Introduction of a PG binder specifications in SA

Progress report to the 25th RPF

May 2013

New impetus

Current developments driving of a PG spec:

Implementation in 2013 of:

- SANRAL-sponsored SAPDM
- Sabita-sponsored revision of a national asphalt mix design method

Necessitated the adoption of a PG system for bituminous binders to ensure optimal performance of pavements

Sabita – US symposium 29th November 2012

- Attended by 35 informed delegates
- Gave impetus to translation to a performance based specification
- Up-to-date perspective of developments in the USA and EU & opportunity to interact with two experts from abroad
  - Professor ***Hussain Bahia***, University of Wisconsin-Madison
  - ***Martin vd Ven,*** associate professor TU Delft

Purpose

- Evaluate progress made locally with the development of a PG system for SA
- Review the current status of PG system in the USA and to learn from the "school fees" paid.
- Assess the position in the EU
- A critical examination of the status quo globally to arrive at solutions that will stand SA practice in good stead.

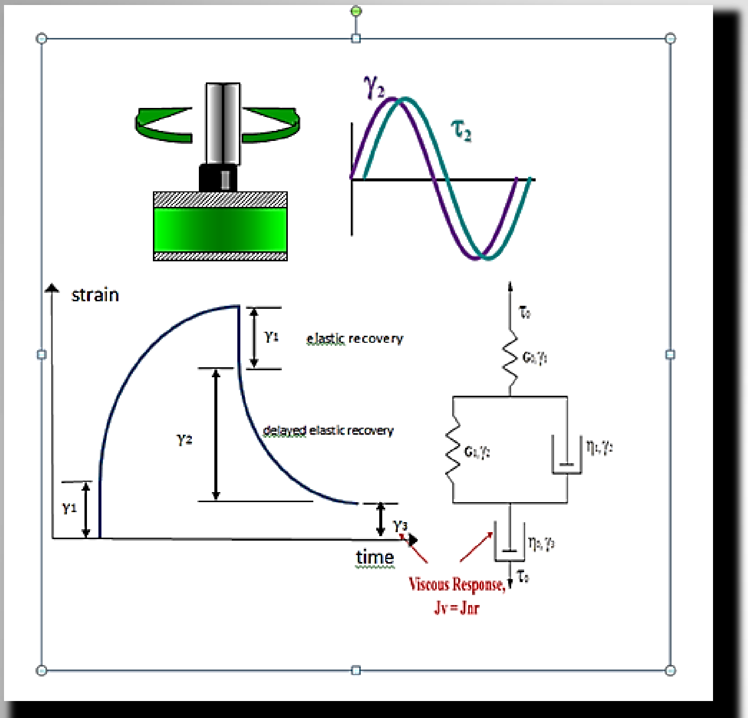
Assessment of USA situation

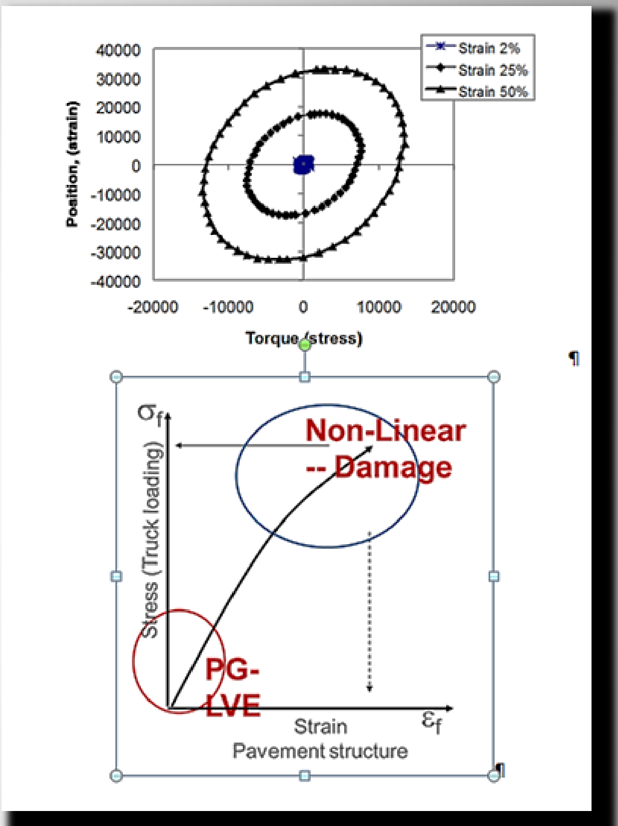
- PG (AASHTO MP19) enhanced quality assurance of bituminous binders
- Notable benefits of implementation of the PG :
  - Testing to suit specific climate conditions;
  - Measurement of rheology - a game changer, identification by refineries of limitations of some crudes;
  - Market shifts to accommodate regional grades;
  - Benefits of modification more clearly articulated

Shortcomings identified

- PG system underestimated the complexity of binder response to imposed stresses (especially of modified binders -50% of market)
- The dissipated energy concept, as characterised by G^* and $sin\delta$ flawed:
  - separate delayed elasticity from viscous damage
  - small strain levels adopted in LVE characterisation by DSR could not fairly predict binder fatigue performance

Limitations of LVE



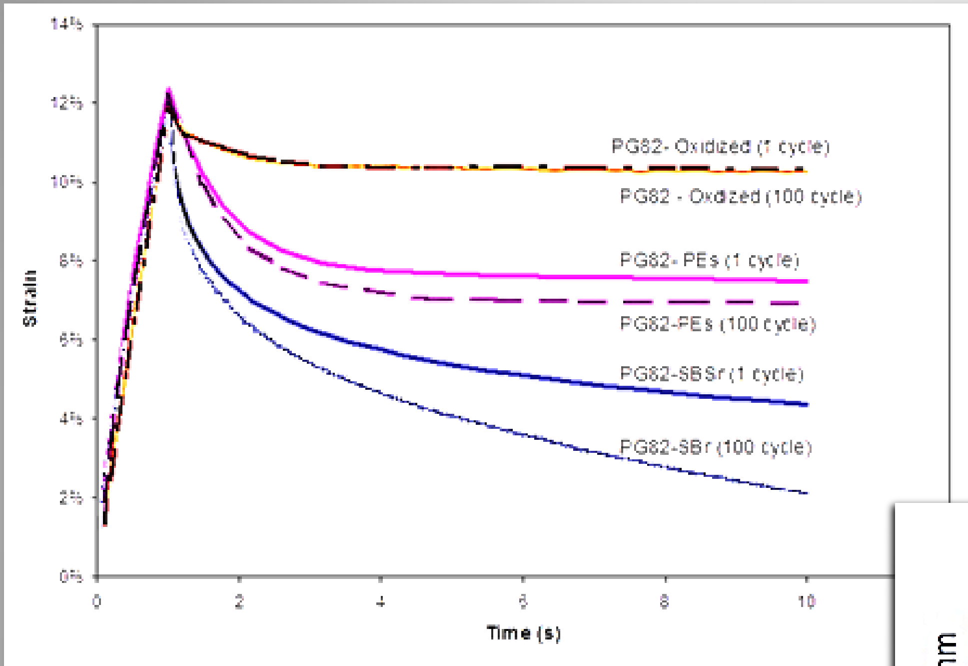


$$W_{total} = \pi.\tau.\varepsilon.\sin\delta$$

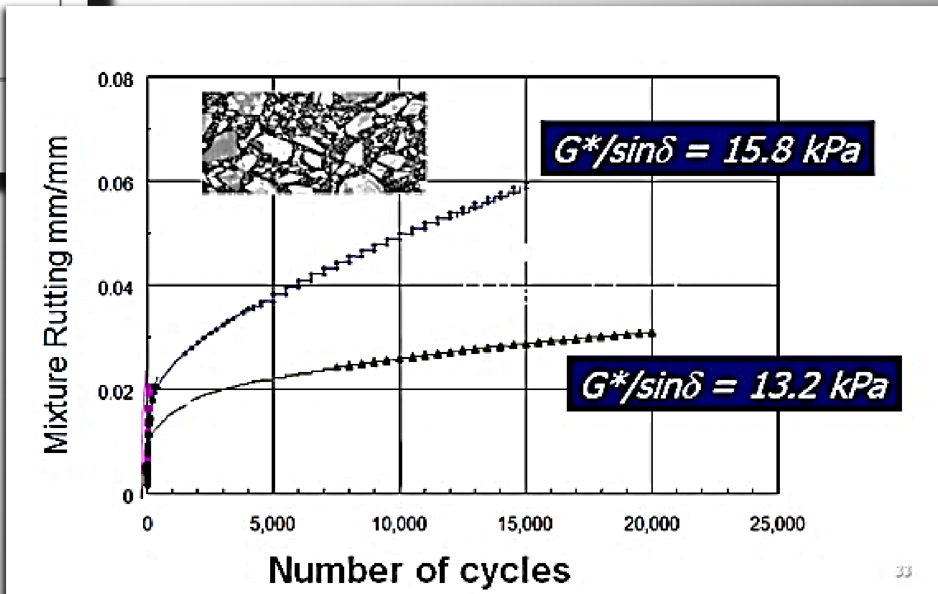
$$W_{total} = \pi.\tau_0{}^2/(G^*/\sin\delta)$$ (rutting - stress controlled)

$$W_{total} = \pi.\varepsilon_0{}^2 G^*\sin\delta$$ (fatigue - strain controlled)

$G^*/sin\delta$

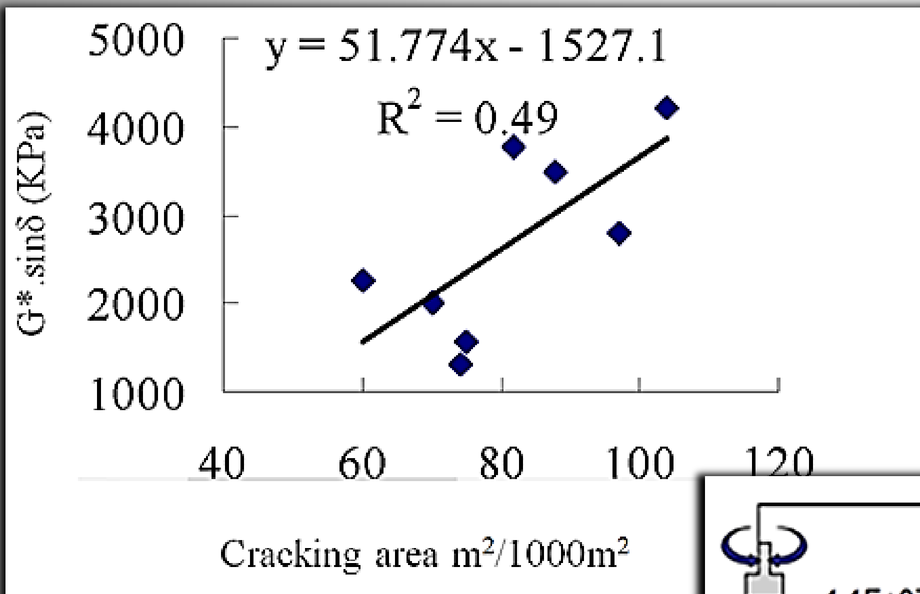


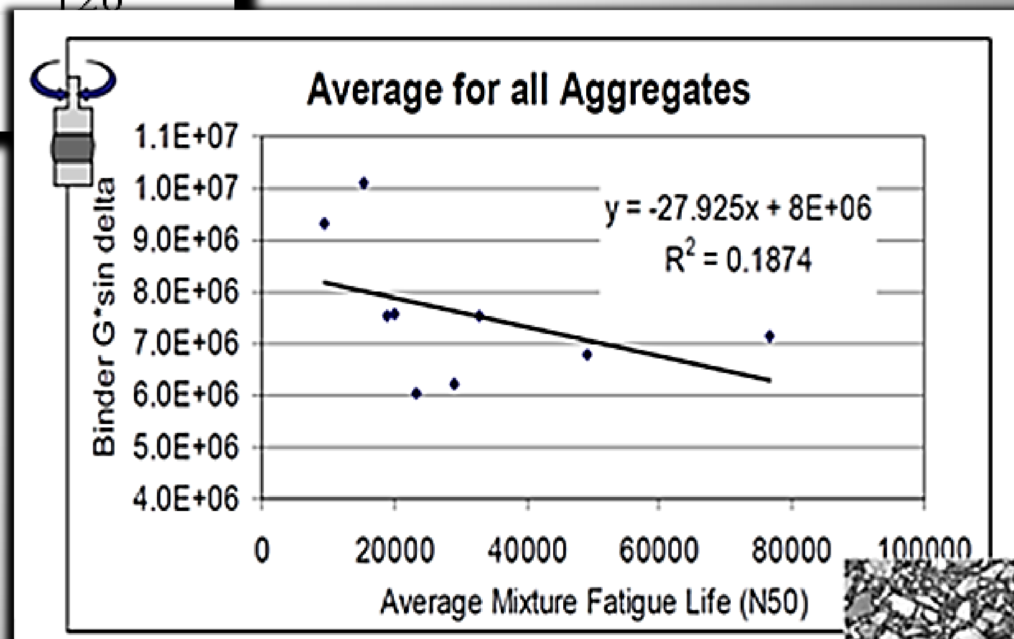
14%
12%
10%
8%
6%
4%
2%
0%
Strain
0
2
4
6
8
10
Time (s)
PG82- Oxidized (1 cycle)
PG82 - Oxdized (100 cycle)
PG82- PEs (1 cycle)
PG82-PEs (100 cycle)
PG82-SBSr (1 cycle)
PG82-SBr (100 cycle)



0.08
0.06
0.04
0.02
0
Mixture Rutting mm/mm
0
5,000
10,000
15,000
20,000
25,000
Number of cycles
G*/sinδ = 15.8 kPa
G*/sinδ = 13.2 kPa

$G^* \times sin\delta$





New approach

Concept of DRC developed to measure binder response:

1. Viscous deformation
2. Resistance to fatigue
3. Low temperature fracture

Position in EU

- Harmonised specifications classify binders as rheologically:
  - *Simple*
  - Complex
- Simple
  - EN 12591 Paving grade bitumens; and
- Complex
  - EN 14023 Polymer modified bitumens
  - EN 13924 Hard paving grade bitumens

EU/cont …

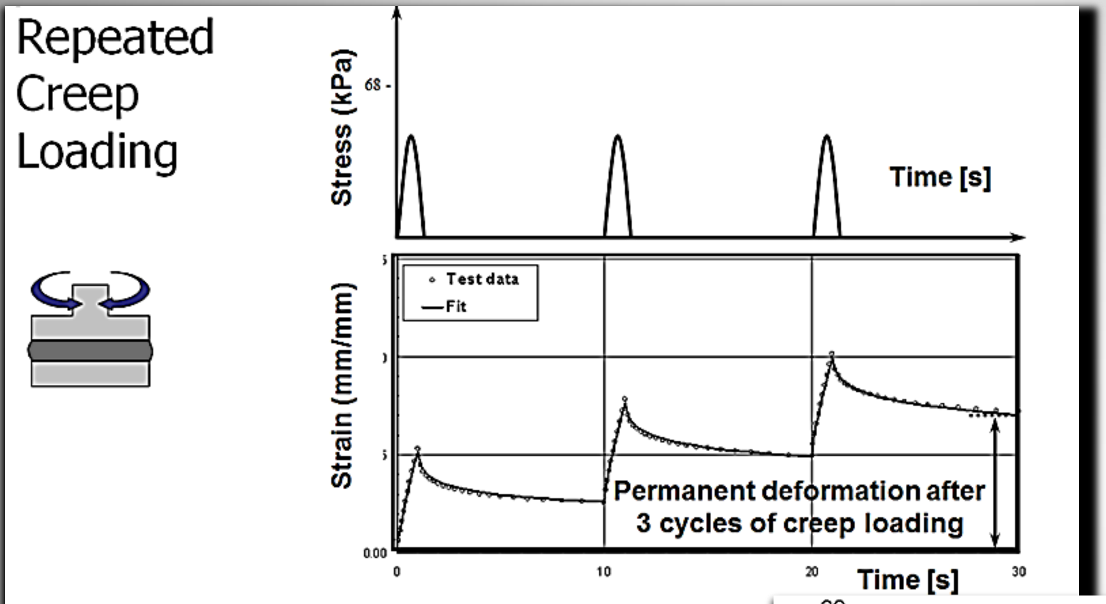
January 2012

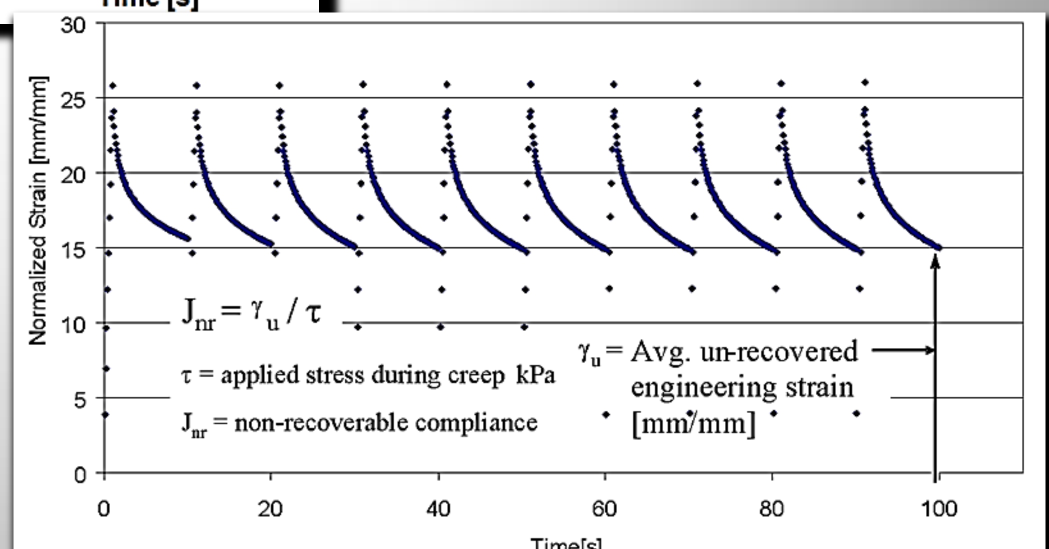
- Specification for simple binders
  - ***Adequate***
  - ***Remain unchanged for 5 years***
- Specifications for complex binders requires revision
  - High and low temperature behaviour
  - DSR testing likely to be introduced

US - DRC

- Resistance to permanent deformation at elevated temperature
  - Non recoverable compliance J_{NR} (MSCR) well established – ready for implementation here
  - Higher stress and strain levels captures:
    - Stiffening effects of a modifier
    - Delayed elastic effects
  - Introduced in the latest revision of Superpave

MSCR test (DSR)





Stress

– 3.2 KPa to be increased?

Fatigue and fracture

Several initiatives underway in the USA

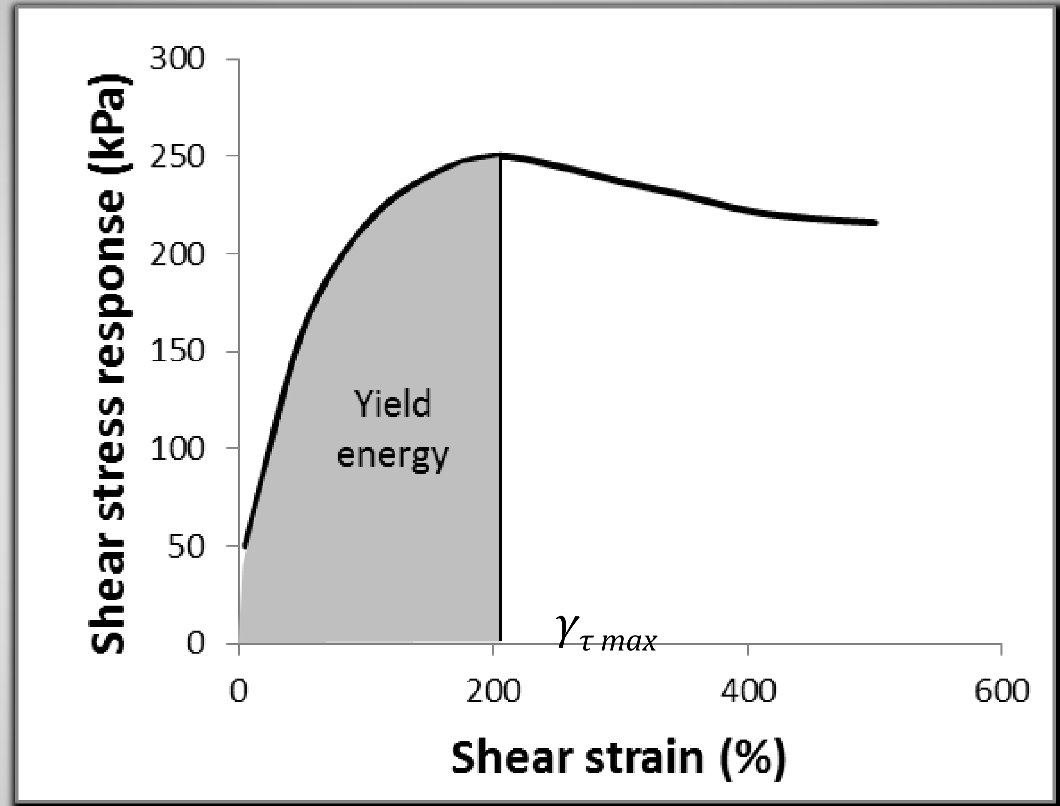
Candidates for SA :

- Fatigue
  - DSR
    - Monotonic Binder Yield Energy Test (BYET)
    - Linear Amplitude Sweep Test (LAS)
- Low temperature fracture
  - DSR (to be developed)
  - Single Edge notch Beam (SENB)

Fatigue - BYET

- Strong candidate (AASHTO T XXX 13)
- Monotonic DSR application
  - 8 mm plate
  - Temperature e.g. intermediate minus 8 °C
  - RTFO (and PAV?) residue
- Monotonic shear @ 1% strain/s
- Stress, strain recorded at every 2 s
- Up to 3600% strain (60 minutes)

Yield Energy



$$BYE = (\tau_{i-1})(\gamma_{i-1})/2 + \sum_{i=1}^{N}\left(\frac{\tau_i + \tau_{i-1}}{2}\right)(\gamma_i - \gamma_{i-1})$$

Correlation with FHWA ALF testing

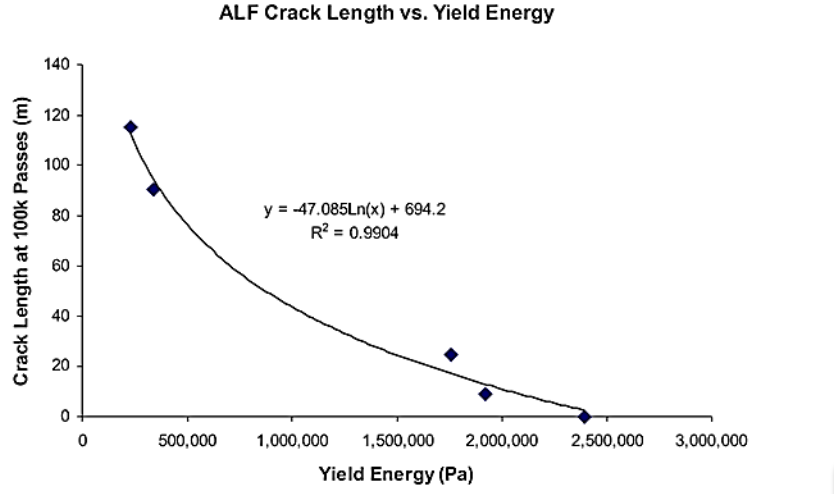


FIGURE 5*a* Yield energy ($\dot{\gamma} = 0.0075 / s$) versus ALF fatigue crack length.

Both:

Yield Energy

Strain at max stress

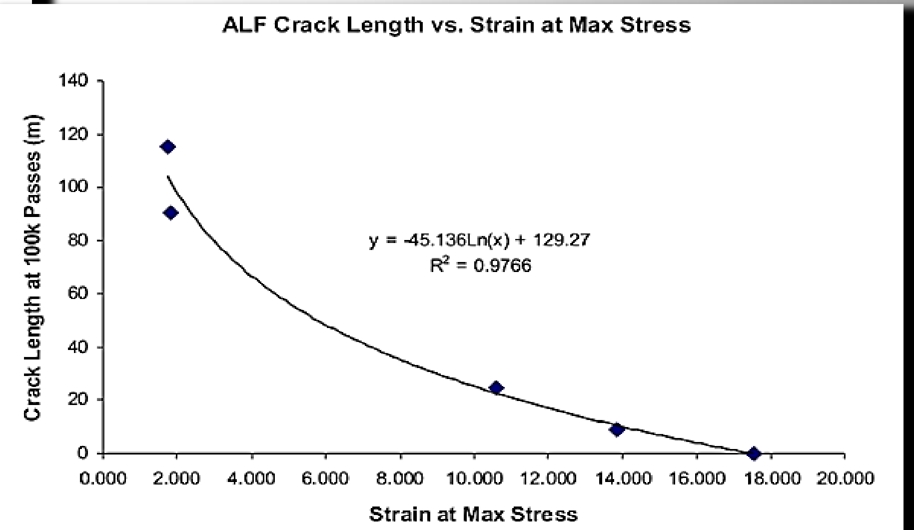


FIGURE 5*b* $\gamma_{\tau\,max}$ **versus ALF fatigue crack length.**

FHWA ALF 2012 – Gibson et al

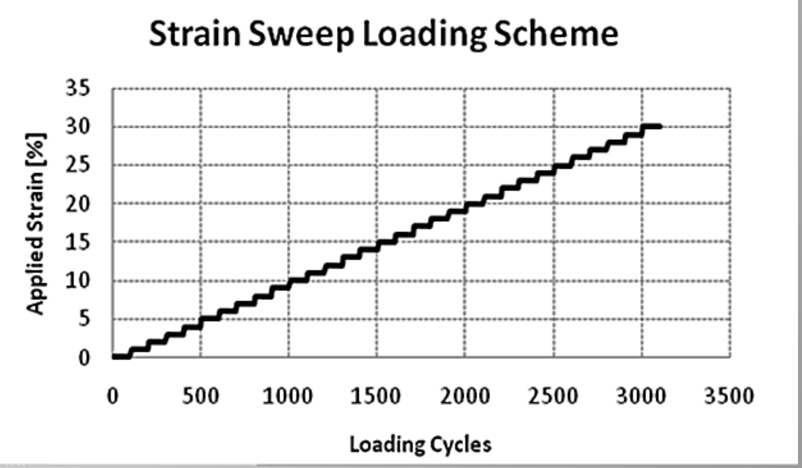
Table 105. Ranked binder fatigue cracking parameters from 4-inch (100-mm) ALF lanes.

Binder Test for Fatigue Cracking	Comparative Data	$1\text{-}p_{Reg}$ (percent)	τ_K	$1\text{-}p_{\tau K}$ (percent)	R	Composite Score
CTOD	Axial fatigue	99	1.00	99	0.95	
	ALF cracking	100	1.00	99	0.98	0.99
Binder yield energy	Axial fatigue	94	0.80	96	0.87	
	ALF cracking	90	0.80	99	0.80	0.88
Time sweep	Axial fatigue	89	0.80	96	0.79	
	ALF cracking	95	0.80	96	0.88	0.88
Failure strain in low-temperature DT test	Axial fatigue	92	0.60	88	0.83	
	ALF cracking	93	0.60	88	0.85	0.81
Superpave® $\|G^*\|\sin\delta$	Axial fatigue	84	-0.60	88	-0.73	
	ALF cracking	78	-0.60	88	-0.66	0.75
Large strain time sweep surrogate	Axial fatigue	85	-0.40	76	-0.74	
	ALF cracking	78	-0.40	76	-0.67	0.67
EWF	Axial fatigue	53	0.40	76	0.43	
	ALF cracking	60	0.40	76	0.50	0.55
m-value from low-temperature BBR	Axial fatigue	63	0.40	76	0.52	
	ALF cracking	47	0.40	76	0.38	0.54
Stress sweep	Axial fatigue	89	-0.40	76	-0.79	
	ALF cracking	83	-0.40	76	-0.73	0.69*

*Incorrect trend direction

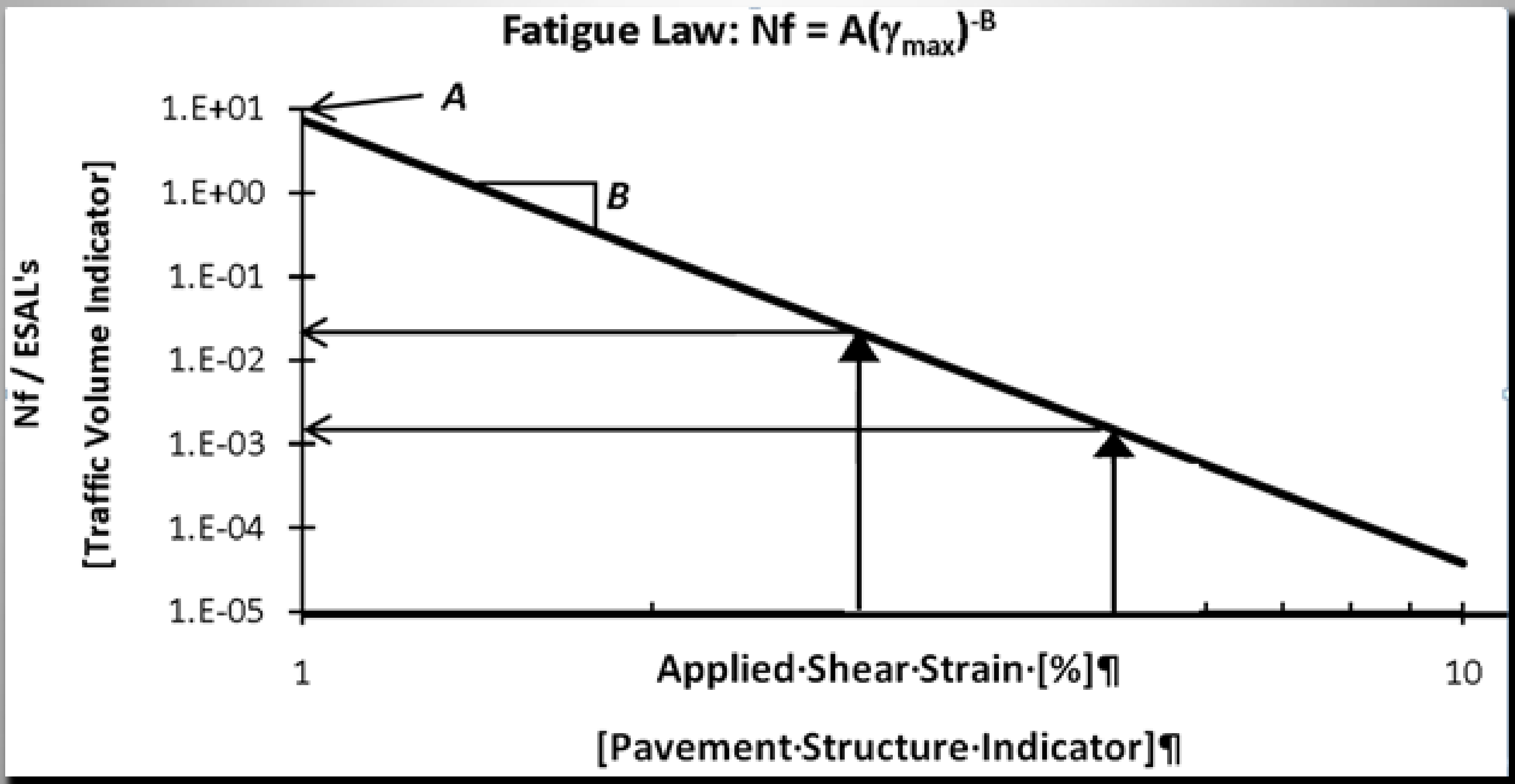
Linear amplitude sweep test

- Conducted on RTFO and/or PAV aged specimens
- 8 mm plate geometry
- Cyclical testing with ramped amplitude
- Frequency sweep on G* and sinδ
- Log-strain/log-N



LAS

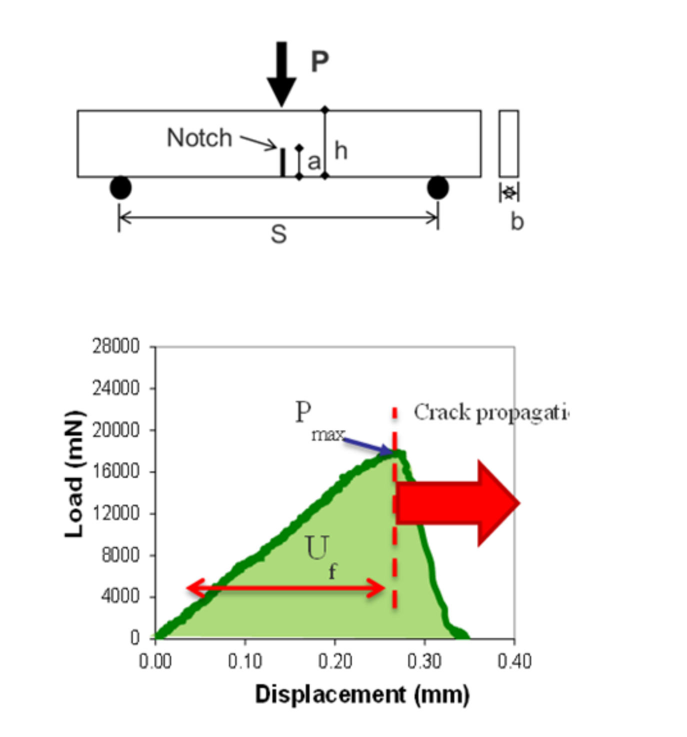
Complicated procedure requiring advanced techniques



Low temperature fracture

- Two candidate test methods
  - Single-Edge Notched Beam (SENB)
  - DSR low temperature stiffness and stress relaxation

SENB



Fracture toughness $K_f = \frac{P_{max}.S}{bh^{3/2}} f\left(\frac{a}{h}\right)$

where

$f\left(\frac{a}{h}\right)$ is a function of the ratio a/h

Fracture energy

$$G_f = \frac{W_f}{A_{lig}}$$

Where

W_f, the work done $= \int P du$

A_{lig} is the area above the notch (ligature

DSR procedure

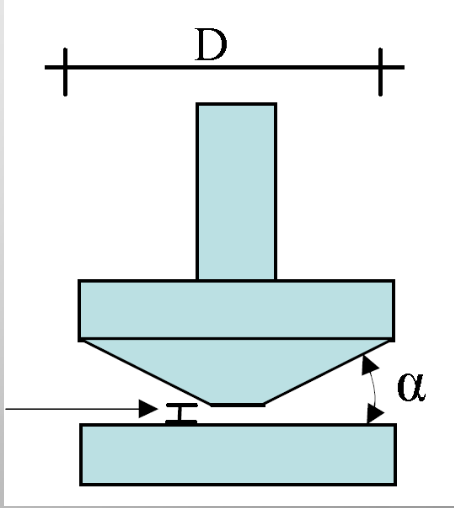
- Requires no additional equipment
- Determines
  - Stiffness (S) - max
  - Logarithmic creep rate (m) - min
- Conducted at low temperature (5 or 10 °C)

  m – slope of the log S/log t curve at 2 s, say

  Represents the ability of the binder to relax thermal stress during cooling
- Proposal of assistance by Hussain Bahia being considered by CSIR

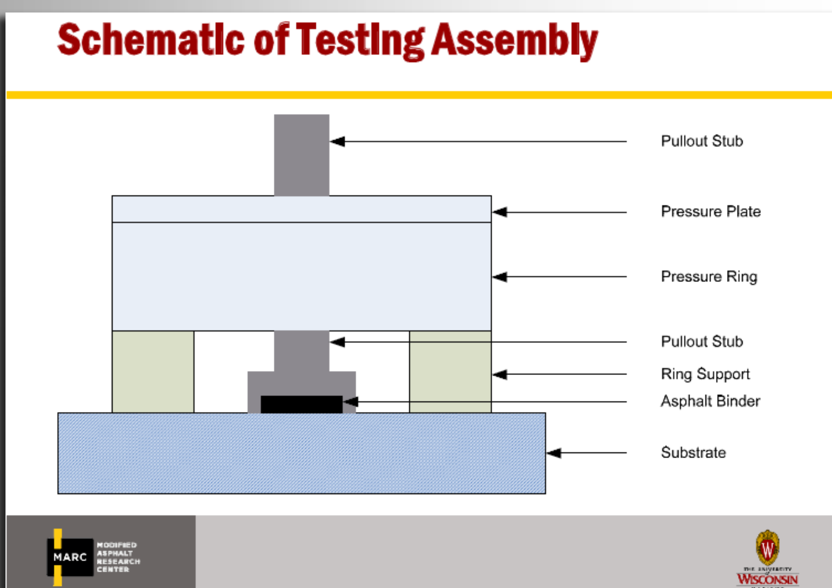
Handling

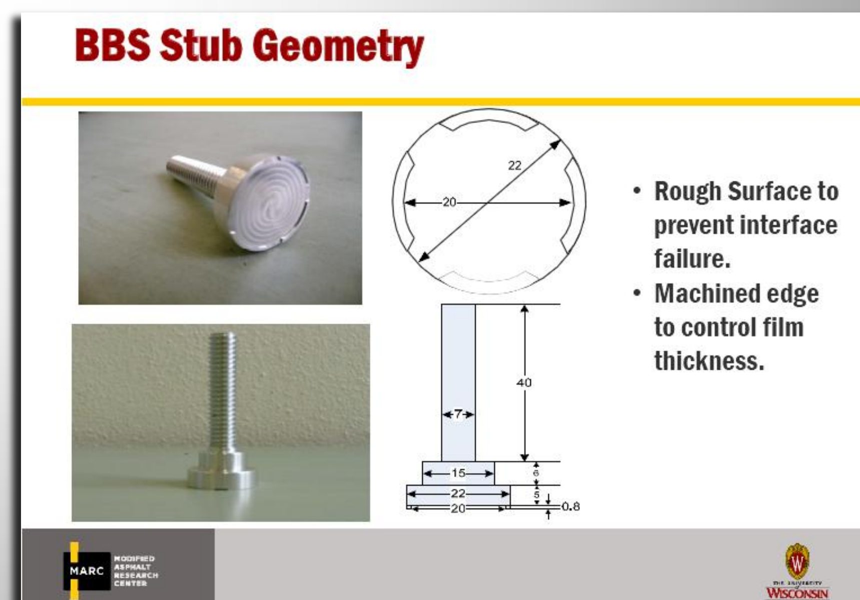
- Introduction of DSR testing – inevitable
- Viscosity at elevated temperature (135 °C)
- As proposed in RPF task group on bitumen specifications – DSR cone and plate configuration instead of the RV



Adhesion

- Bitumen Bond Strength (BBS)
  - Hot binders
  - Emulsions
  - Glass/aggregate substrate

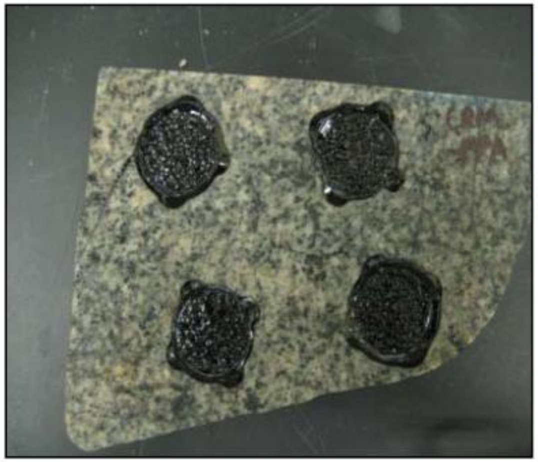




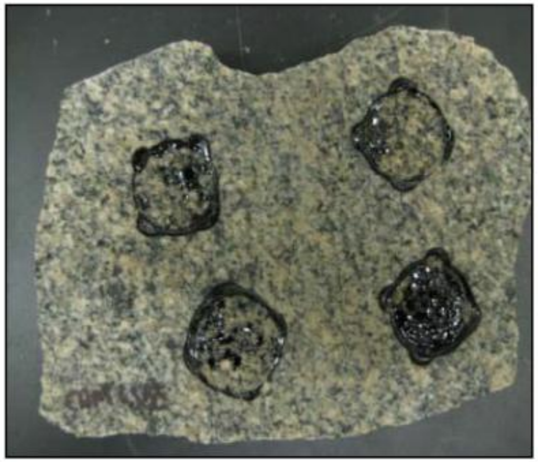
Data analysis

- Pull Off Tensile Strength (POTS):
  - Mean of at least three replicates.
- Consistent Loading Rate
  - POTS is rate dependent.
- Examine/Image Failure Surface
  - *Adhesive Failure* (>50% Aggregate Surface Exposed)
  - *C*ohesive Failure (<50%)

Failure



Cohesive Failure



Adhesive Failure

MODIFIED ASPHALT RESEARCH CENTER

THE UNIVERSITY of WISCONSIN MADISON

SA Environment

- CSIR ThermalPADS software- 118 data points:
  - 7-day average max asphalt temp (20 mm depth); and
  - min asphalt surf temp day temperatures,
- Two max zones: **- 64 and 58 ^{o}C**. In
- A single lower temperature: **– 10 ^{o}C**
- No provision for “p” grades – binder-blind
- Provision for HiMA grades – rheologically unique

Likely specification framework

Property	Classification							
	58	64	58H	64H	58V	64V	HiMA 58	HiMA 64
	-10	-10	-10	-10	-10	-10	-10	-10
Max pavement design temp (˚C)	≥ 58	≥ 64	≥ 58	≥ 64	≥ 58	≥ 64	≥ 58	≥ 64
Original binder								
J_{nr} (at σ = XX kPa) @ max pavement design temp								
Viscosity Pa.s @ 135 ^{o}C	≤ 3,0							
Flash Point (˚C)	≥ 230							
Storage stability Max % diff J_{NR} top and J_{NR} bottom	5							
RTFO binder								
Maximum Mass Change (m/m %).	|0,3|							
J_{nr} (at σ = XX kPa) @ max pavement design temp								
Bitumen Bond Strength (kPa)								
PAV binder @ 100 (?) ^{o}C								
DSR Binder Yield Energy @ intermediate temp								
DSR (S – m) 2 seconds at 5 ^{o}C (or 10 ^{o}C)								

Concluding remarks

- Use of the MSCR – well established
- More severe conditions for PAV
- Versatility of DSR may limit special testing equipment required to three:
  - PAV
  - RTFO
  - DSR

Conclusions/cont.

- PG spec based on binder performance requirements in asphalt mixes
  - Safeguard satisfactorily performance in spray seal applications. (Texas TI, FHWA)
  - Two distinct specifications (e.g. RTFO not in seal binders)
- Latest developments – abandonment of $G^*/sin\delta$ & $G^* \times sin\delta$ enables a binder-blind specification – worthy goal

Finally – a thought

Report FHWA/TX-05/1872-2 (Aug 2002)

Glover et al

"As modified binders oxidize, the asphalt (bitumen) hardens …

"After enough aging, the improvement is gone and modified binders perform no better than their aged unmodified counterpart.

A critical issue is whether the life extension is … cost effective."