Verification of the performance of thermoplastic plant mix additive used to produce bridge deck waterproofing materials

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Introduction

- Plant mixed modifier (PMM) has been used for the past 25-years to produce waterproofing asphalt materials for bridge deck applications
- Paper discusses how the performance of this material is define

Plant mix modifier – what is it?

- Thermoplastic polymer based additive that is added as a powder directly to the mix
- Supplied in bags or in bulk form
- Very easy to implement with conventional HMA plant and equipment
- Currently projects in USA, Canada and China


Material is paved and compacted to
produce a waterproof surface

Performance definition

- Difficult to define performance with convention binder tests
- Mixture tests developed during SHRP more appropriate for performance assessment and definition

Bridge Deck Performance requirements

- Performance
  - Skid resistance
  - Waterproofing
  - Smooth ride quality
  - Resistance to fatigue
  - Deformation resistance
  - Durability
  - Long life
- Attributes
  - Quick installation
  - Ease of application
  - Low cost compared to other materials
  - Use of conventional equipment

Bridge Deck Performance requirements

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  - **Waterproofing**
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  - **Low temperature performance**
  - **Deformation resistance**
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Specimen preparation

- Detailed attention made to specimen preparation
- Work conducted at Asphalt Institute

Specimen preparation

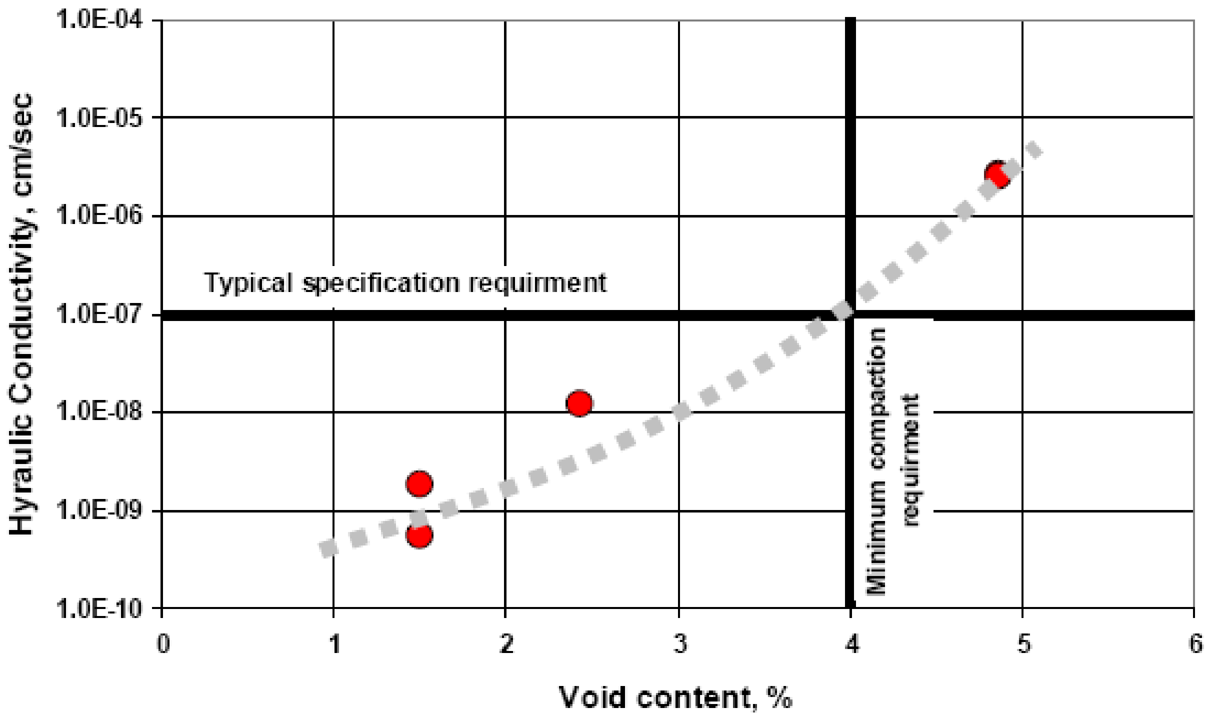
- Mixtures were reheated (covered) with care to prevent aging
- Gravities were checked
- Samples were compacted and trimmed as required for testing
- Samples were prepared to 1.0-2.0% air voids to simulate field conditions

Property assessment

Waterproofing

Waterproofing

- Assessed via various methods
- ASTM D5084 – $1x10^{-7}$ cm/sec used as standard in many specifications



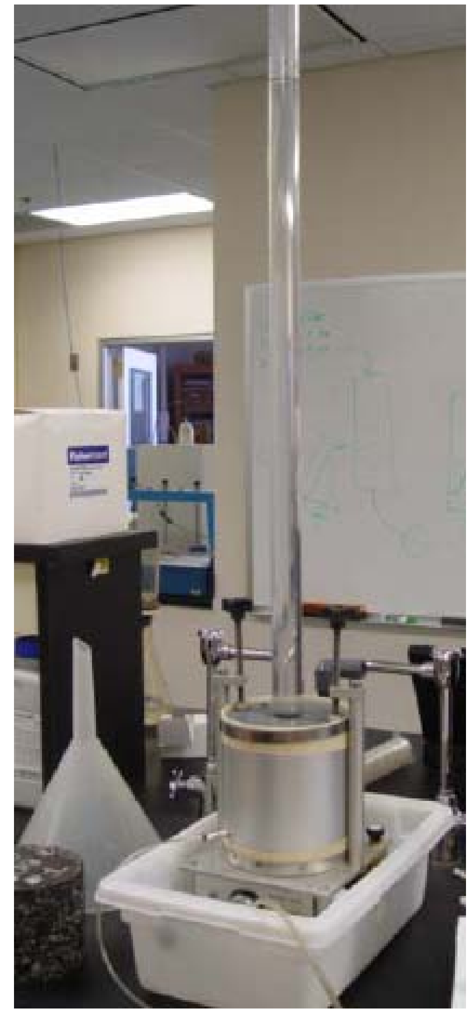
Other studies have looked at salt penetration but ASTM D5084 considered easy to incorporate in specifications

Other tests

- Other testing has included AASHTO T 259-80, "Resistance of Chloride Ion Penetration"
- Mallick and Bergendahl measured water permeability
- Material provides effective water proofing for a structure

Sample ID	Chlorides, %
Control 0.0625" – 0.5"	0.01
Control 0.5" – 1.0"	0.01
Sample 1 0.0625" – 0.5"	0.01
Sample 1 0.5" – 1.0"	0.01
Sample 2 0.0625" – 0.5"	0.02
Sample 2 0.5" – 1.0"	0.01
Sample 3 0.0625" – 0.5"	0.02
Sample 3 0.5" – 1.0"	0.02

(after PSI, 2000)

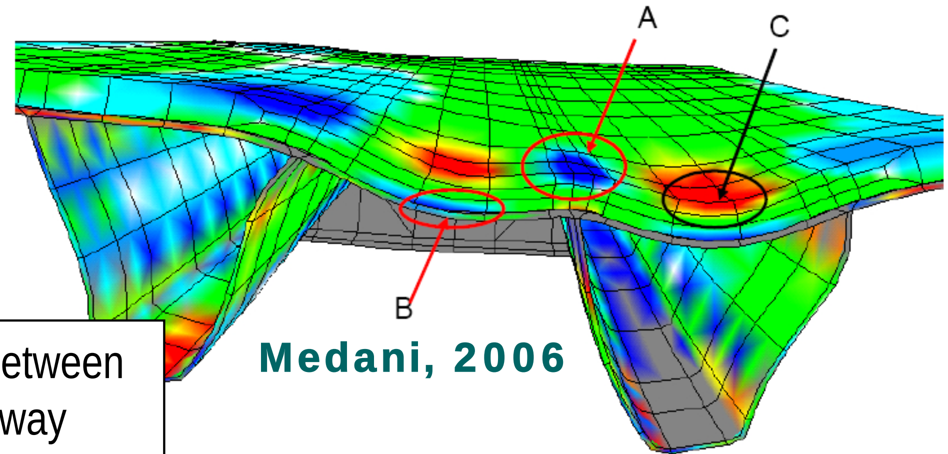


Water permeability apparatus (Mallick and Bergendahl, 2004)

Resistance to fatigue

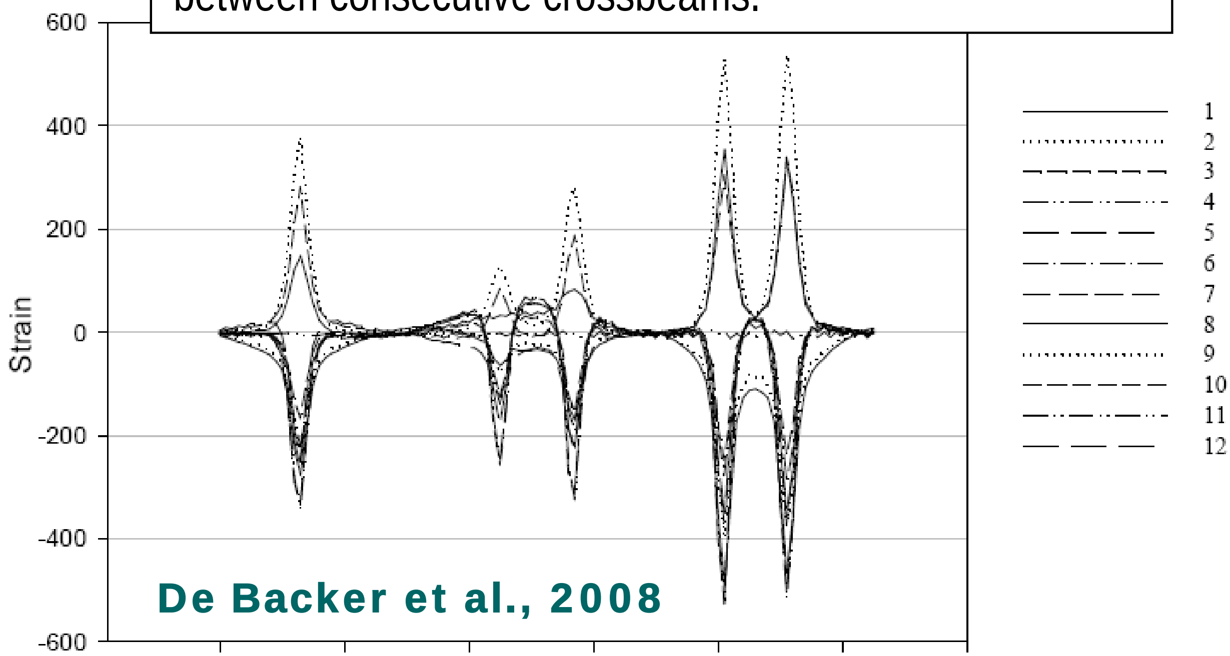
Fatigue demand

- Review of various references suggest strains in steel decks suggests a typical average strain of 500 με, max strain of about 900 to 1500με



Medani, 2006

12 strain gauges were used, all of them located between the first and second longitudinal stiffener and halfway between consecutive crossbeams.



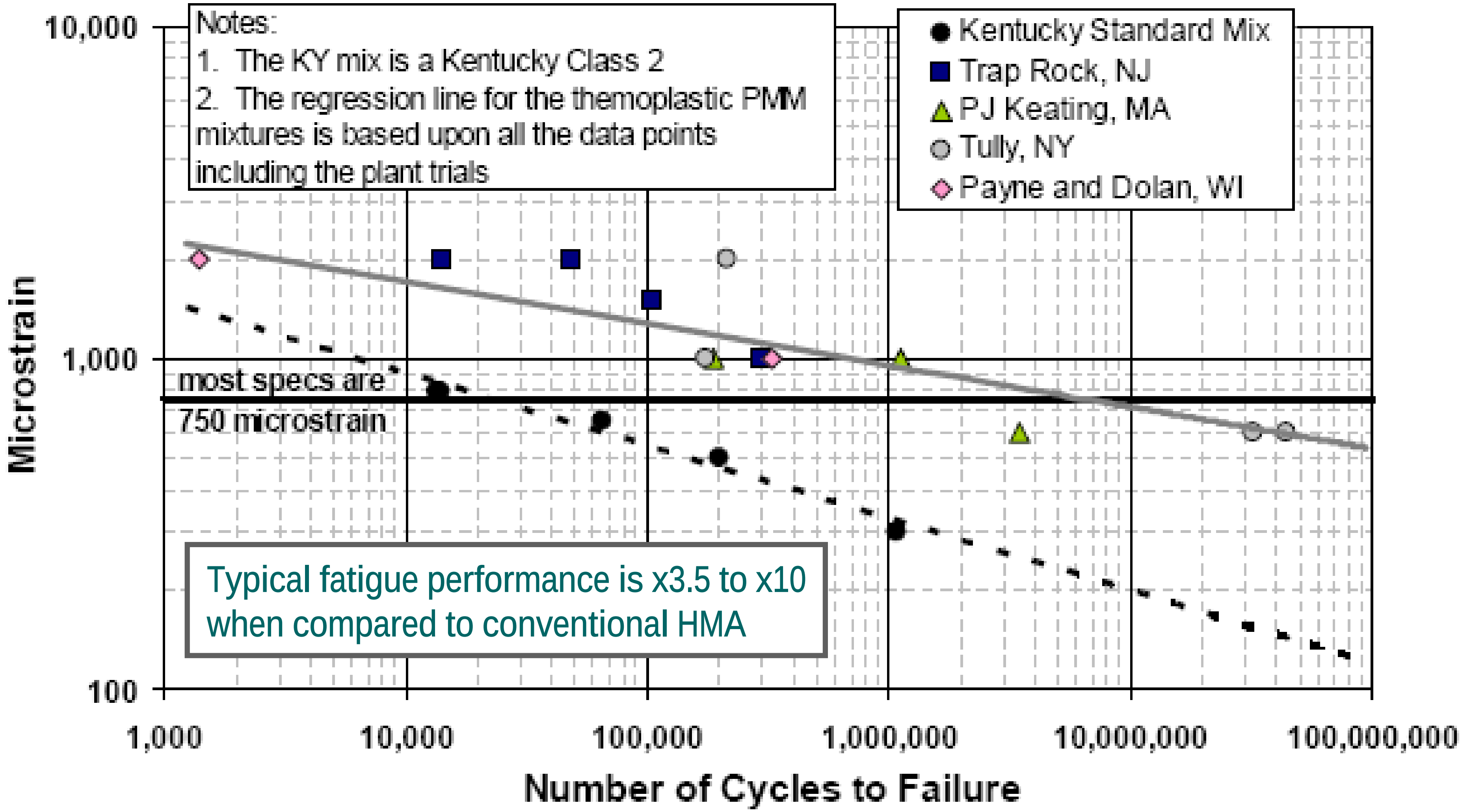
De Backer et al., 2008

- Overlays on concrete decks have low fatigue requirement
- Most specifications set at approximately 750 to 900 με
- Testing with ASSHTO T321 or ASTM D7460

Fatigue testing

- Tests conducted in 4-point bending beam apparatus
- Method is given in AASHTO T321
- Analysis also conducted in accordance with ASTM D7460

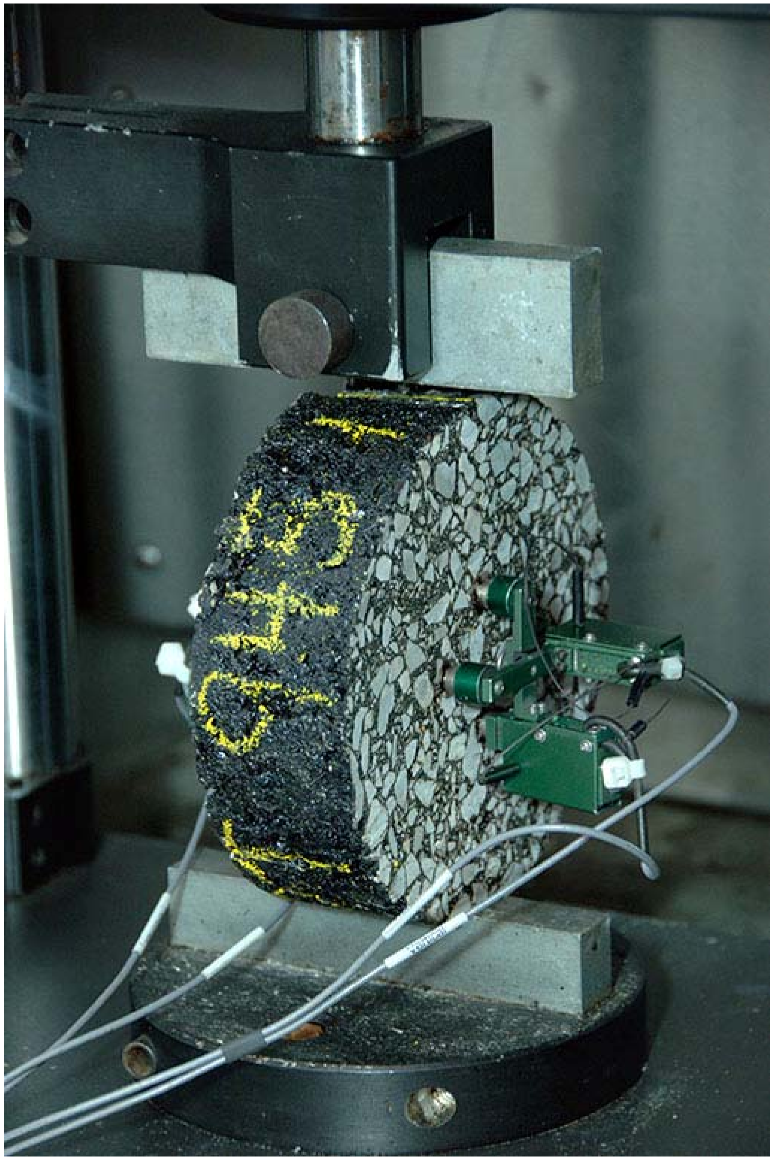
Fatigue performance



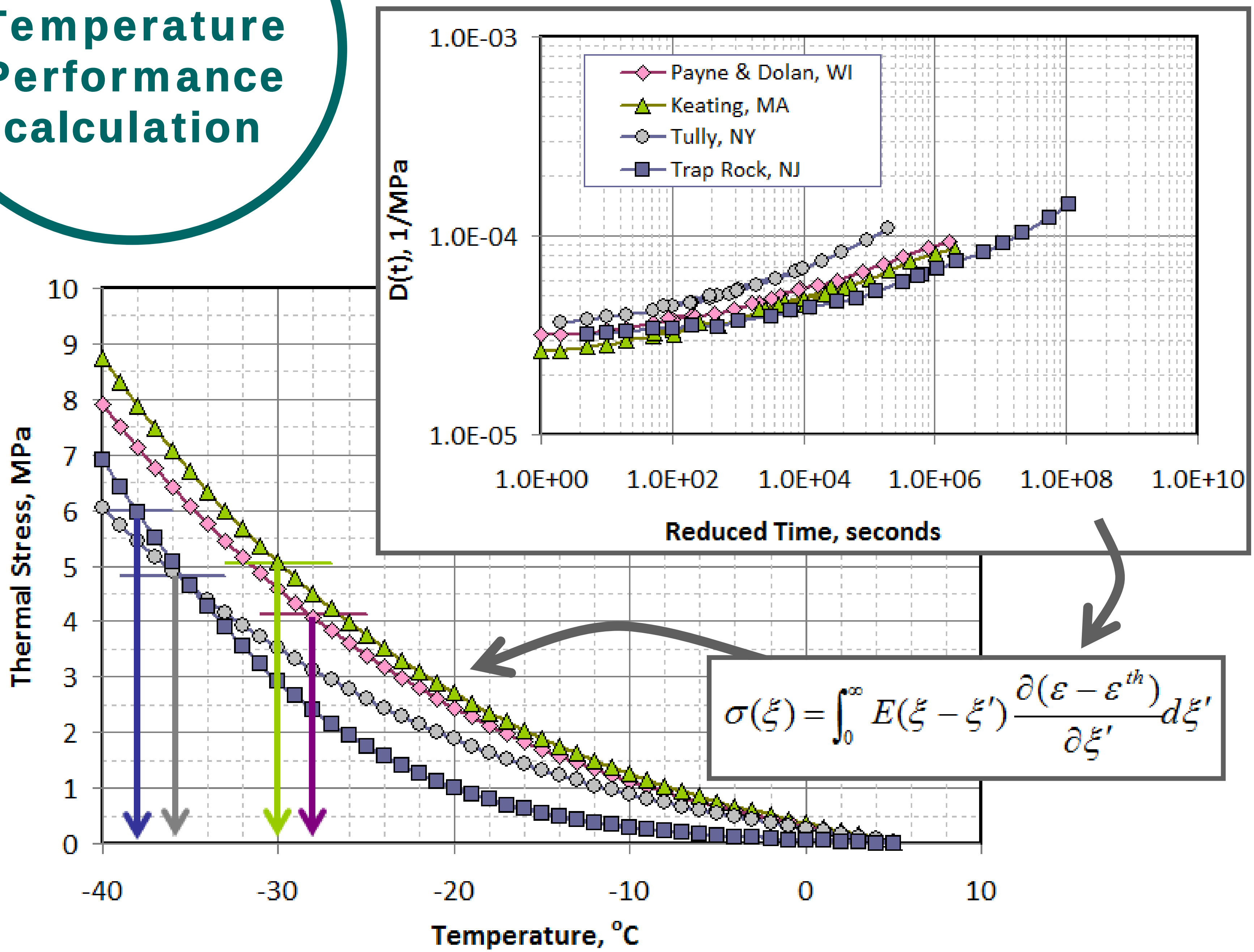
Low temperature performance

Low temperature performance

- Measured in indirect tensile test and calculations of expected critical cracking temperature with assumed cooling rate



Low Temperature Performance calculation



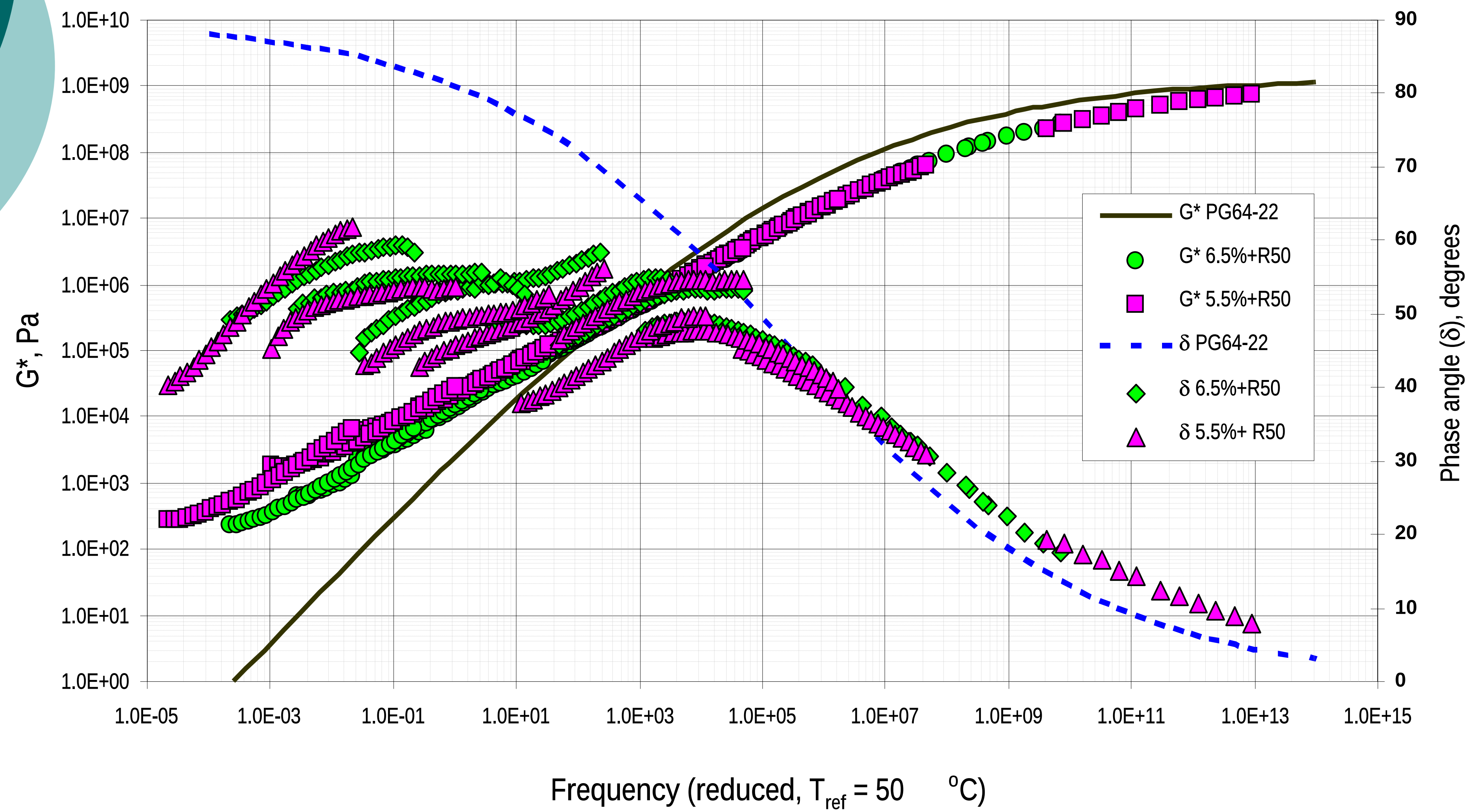
$$\sigma(\xi) = \int_0^\infty E(\xi - \xi') \frac{\partial(\varepsilon - \varepsilon^{th})}{\partial \xi'} d\xi'$$

Deformation

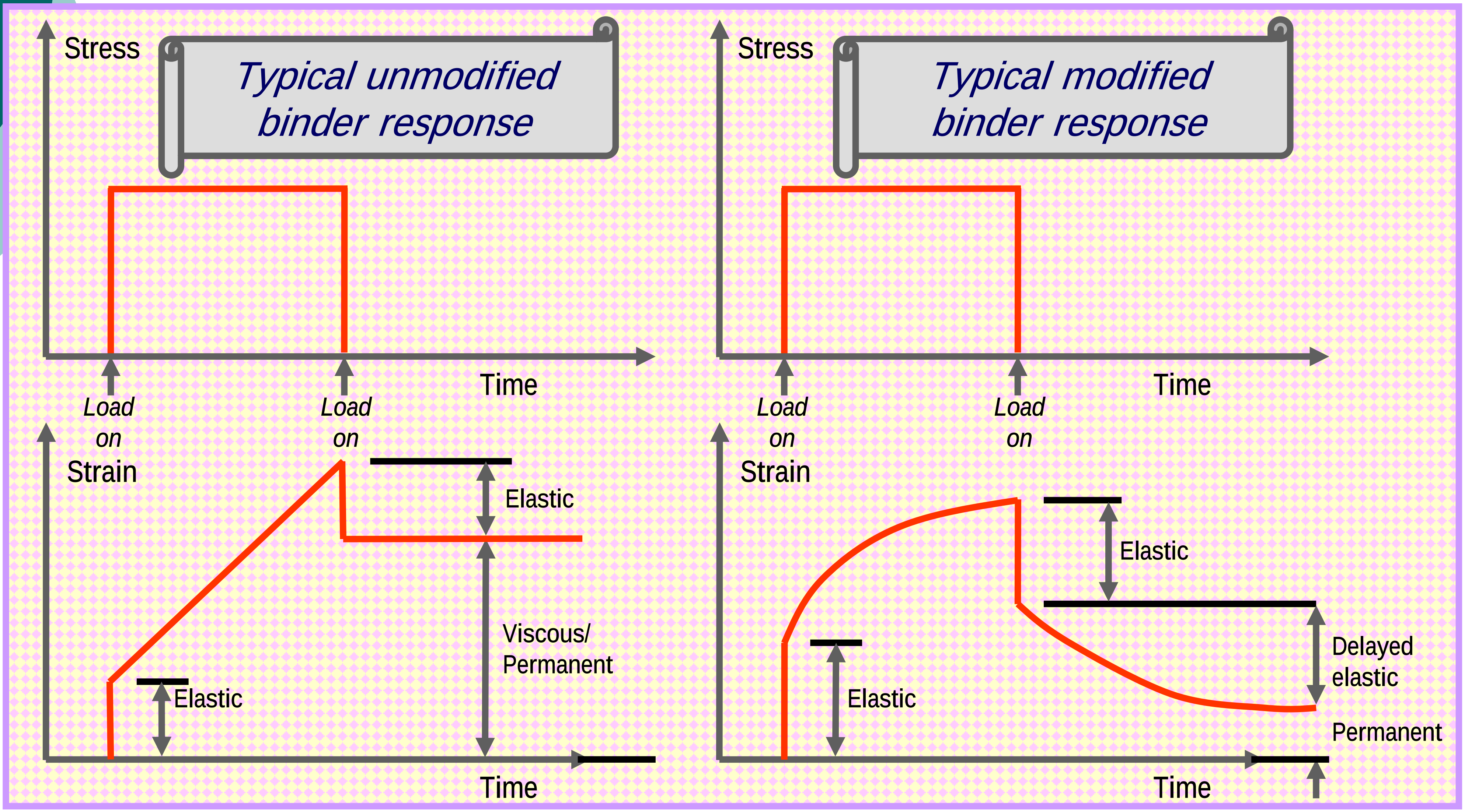
- Can look at rheology
- Important to have a material that is behaving close to a thermoplastic visco-elastic solid
- Sufficient use of polymers enable this while still allowing mixing and compaction with conventional equipment

Testing conducted in DSR

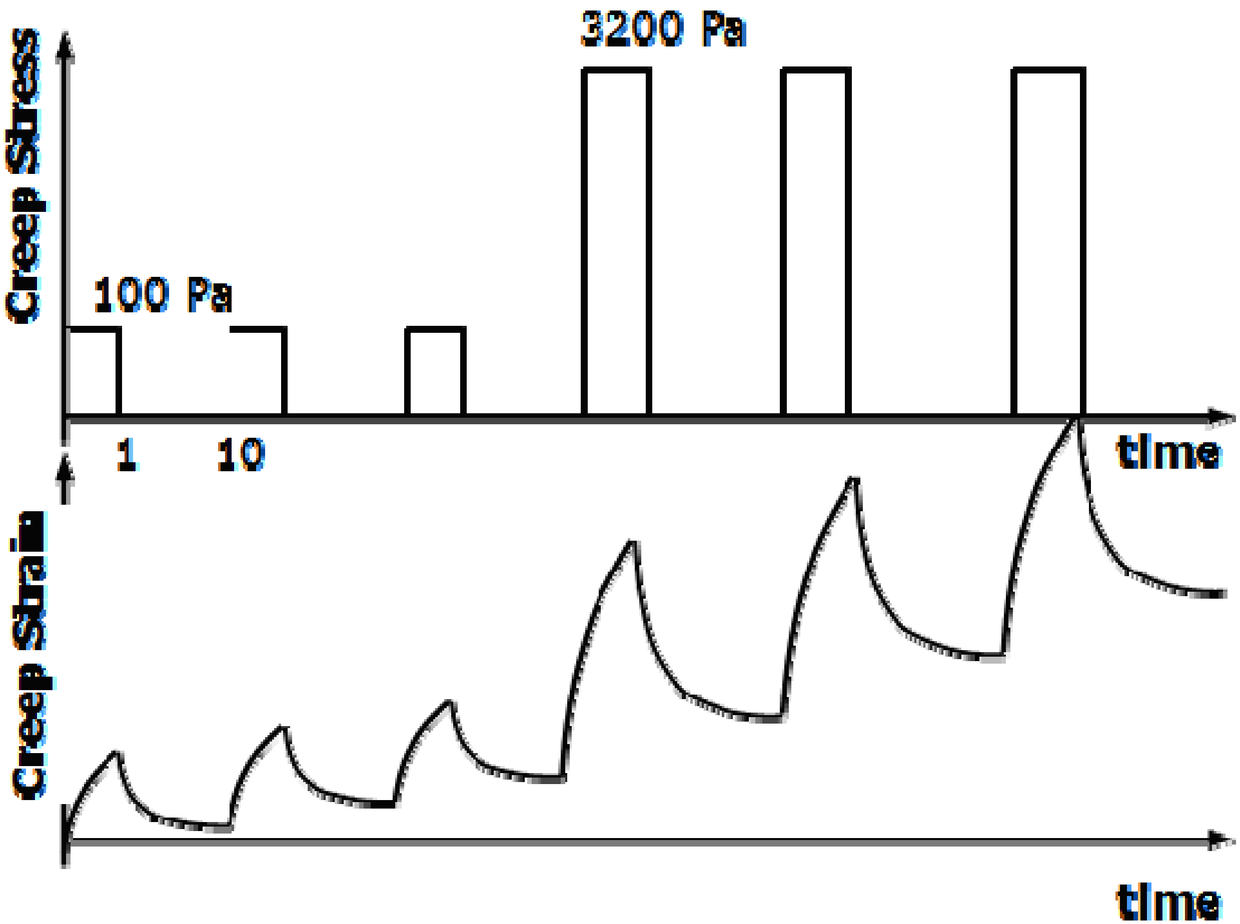
Rheology of various binders + PMM compared to PG64-22

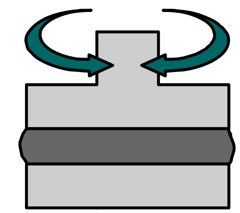


Modified vs. unmodified binder response to loading



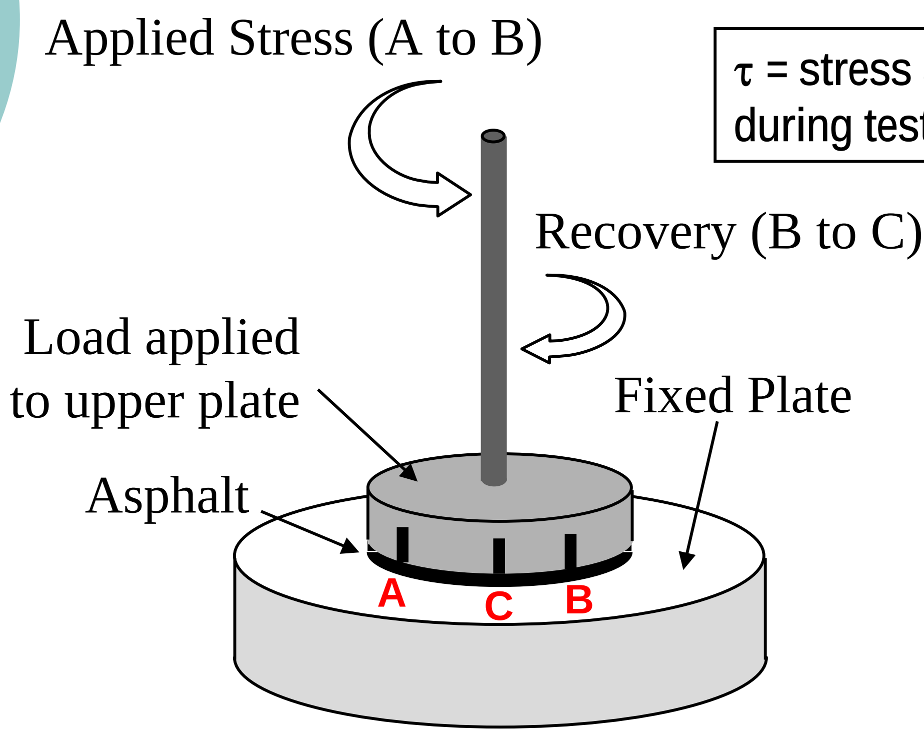
Multi Step Creep and Recovery

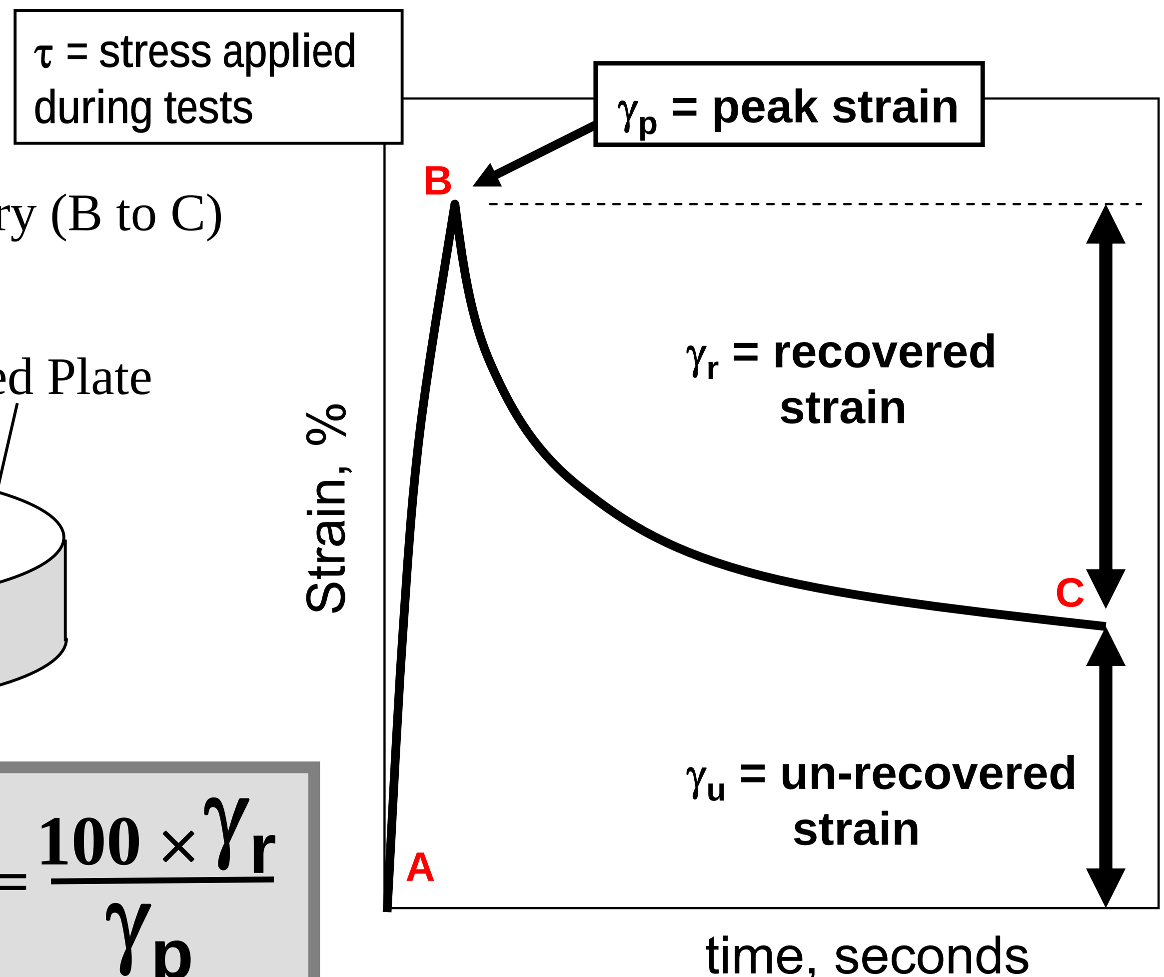




Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.

MSCR test performed in DSR

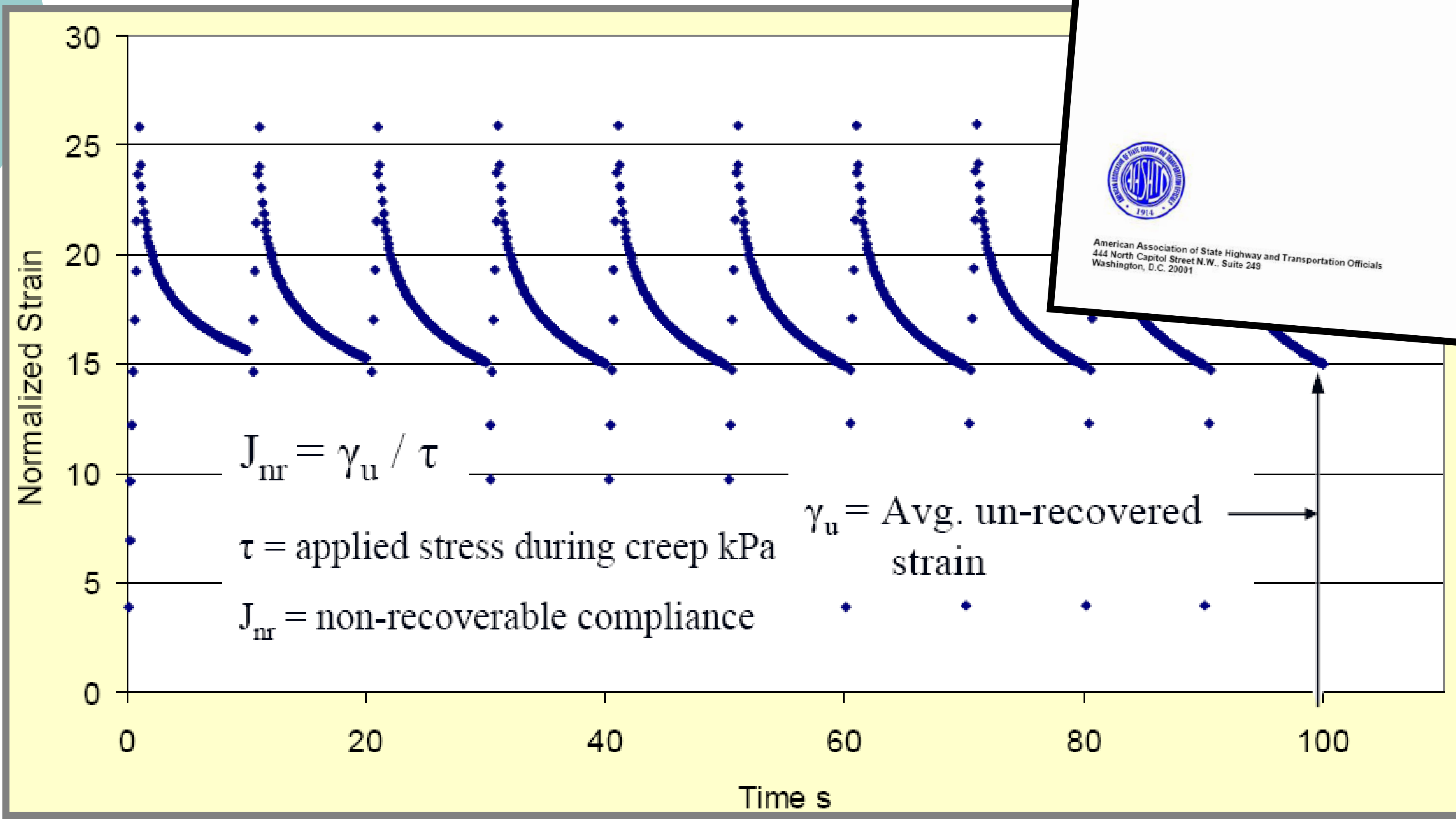


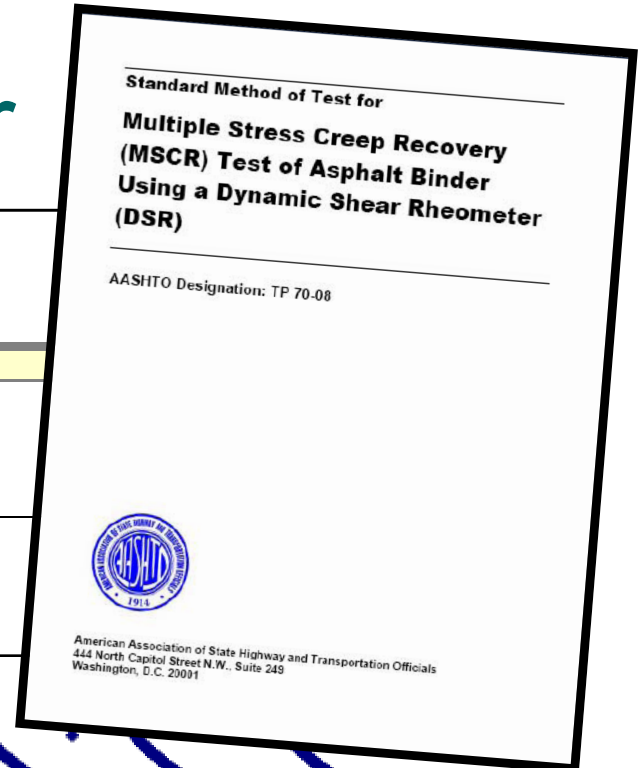


$$J_{nr} = \frac{\gamma_u}{\tau}$$

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

MSCR test to obtain Jnr





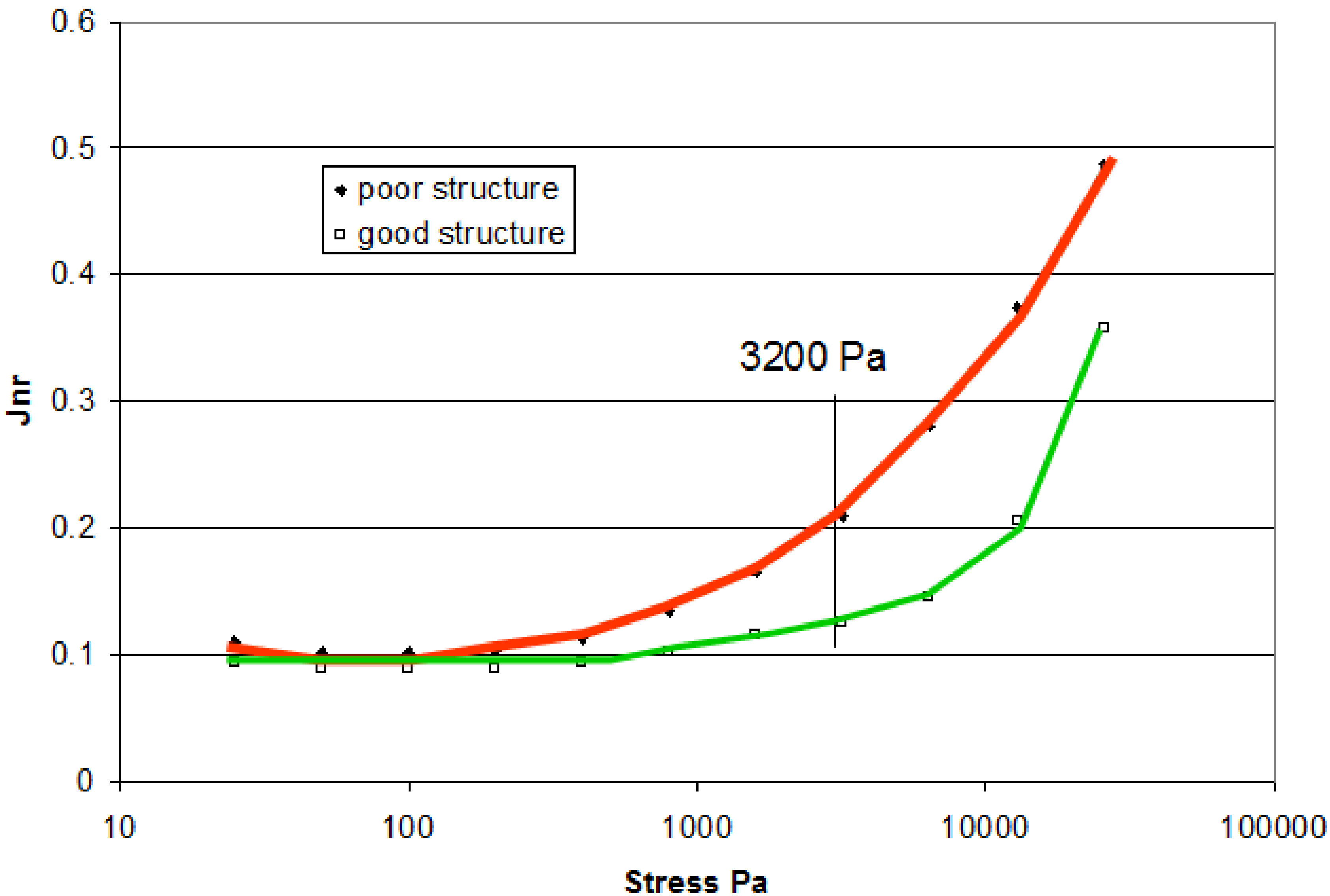
Standard Method of Test for

Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

AASHTO Designation: TP 70-08

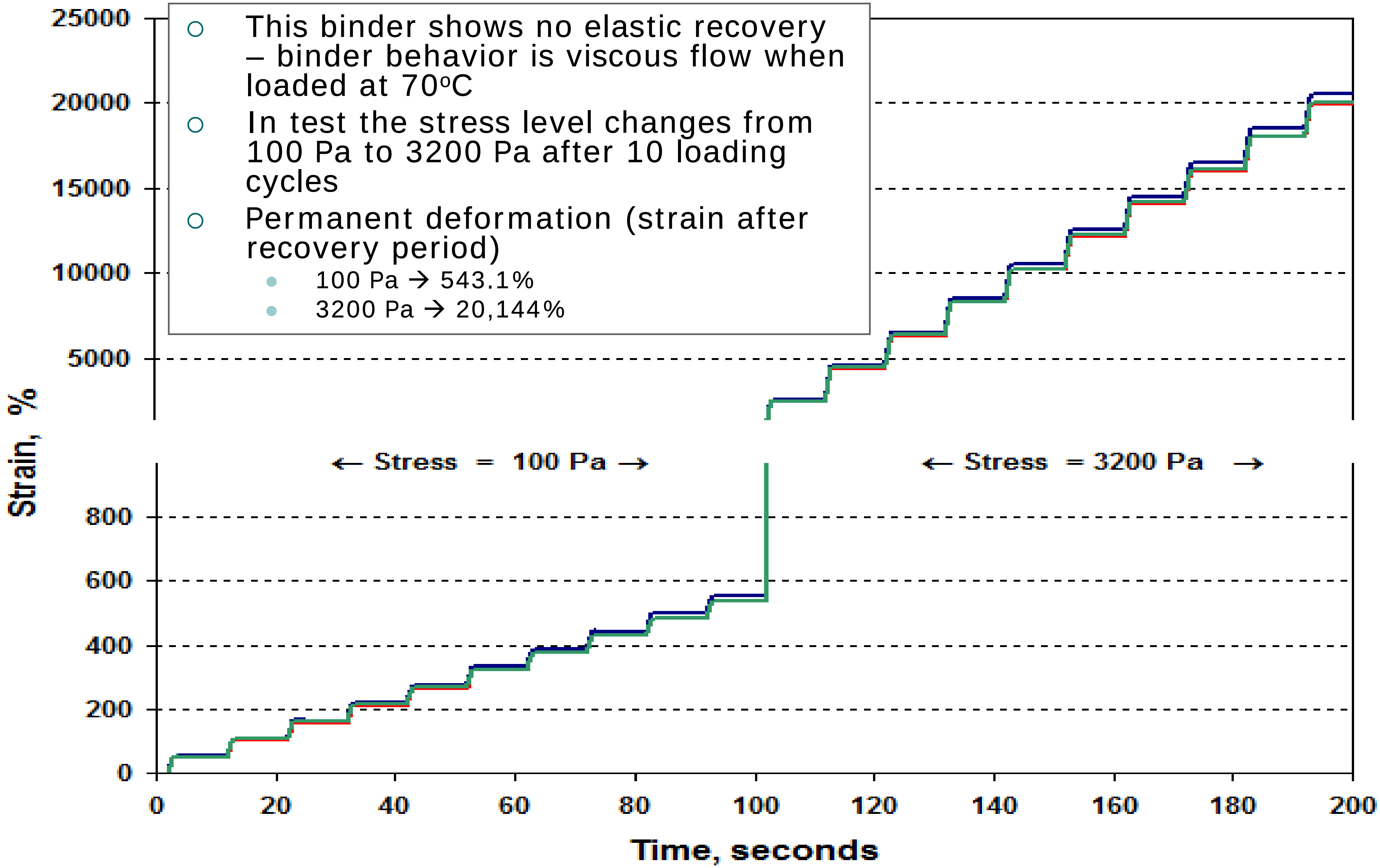
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Why different stress levels



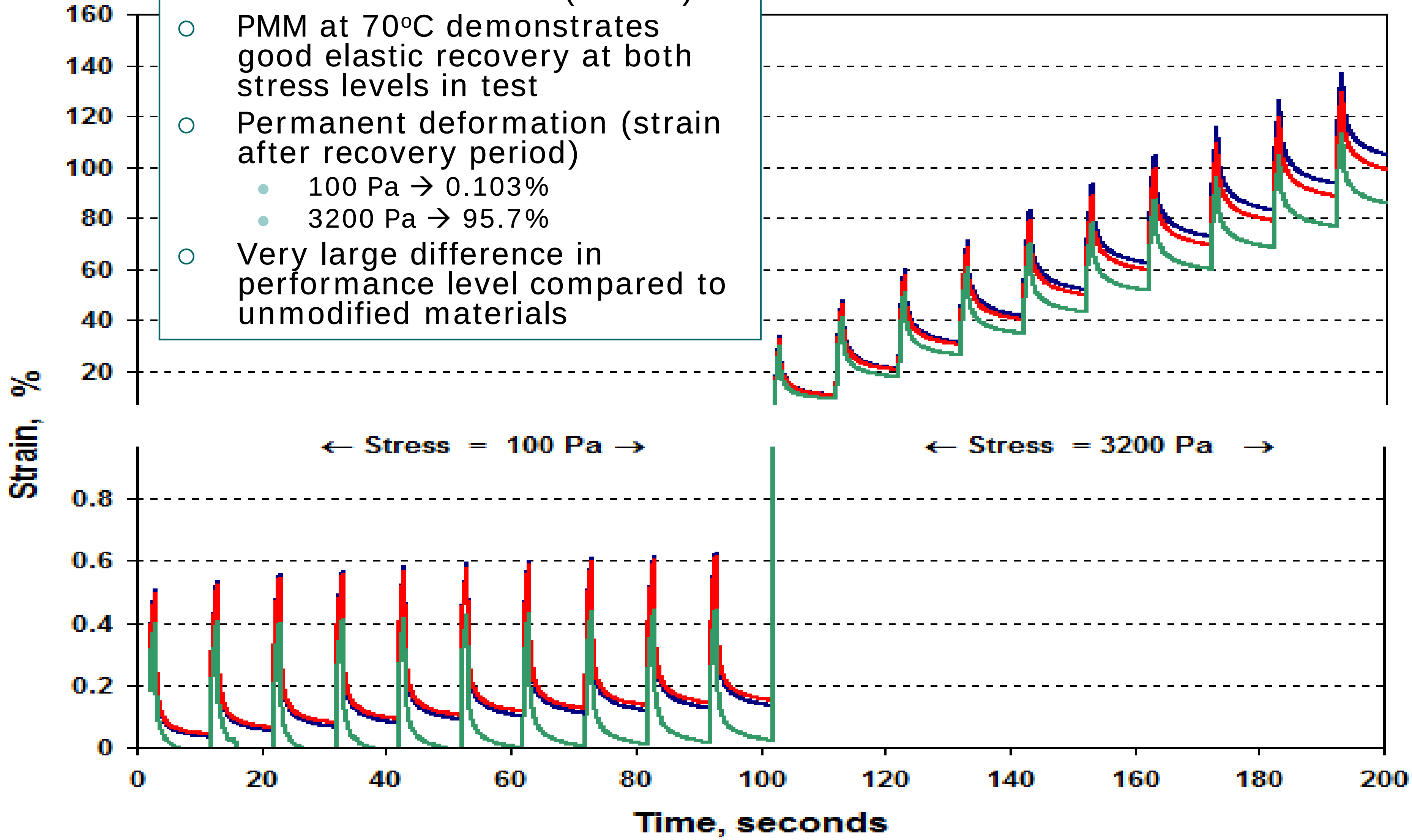
PG64-22, MSCR at 70°C

- This binder shows no elastic recovery – binder behavior is viscous flow when loaded at 70°C
- In test the stress level changes from 100 Pa to 3200 Pa after 10 loading cycles
- Permanent deformation (strain after recovery period)
  - 100 Pa → 543.1%
  - 3200 Pa → 20,144%



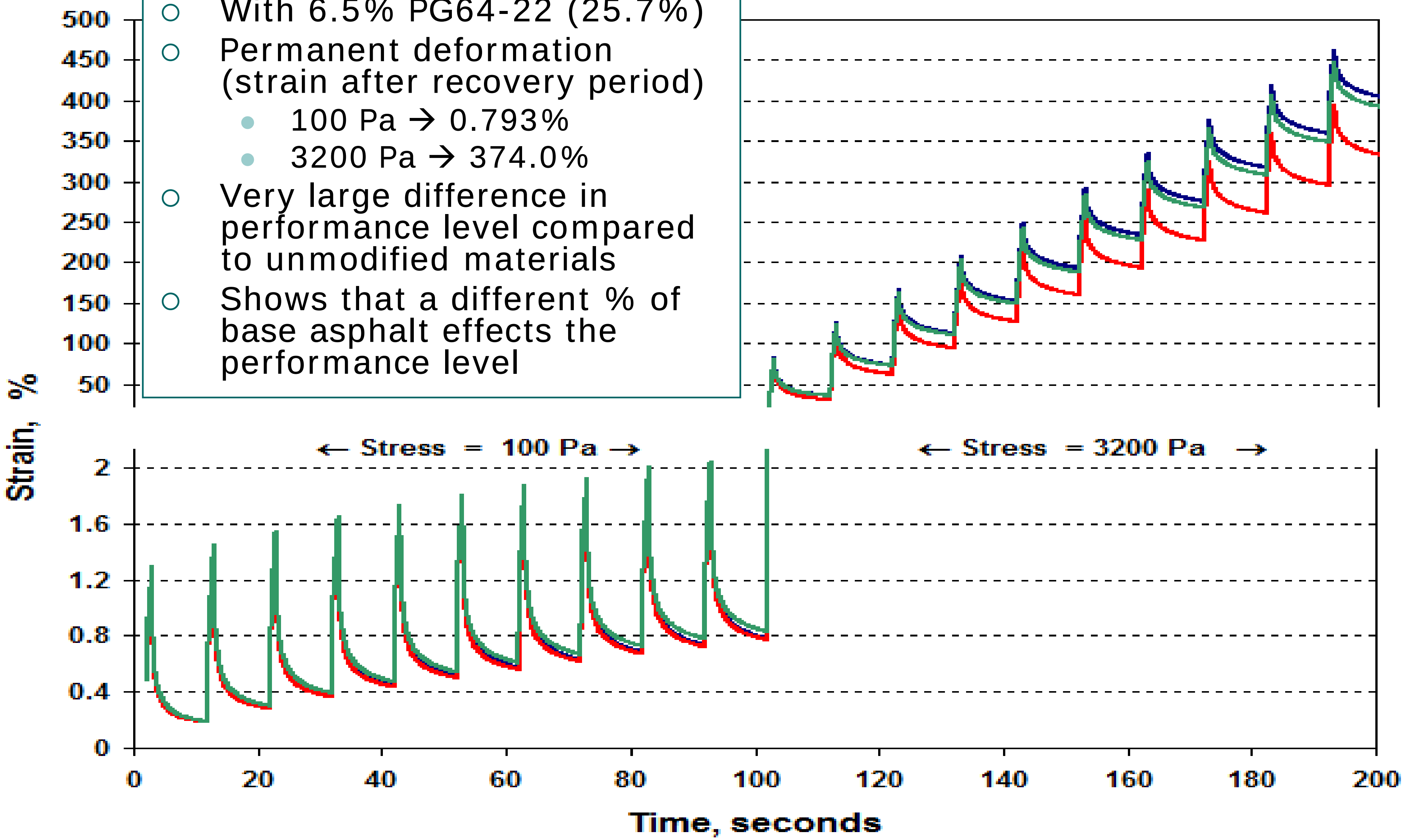
PMM in PG64-22, MSCR at 70°C

- With 5.5% PG64-22 (29.0%)
- PMM at 70°C demonstrates good elastic recovery at both stress levels in test
- Permanent deformation (strain after recovery period)
  - 100 Pa → 0.103%
  - 3200 Pa → 95.7%
- Very large difference in performance level compared to unmodified materials



PMM, MSCR at 70°C

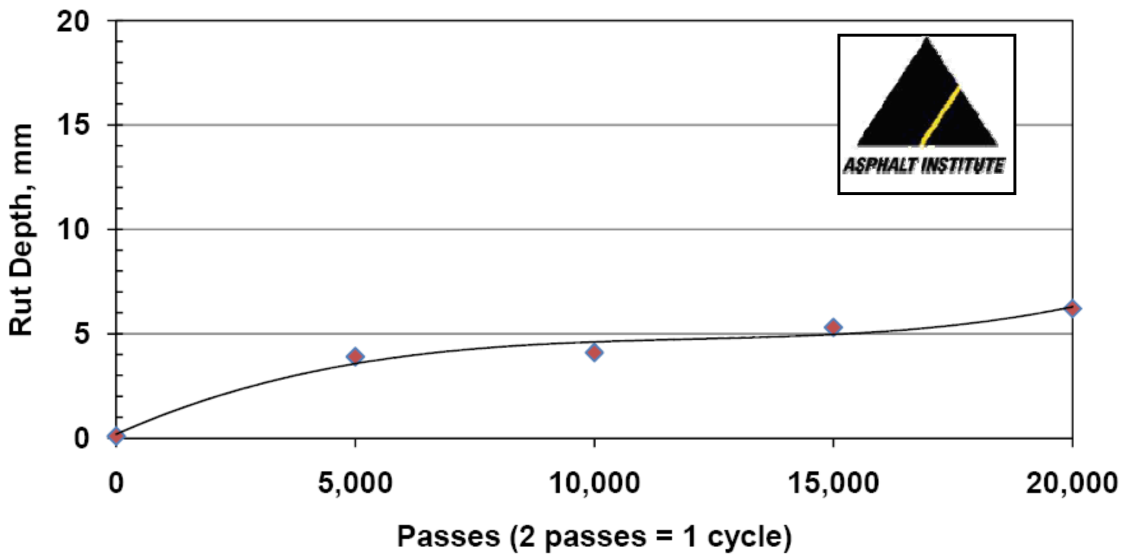
- With 6.5% PG64-22 (25.7%)
- Permanent deformation (strain after recovery period)
  - 100 Pa → 0.793%
  - 3200 Pa → 374.0%
- Very large difference in performance level compared to unmodified materials
- Shows that a different % of base asphalt effects the performance level

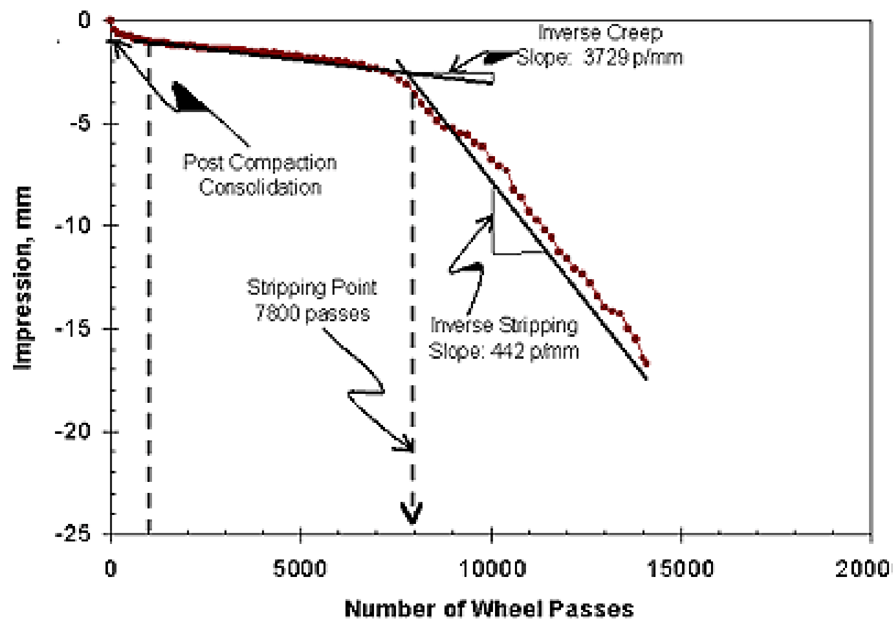


Hamburg wheel tracking test

- Test conducted at 50°C

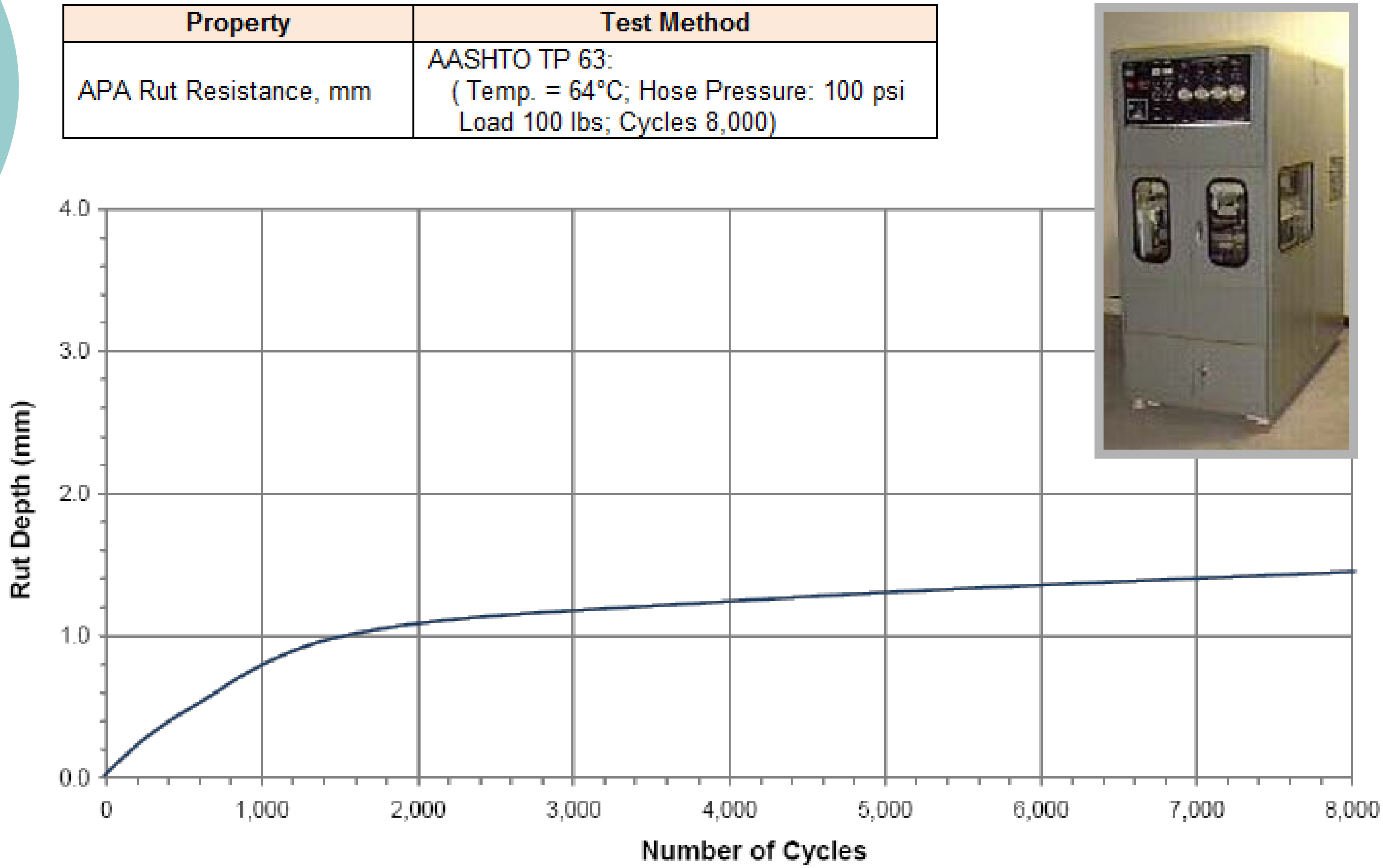
Number of Passes	Rut Depth, mm
0.1	0.1
5,000	3.9
10,000	4.1
15,000	5.3
20,000	6.2





APA wheel tracking test

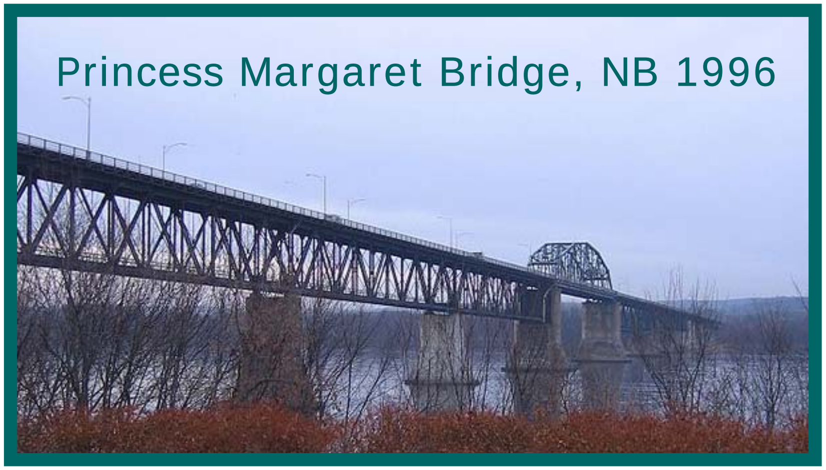
Property	Test Method
APA Rut Resistance, mm	AASHTO TP 63: (Temp. = 64°C; Hose Pressure: 100 psi Load 100 lbs; Cycles 8,000)



Deformation performance

- Deformation performance is consistent with the performance of a thermoplastic visco-elastic solid
- Low deformation – generally associated with secondary compaction of aggregate skeleton

PMM materials implementation



Used since 1983 on various structures

Summary (1)

- The evaluation of the thermoplastic PMM as an alternate bridge deck waterproofing system has demonstrated the use of extensive laboratory and field evaluations.
- The key functionality requirements after the material has been placed are the ability of the material to act as a waterproofing layer, demonstrate good flexibility and resist permanent deformation.
- The thermoplastic PMM achieves all three of these performance criteria via a unique "dry process" modification.
- Each of these requirements relies upon a characteristic of the mixture or binder modification to achieve the desired functionality.

Summary (2)

- The testing and evaluation of these materials can be performed rapidly with mixture specimens produced within
- Fatigue and Flexure, ASTM D7460 - ≥1,000,000 cycles, 20ºC, 750με. The reduction in binder stiffness through modification and the use of thermoplastic elastomeric modifiers enables an increase of fatigue and flexibility when this material is compared to conventional asphalt mixtures.
  - ASTM D 7460 is preferred by the authors over AASHTO T321 due to the better definition of failure life.
- Low temperature performance, AASHTO T322 (and calculations), ≤-30ºC.
- Permanent deformation, AASHTO TP 63 - ≤10mm, 8,000 cycles, 64ºC.

Summary (3)

- The stiffness and elastic recovery of the binder modification at a high temperature and low loading speed enables deformation to be recovered after each loading pass.
- Hydraulic conductivity below $1x10^{-7}$ cm/sec (ASTM D-5084) is recommended to ensure that durability and waterproofing requirements are met
- The thermoplastic PMM materials enable an alternate solution for bridge deck waterproofing that can be easily specified and implemented.

Summary (4)

- The use of plant mix additives allows
  - increased flexibility for HMA manufactures (no liquid storage needed)
  - Significantly higher modification levels can be used than those which can be achieved with conventional plant
  - Rapid construction time
  - Use of conventional equipment
- This paper shows how plant mix modifiers can be applied in specification with suggestion for specifications

Acknowledgements

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Thank you for your attention – Questions?
23,000 tons
installed in 15 days
no road closure