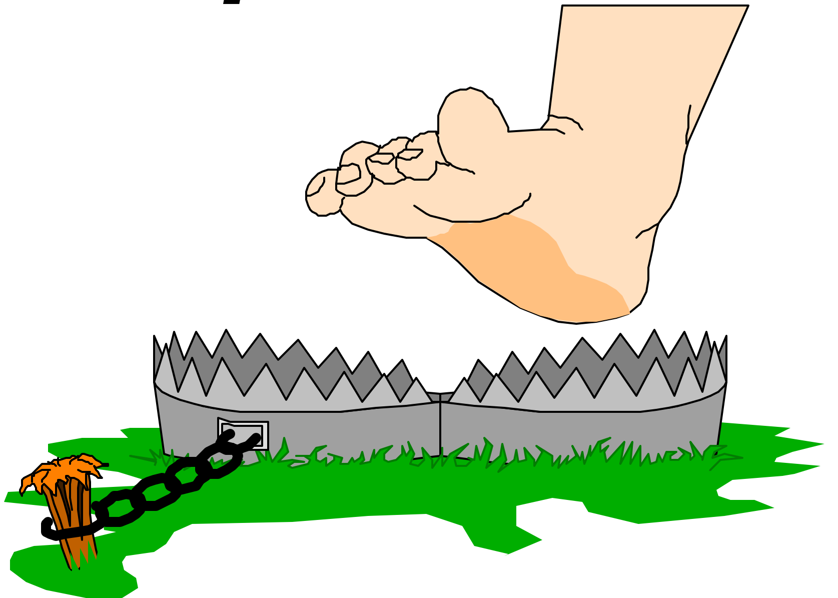
George Way, ADOT, 1998

Other Field Trials & Life Cycle Cost Comparisons

- *Texas: Jones, Kennedy & Torshizi, TRB, 1993*
- *Michigan: Hawley & Baladi, MDOT, 1996*
- *California: Reese & Goodrich, AAPT, 1993*
- *Kentucky: Blankenship, et. al., AAPT, 1998*
- *Canada: Carrick & Fraser, CTAA, 1996*
- *Pennsylvania: Anderson & Maurer, TRB, 1999*
- *Many others*

Implications

Do the PG specs include the desired properties to ensure field performance?



Summary

- ***Additives have been used to improved pavement performance***
- ***Additives are used to modify the grade of the asphalt, but the performance of the additives in the mix can vary***
- ***Binder specifications alone do not guarantee good field performance***

Summary

- ***PG binders have reduced rutting & low temperature cracking failures***
- ***PG binders give more consistent quality, but still need better characterization of modified materials***
- ***Mixture tests are needed to insure that the additive will perform as expected in the field.***

Thanks

Any Questions?