Illinois Bituminous Paving Conference

The 56th Illinois Bituminous Paving Conference

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I-Hotel

Champaign, Illinois

Asphalt Modification

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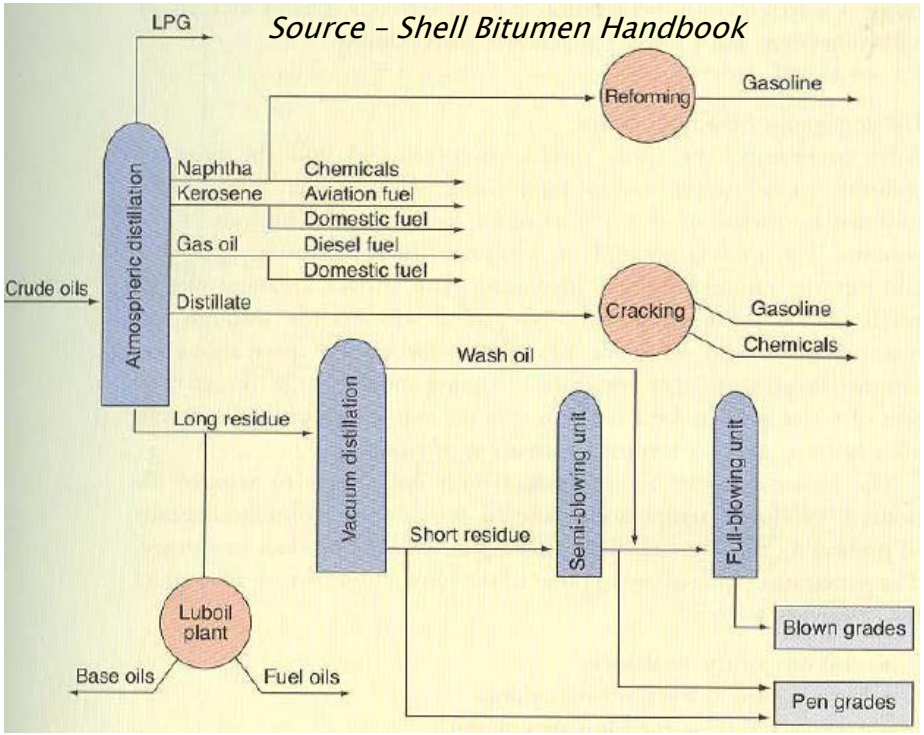
Abatech, Inc.

Asphalt modification

- Historical
  - Asphalt modification dates to 100+ years – depending on definitions!
    - Oils and refinery processes early 1900's
    - Asphalt rubber – 1950's
    - Many others since
- Why do it?

What is asphalt

- Asphalt (or bitumen)
  - Residual from refinery process (or natural)
  - Process has become more complex with advent of better refinery processes

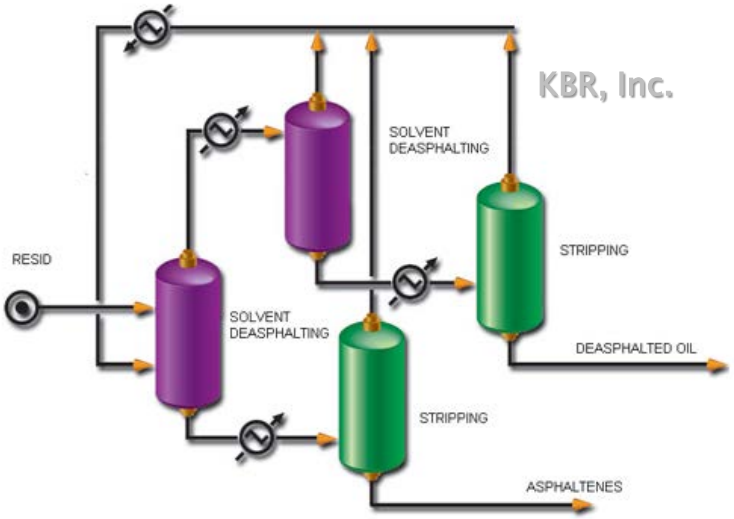


Why we modify

- Address deficiency in specification compliance
- Addresses deficiency in performance
- Enable use of products that may otherwise not be suitable
- Value added to extend margins

Types of asphalt modification

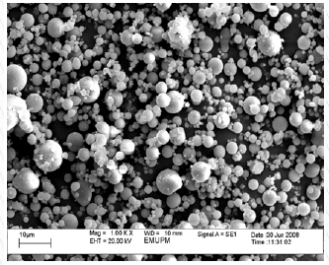
- Refining Process
  - Examples – Propane-Precipitated Asphalt (PPA), Oxidation Process, Residuum Oil Supercritical Extraction (ROSE) process, etc.
  - Examples
    - Production of oxidized grades, BND grades, etc.
- Material additions
  - Polymers (rubbers, plastics), Waxes, Resins, Hard/Natural Asphalts, Oils (various types), Powders (Carbon Black, dusts, fillers, etc.), Anti-strip additives, extenders (Sulphur), etc.

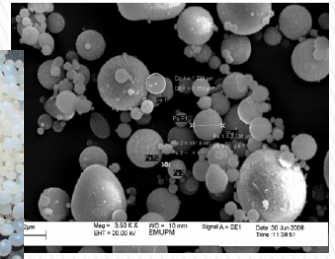


A partial list .....

- Chemical modifiers
  - Organo-metallic compounds
  - Sulphur
  - Lignin
- Fibers
  - Cellulose
  - Alumina-magnesium silicate
  - Glass fiber
  - Asbestos
  - Polyester
  - Polypropylene
- Adhesion improvers
  - Organic amines
  - Amides
  - Organo- Silanes
- Antioxidants
  - Amines
  - Phenols
  - Organo-zinc
  - Organo-lead compounds
- Natural asphalts
  - Trinidad Lake Asphalt
  - Gilsonite
  - Rock asphalt
- Fillers
  - Carbon black
  - Hydrated lime
  - Lime
  - Fly ash
- Thermoplastic elastomers
  - Styrene-butadiene-styrene (SBS)
  - Styrene-butadiene-rubber (SBR)
  - Styrene-isoprene-styrene (SIS)
  - Styrene-ethylene-butadiene-styrene (SEBS)
  - Ethylene-propylene-diene terpolymer (EPDM)
  - Isobutene-isoprene copolymer (IIR)
  - Natural rubber
  - Crumb tire rubber
  - Polybutadiene (PBD)
  - Polyisoprene
- Thermoplastic polymers
  - Ethylene vinyl acetate (EVA)
  - Ethylene methyl acrylate (EMA)
  - Ethylene butyl acrylate (EBA)
  - Atactic polypropylene (APP)
  - Polyethylene (PE)
  - Polyvinyl chloride (PVC)
  - Polystyrene (PS)
- Thermosetting polymers
  - Epoxy resin
  - Polyurethane resin
  - Acrylic resin
  - Phenolic resin
- Warm mix modifiers
  - Chemical amines, oils, etc.
  - Waxes
  - Zeolites
- Chemical
  - Organo-metallic compounds
  - Sulphur
  - Poly-phosphoric acid
  - Lignin
- Oils
  - Naphthenic
  - Aromatic
  - Paraffinic
  - REOBs

Too many to consider in detail – we will talk with view to general requirements!





Sources – Shell Bitumen Handbook and Abatech

What is an ideal binder?

- For a given climate
  - **Low pavement temperature** – Adequate flexibility at low temperatures, low stiffness and good relaxation properties to resist cracking
  - **High pavement temperature** – Sufficient stiffness and elastic properties that permanent flow will not occur
  - **Compaction temperatures** – Sufficient mobility to allow compaction to occur
  - **Mixing temperatures** – Adequate flow and coating properties to obtain wetting of aggregate with binder and to ensure good coating is maintained

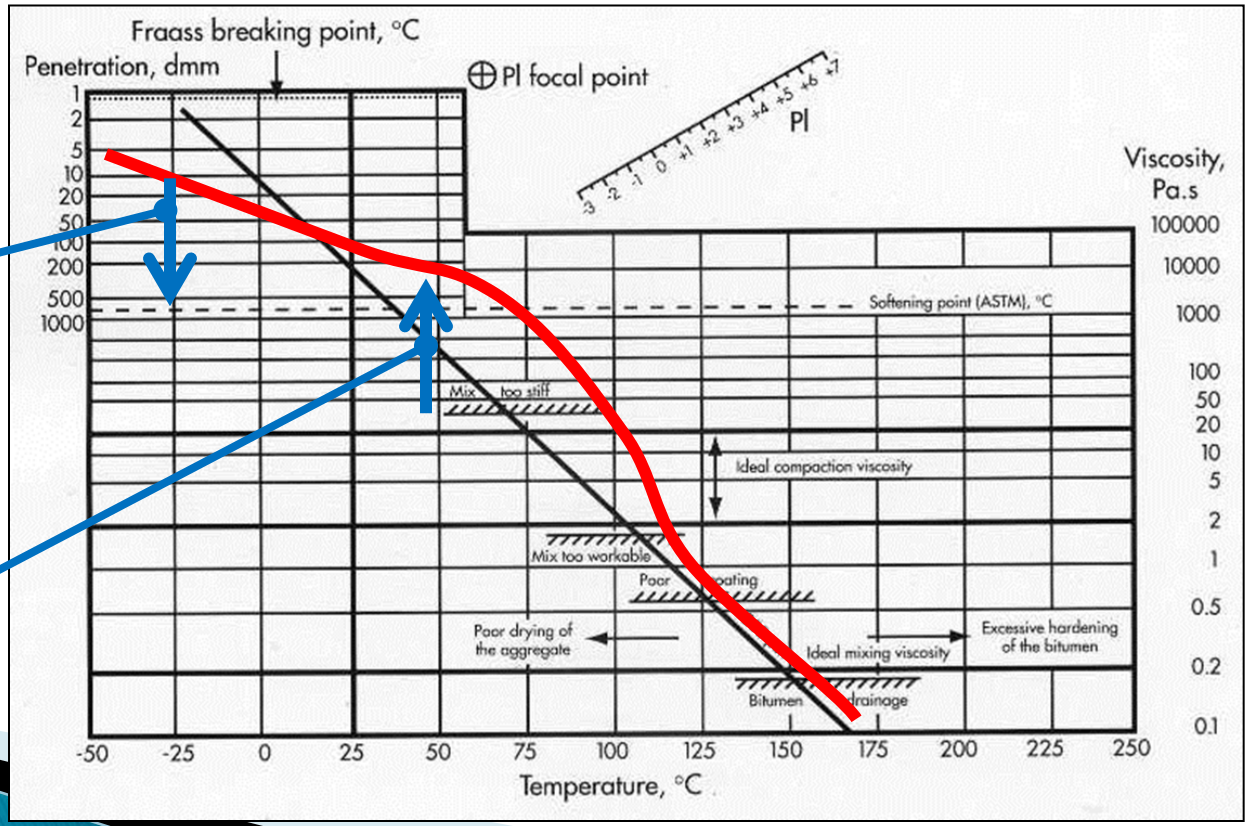
And a product that maintains these properties with time (low aging propensity)

How is this represented

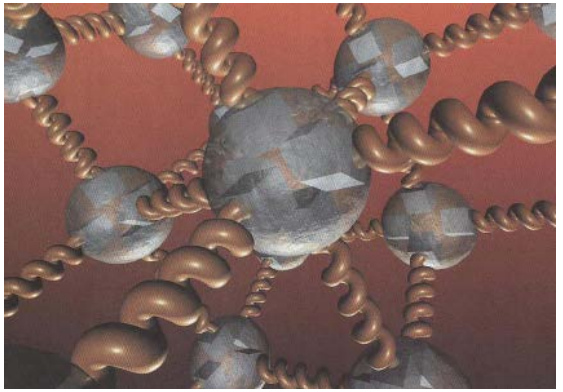
- Typically consideration of viscosity, stiffness properties of a wide range of temperatures
  - Pre rheology – example Bitumen Test Data Chart (BTDC)

Higher PEN
Lower Fraass
Better low temperature properties

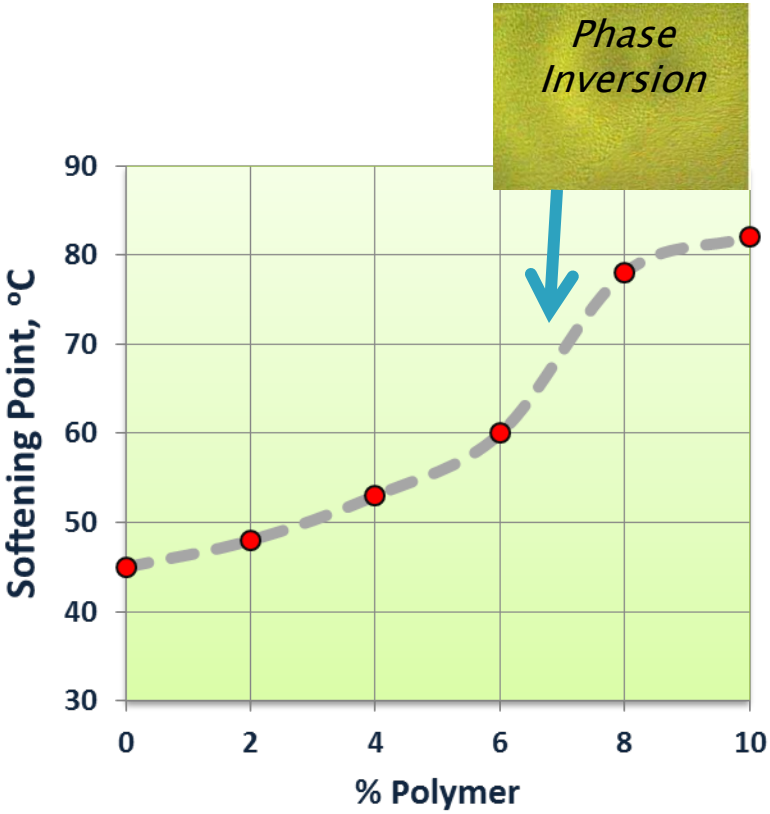
Lower PEN
Higher SP
Better high temperature properties



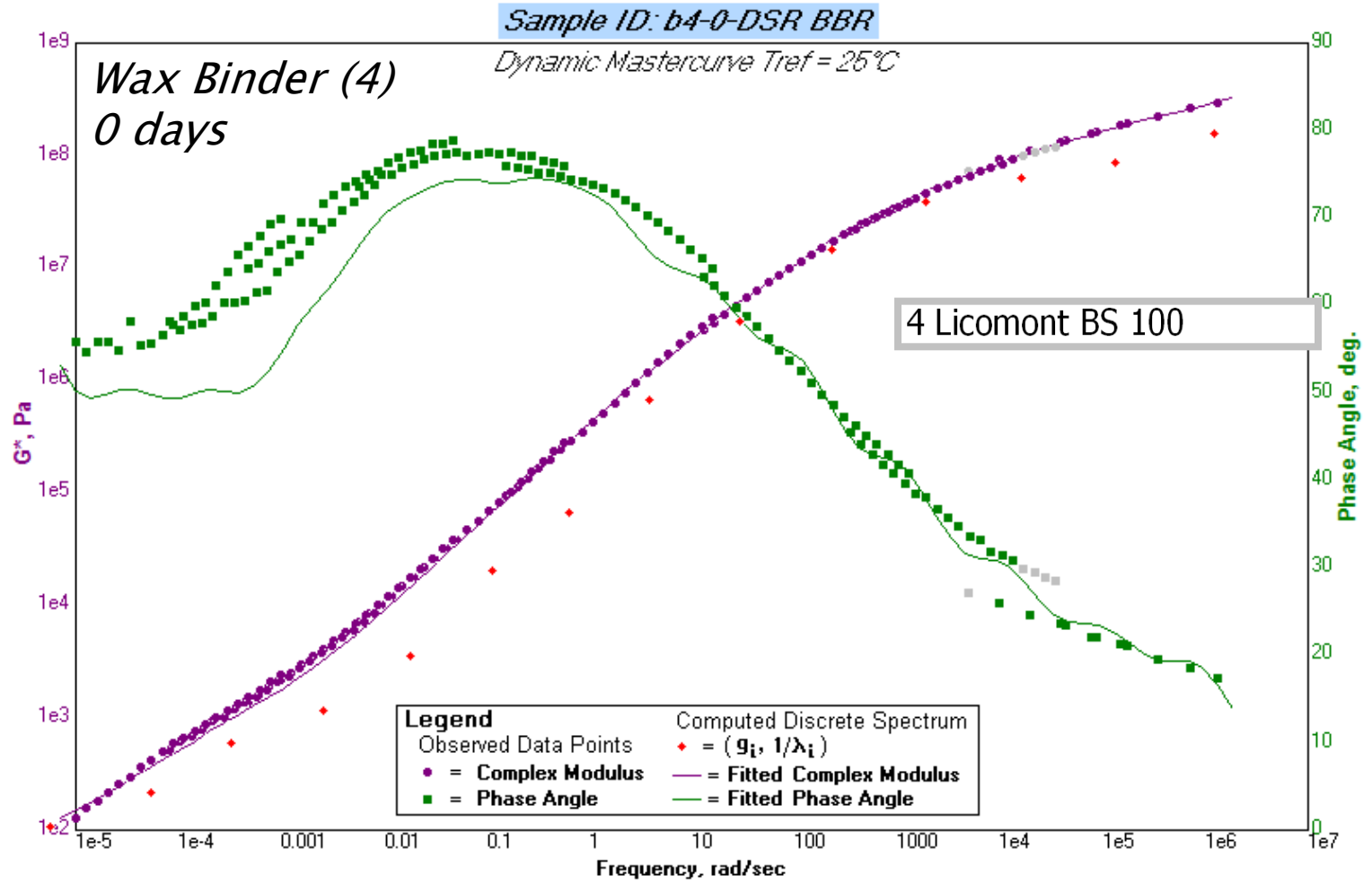
Quantity of modifier



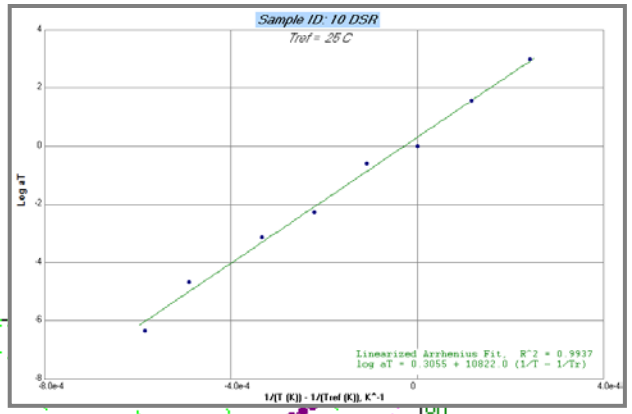
- A linear relationship does not exist!
- Some additives have an optimum amount!
- Some additives can result in poor performance if too much is added!
  - Need stability in blend!

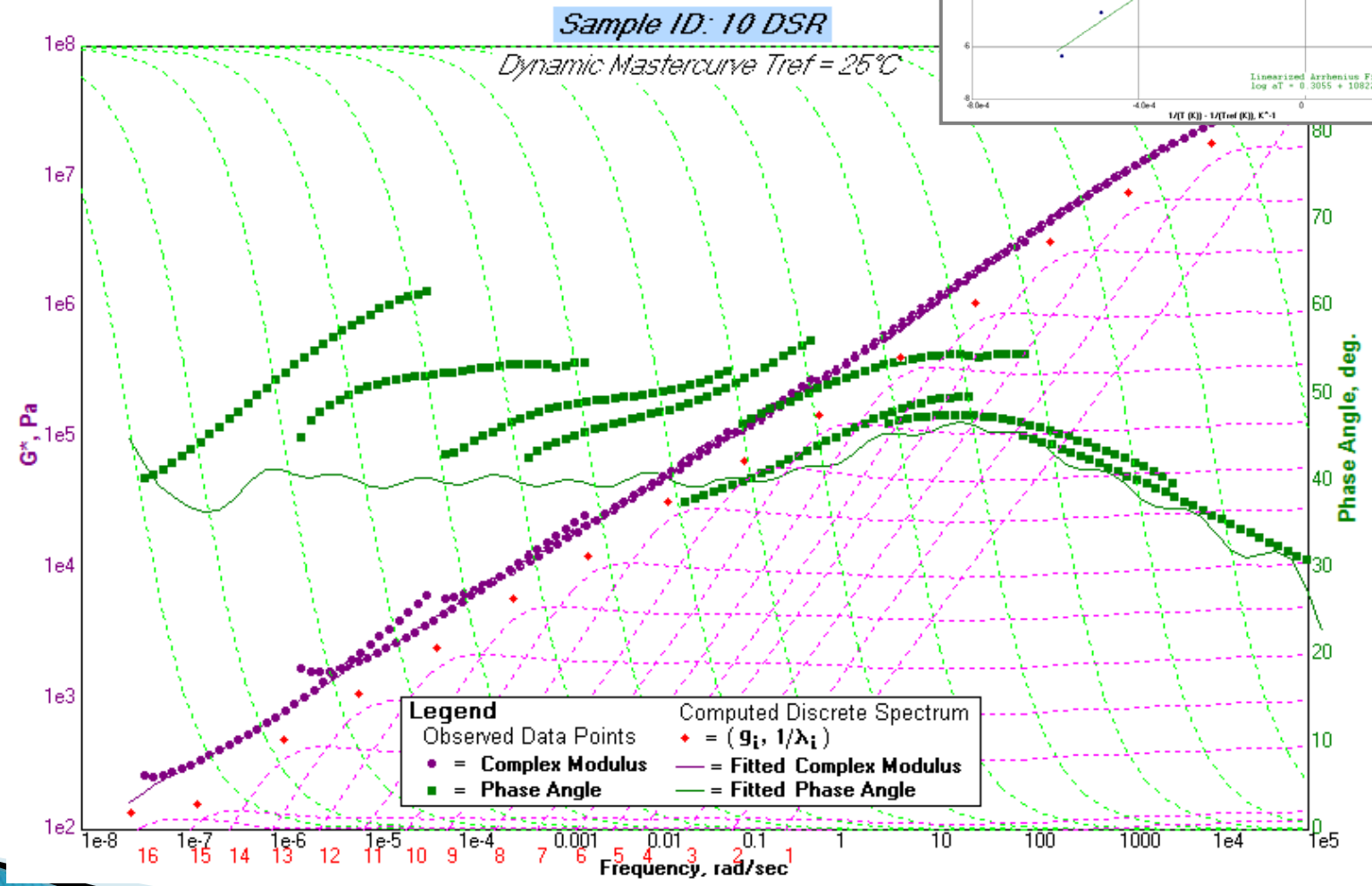


Master curve from rheology testing



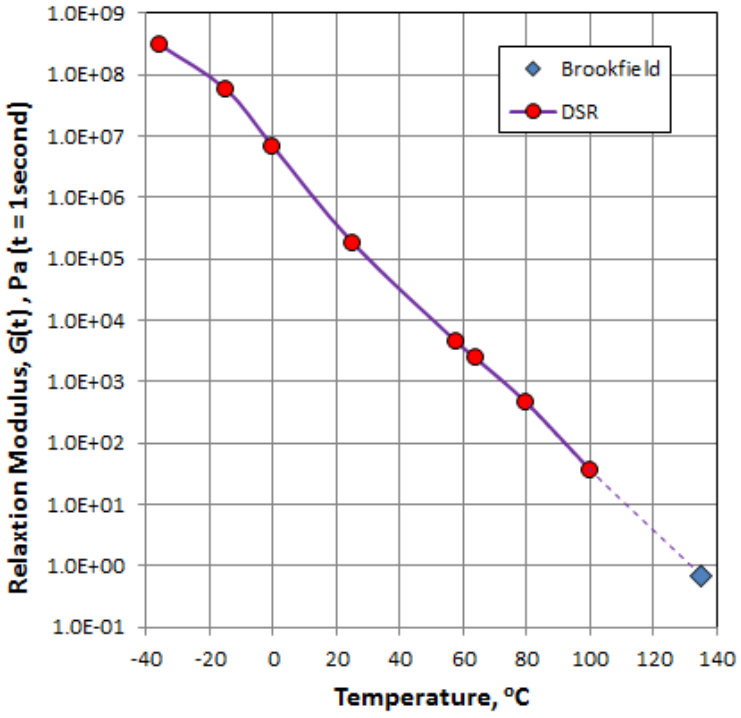
Master curve – poor shifting

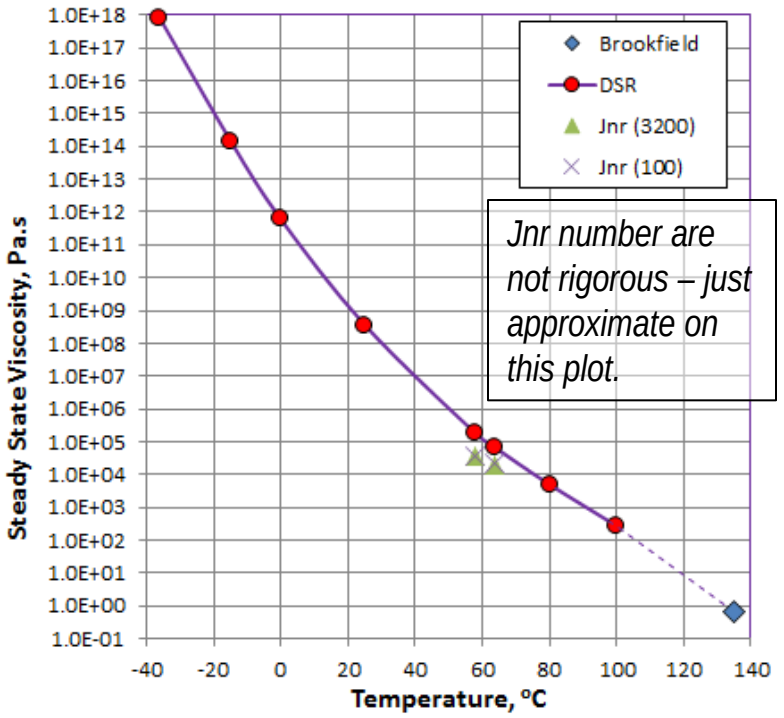




With today's equipment!

- Using BBR, DSR and Brookfield – we can represent data on single plots as either stiffness or viscosity
  - Many data representations exist!





Typical PG grade specification representation

- PGXX-YY
  - Typically – when XX + YY > 90 then modified
  - Difficult for non-modified binder to have a temperature range >90°C – although several do exist

What tools do we have?

- In USA – PG graded binders
  - Two specifications
    - M320 – Based on high temperature $G^*/\sin\delta$
      - Table 1 and Table 2
    - M322 – Based on high temperature MSCR

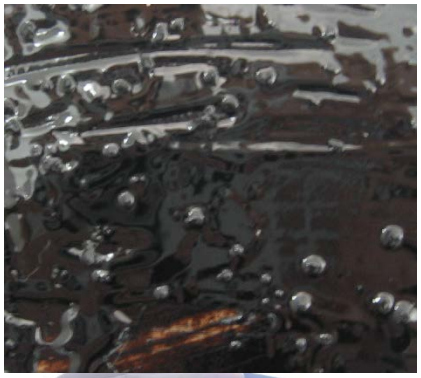
- Are these specifications adequate for understanding our modified asphalt and impact on performance?

No – limited at best!

Standards developed around materials in use at time of development!

The challenge

- How we define and characterize modified binders
  - SHRP program – did limited work on modified binders
  - Did leave some useful tools to further understand
- Consideration of distress areas
- Consideration of aging
- What improvements should we use?
- What other improvements should we make today?
- What work do we need to do?



Highway distresses

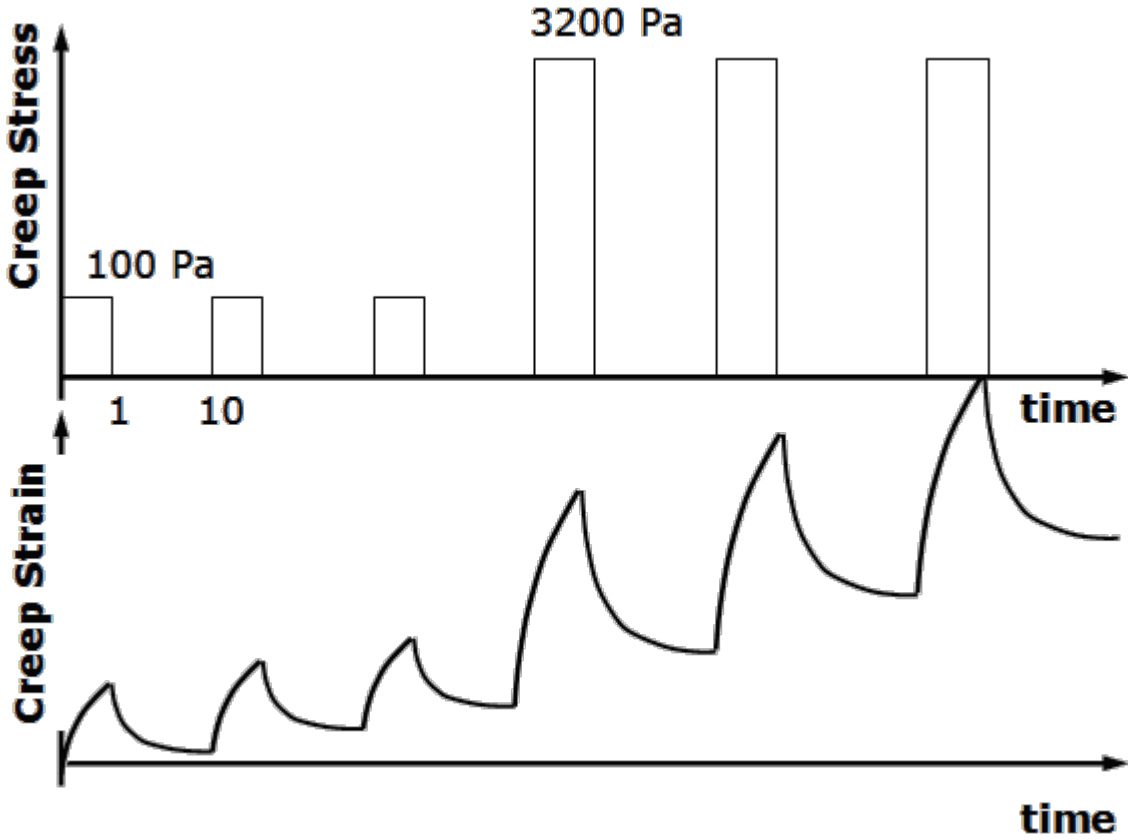
- Two main areas considered to be related to asphalt binder
  - Rutting
    - Deformation/rutting
    - Flow
  - Cracking
    - Fatigue Cracking
    - Durability
    - Low Temperature Cracking

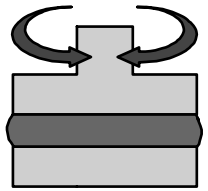
(Could also consider adhesion – but both mix and binder)

Improvements we should use!

- High temperature performance
  - MSCR
  - MSCR captures to a reasonable degree the polymer network effect and the impact on permanent deformation
  - Requires more widespread adoption of M322 specification
  - What is MSCR?

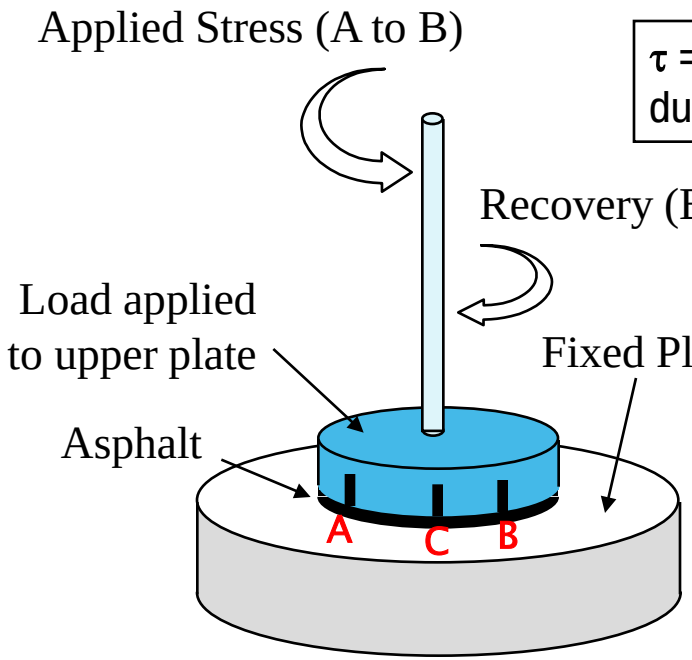
Multi Step Creep and Recovery



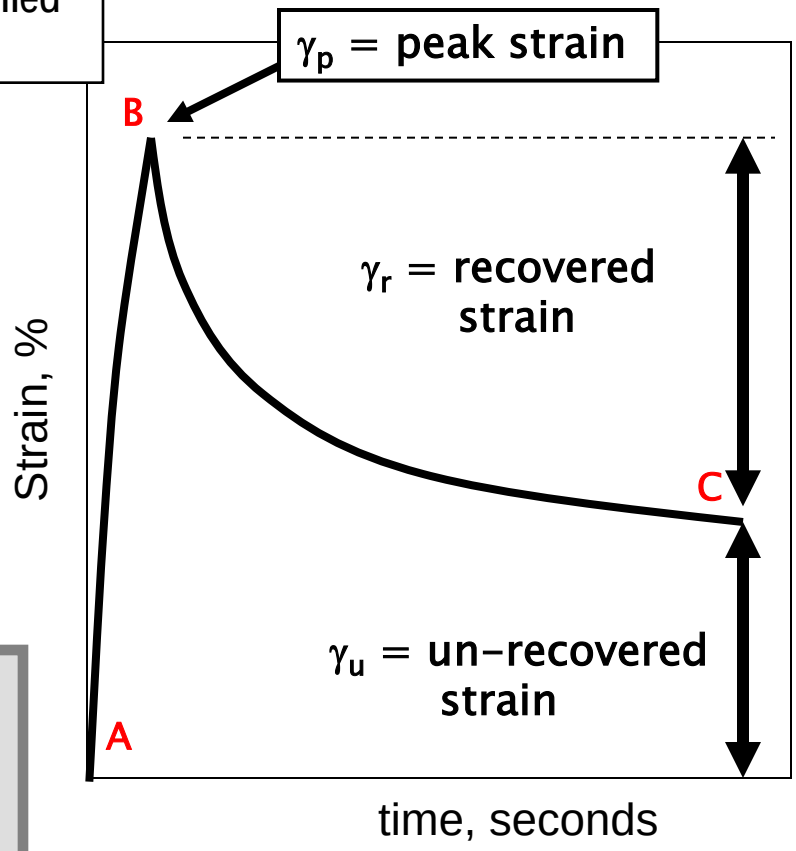


Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.

MSCR test performed in DSR



τ = stress applied during tests



$$J_{nr} = \frac{\gamma_u}{\tau}$$

$$\% \text{ recovery} = \frac{100 \times \gamma_r}{\gamma_p}$$

Higher Strains in MSCR!!

Rutting performance

- We need this ….

- Not this →

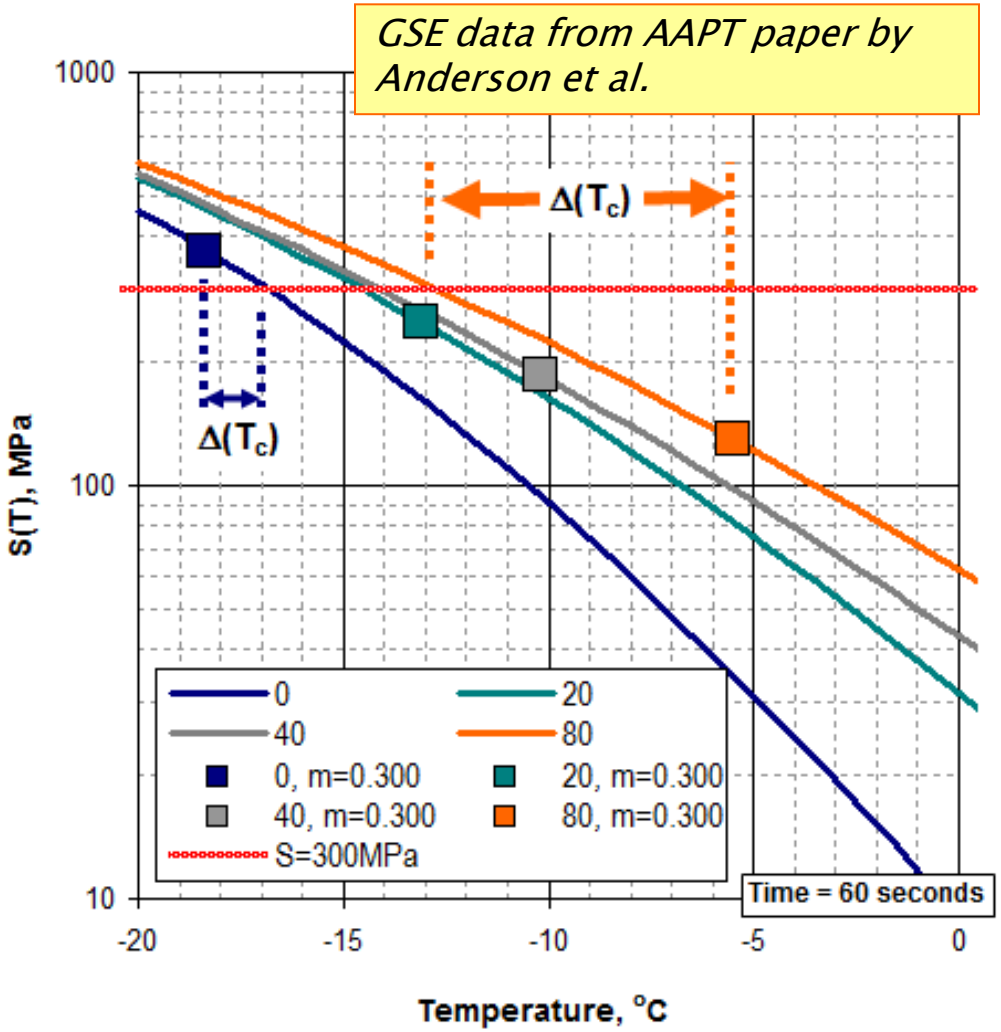
Implement MSCR!

What other improvements should we make today?

- Very strong evidence suggests that we should specify a limit for ΔT_c for surface course asphalt mixes
  - What is ΔT_c?
  - Why is this a good idea?

What is ΔT_c ?

- S(60s) and m(60s) plotted vs. temperature
  - For these we get a limiting temperature value when S=300 MPa and m=0.300



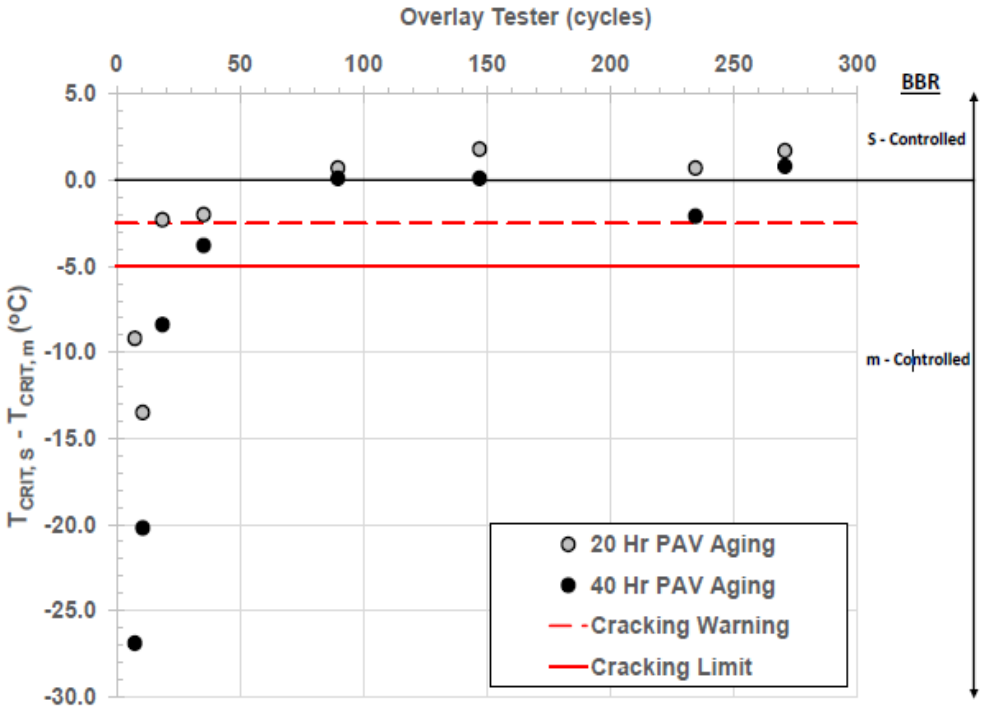
ASTM D7643

- ΔT_C— determine ΔT_C as the difference between continuous grading temperature for S from the continuous grading temperature for the m-value.
- Report ΔT_C as a negative value if the continuous grading temperature for the m-value is lower than the continuous grading temperature for S.

In final ballot process!

Why ΔT_c?

- Large differences appear to be related to durability cracking and early life issues.
- Easy to calculate since all data already captured and is part of typical grade evaluation process.



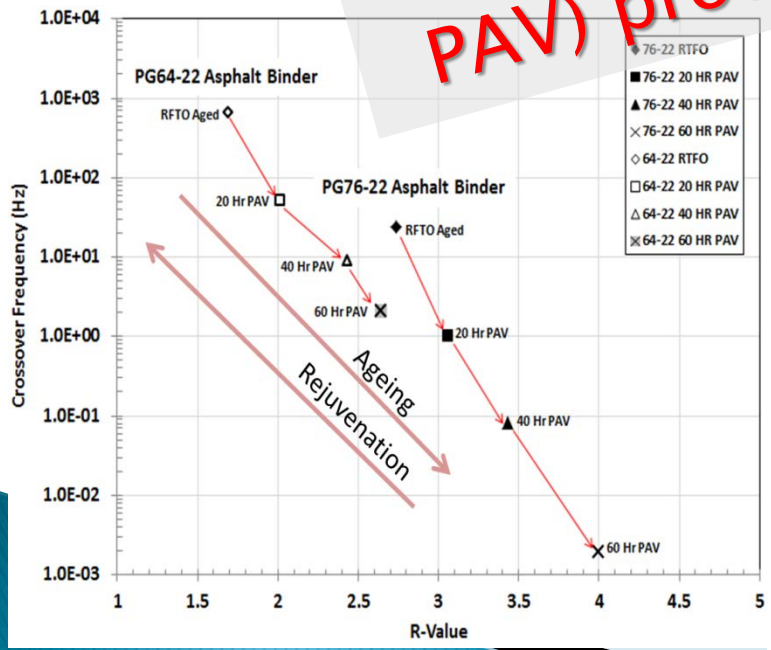
What work do we need to do?

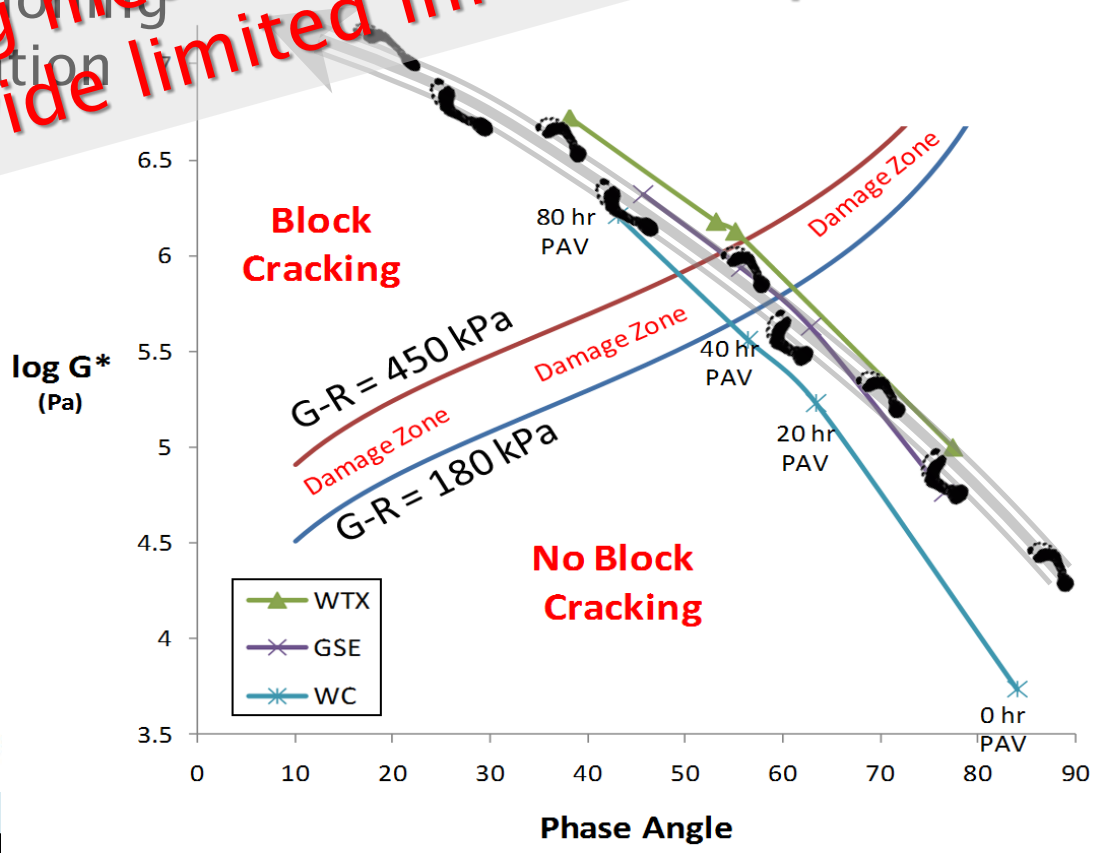
- 4 main areas are of high importance
  - Better understand aging effects with new modification systems
  - Better understand interaction between aging and cracking
  - Better understand mixing and compaction temperature effects
  - Ensure specification development considers full range of issues

Aging

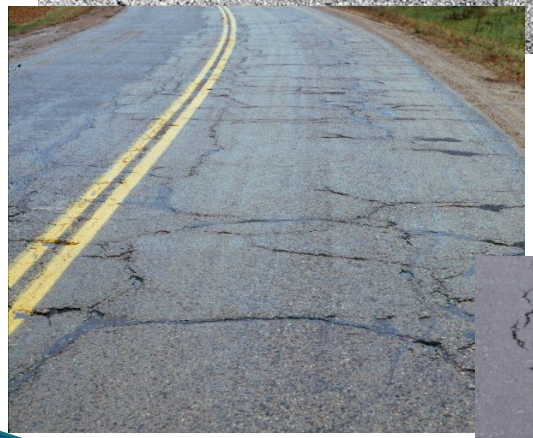
- Binders – as all organic materials – age
  - Oxidation changes behavior
  - Need to better understand aging and lab conditioning effects with modification

Our aging methods (RTFOT and PAV) provide limited information!





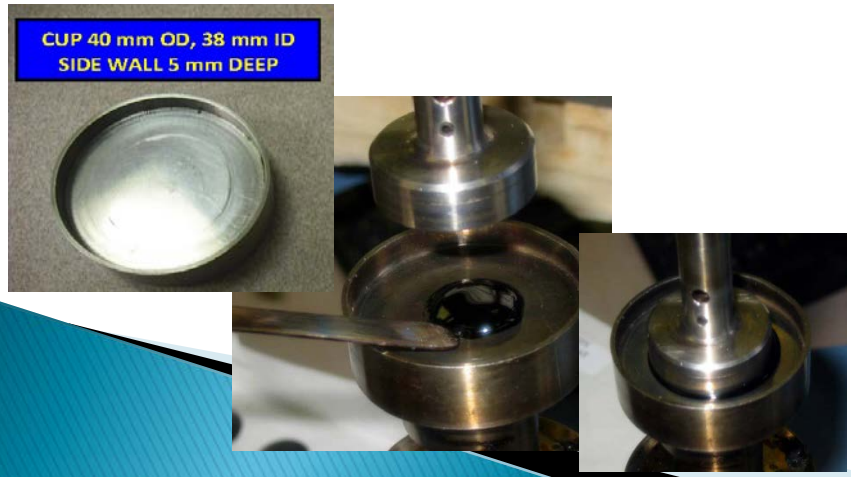
Linkage of cause and effects – aging and cracking

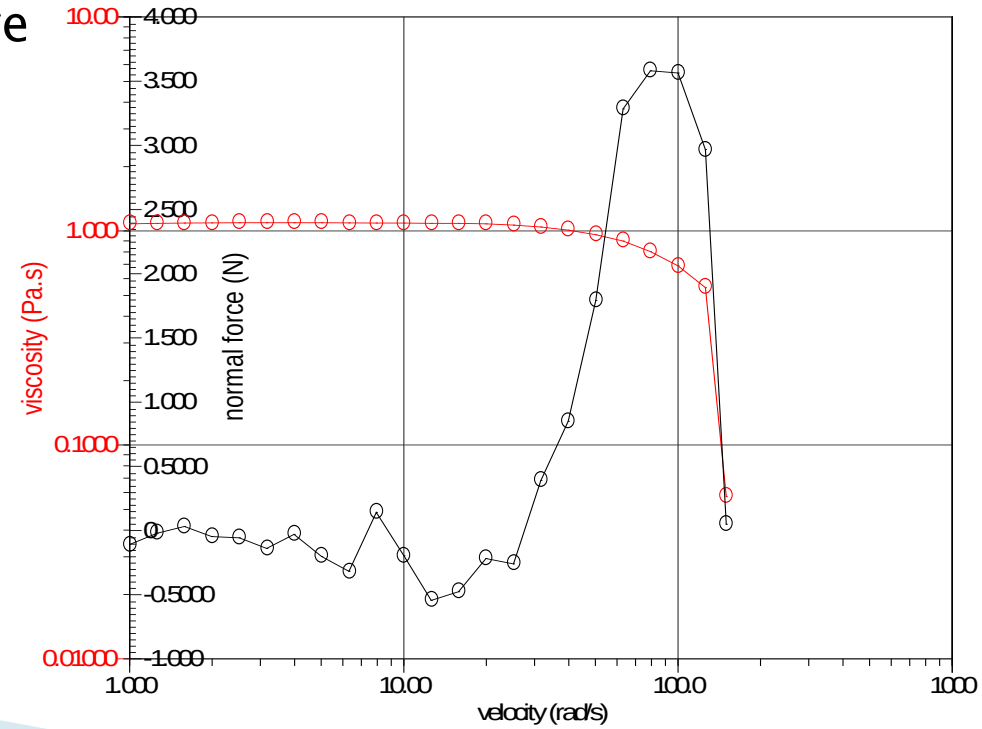


Which are best parameters – ΔTc, G-R, $G^*.\sin\delta$, LAST, etc.?

Understanding mixing and compaction

- Viscosity or lubricity!!!???
  - Historical work has focused on viscosity studies
  - More recent work points to lubricity
    - Several test methods have been developed – example shown!
    - Different researchers have various proposal for substrates, test configurations, etc.





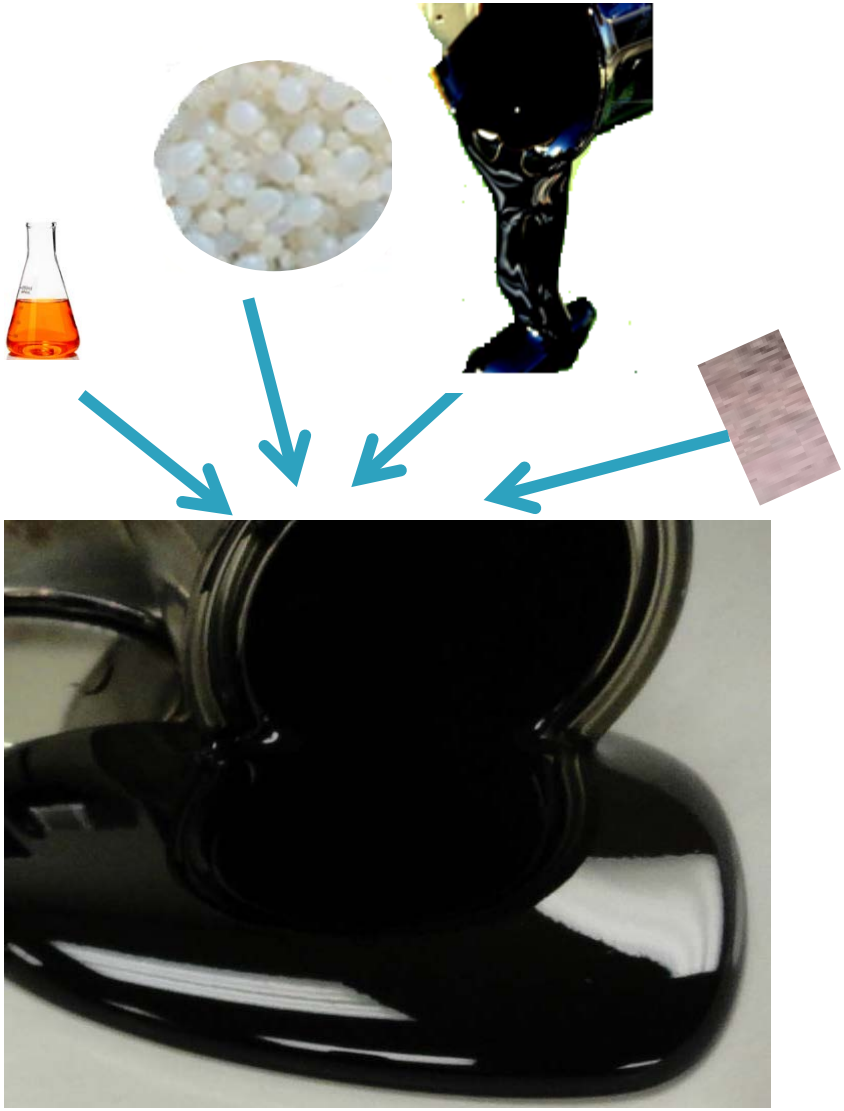
Ensure full understanding

- What is coming next in our understanding of modification!
  - Be aware and consider all options that relate to performance!

"...and this is where we train our employees to think out of the box."

Modification concept

- Base binder
  - Make sure soft enough to resist cracking
  - May need to soften with oils
    - For this check ΔT_c
- Then modify high end with polymer to stiffen at high temperatures
  - Use cross linking
  - PPA in limited amount



Manufacture

- What are options!

  1. At refinery
  2. At terminal
  3. At mix plant

- 1 and 2 – more conventional – lets look a little at #3
  - *Some personal reflections!*

HMA plant – PmB asphalt modification

- PmB – mobile manufacturing units
  - Several designs exist
  - Generally a batch type production
  - Daily production to meet 1-day of HMA production
  - Consists of mixing unit – skid mounted
  - Additional PmB storage

Adding polymer at HMA plant

- Two tanks – separated by pump and high shear mill
  - Tanks have agitation
  - After mixing – material sent to tanks for overnight period

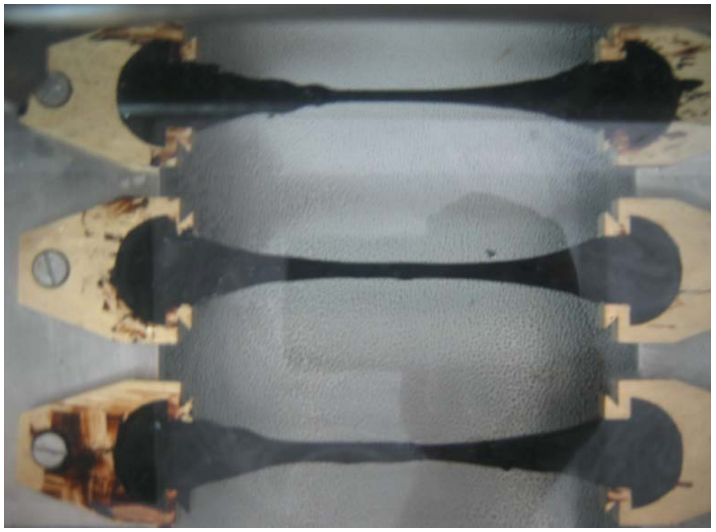
On site QC

- A mix of tests have been applied
  - European style
    - Ductility
    - Elastic recovery
    - Pen
    - Softening Point
    - Fraass
  - PG Graded binders
    - Full PG M320 lab implemented
    - BBR, DSR, etc. (sometime BBR not implemented)
  - Other
    - Fluorescence microscope
    - Other tests/methods

Training of technicians is key need!

Some examples

- What materials do we test
- Basic test methods
- DSR, etc.



Ductility test of lumpy Pmb!

Get the lab level!

Better performing roads

- With care and good setup we achieve the end result!

Binder is only part of process!

- Must implement good mix design
  - Careful attention to volumetrics !!!!!!
  - Basic training needed → Bill Pine for this

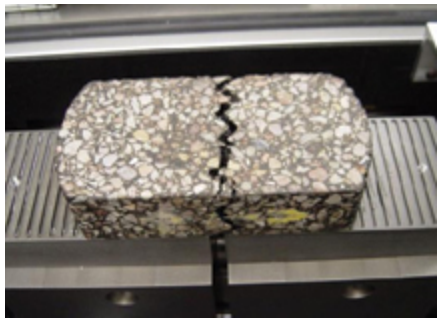
- Understand mix physical tests
  - → see thoughts on next slide
  - Binder goes part way to getting good physical properties!

…. and after all of this – don't forget the mixture!

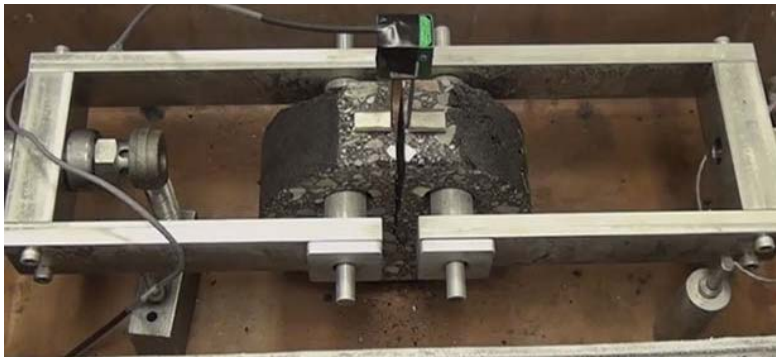
- Hamburg

- SATS
- Fracture tests

Texas Overlay Tester

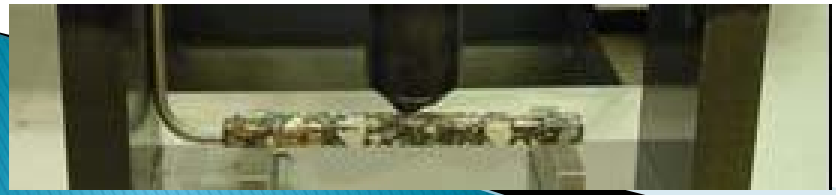


- Bending beam fatigue test



- Tensile tests
  - Use of beam, direct or indirect tension

Direct compact tension test



Semi-circular bend test

… and finally --

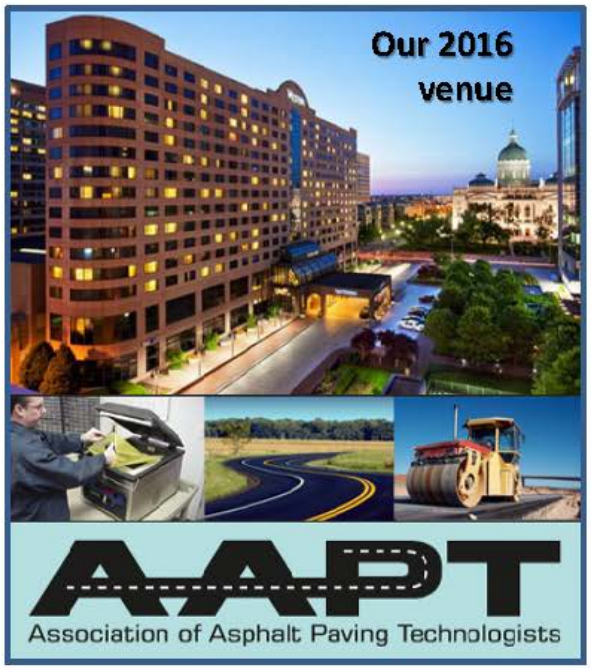
- Don't forget the crew with the paver, rollers, etc…
  - A good binder – will not substitute for good site practice

Thanks for listening …

91st AAPT Annual Meeting and Technical Sessions

The 2016 Annual Meeting will be held March 13-16, 2016

The Westin Indianapolis, 50 South Capitol Ave., Indianapolis, Indiana. USA



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2016 Call for Papers

The Association of Asphalt Paving Technologists is actively soliciting paper offers for its 2016 Annual Meeting and Technical Sessions. Papers reporting on studies concerning any aspect of asphalt paving technology or related fields are considered. These can include research, design, construction and maintenance issues dealing with all types of asphalt binders, asphalt mixtures, and pavement applications – including innovative ideas and improvements to current practice. Papers will be considered for presentation at the Annual Meeting which is attended by specialists from academia, research organizations, material producers, contractors, national and state authorities, and consultants from around the world. Papers offered for the 2016 Annual Meeting must be submitted through the AAPT website.

Important dates

May 1, 2015 web site open for paper submission
August 3, 2015 - deadline for submitting papers
November 4, 2015 - notification of paper acceptance
December 2015 - registration open
March 13 to 16, 2016 - annual meeting and technical sessions

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