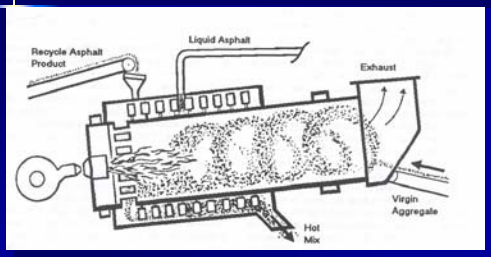
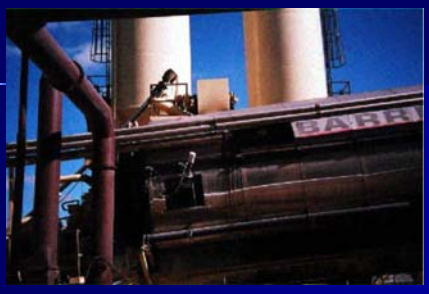
Methods of Adding HL to Asphalt

Georgia Method - Double Barrel Drum Mixer





Double drum asphalt plant with 2 silos – one for hydrated lime & one for mineral filler

Weigh pot (1) dispenses lime through rotary vane feeder to screw conveyor (2) and into outer shell (3) of double drum plant

Utah Method

Hydrated lime added to aggregate and fed into pugmill for mixing

Hydrated lime is dispensed from the silo through a weigh pot

Water delivery system mounted over aggregate conveyor (see arrow)

Hydrated lime added through vane feeder (1) to screw conveyor (2) where water is added (3) to make slurry which is added to aggregate in pugmill

Limed aggregate being discharged from pugmill

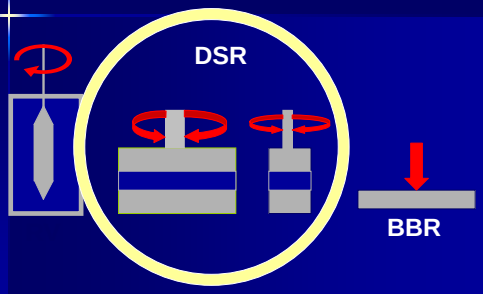
Stacking lime treated aggregate

Impact of Hydrated Lime (HL) in Asphalt

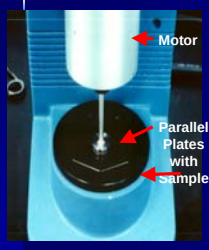
- High temperature performance
- Intermediate temperature performance
- Low temperature performance
- Moisture resistance

At high temperature we want to reduce rutting in the wheel path

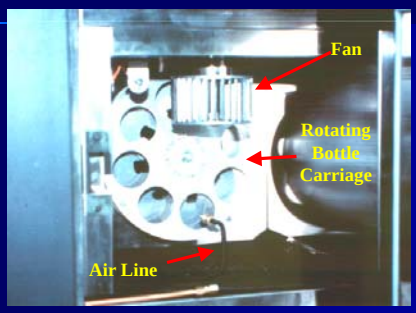
Superpave Approach

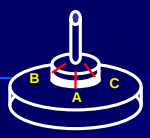


Dynamic Shear Rheometer

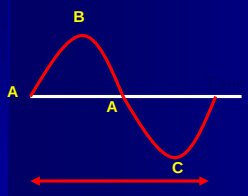


Inside of RTFO



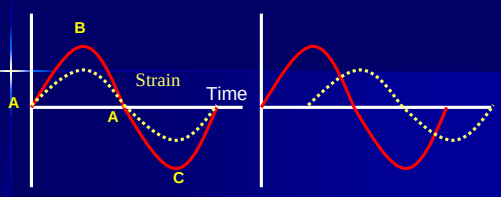


Fixed Plate



Test operates at 10 rad/sec or 1.59 Hz

360° = 2 p radians per circle
1 rad = 57.3°



Strain out-of-phase
d = 90°

Permanent Deformation

Addressed by:

G*/sin δ on unaged binder > 1.00 kPa

G*/sin δ on RTFO aged binder ≥ 2.20 kPa

For the early part of the service life

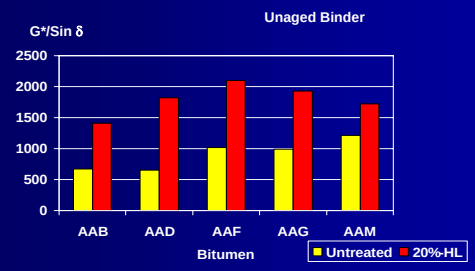
Permanent Deformation

Question: Why a minimum G*/sin δ to address rutting

Answer: We want a *stiff, elastic* binder to contribute to mix rutting resistance

How: By increasing G* or decreasing δ

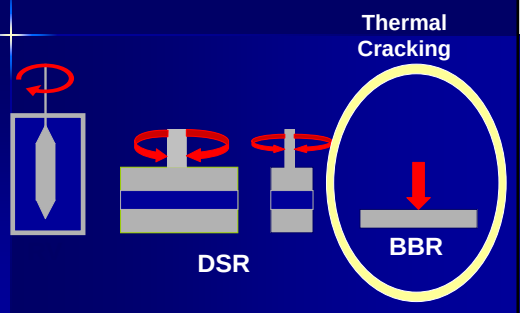
High temperature rheological data for SHRP bitumens (64C):



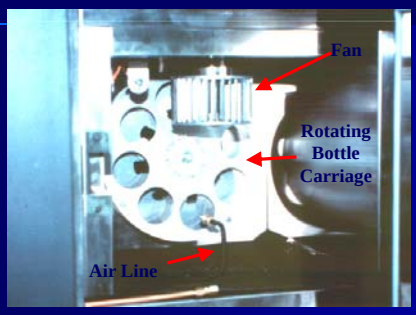
At low temperature we want to reduce thermal cracking

At intermediate and low temperatures we want to resist fatigue Cracking

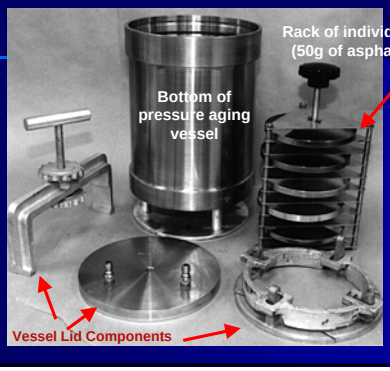
Superpave Approach



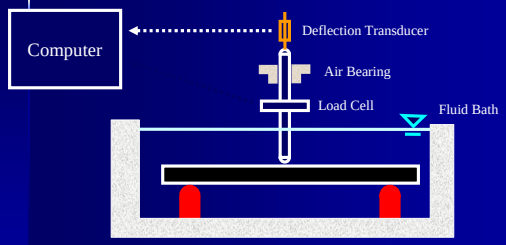
Inside of RTFO



Pressure Aging Vessel

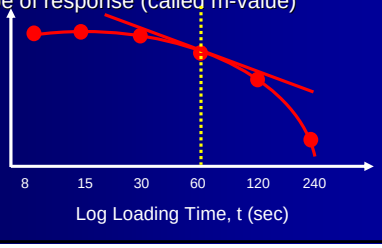


Bending Beam Rheometer



Bending Beam Rheometer

- Evaluates low temperature stiffness properties
  - Creep stiffness
  - Slope of response (called m-value)

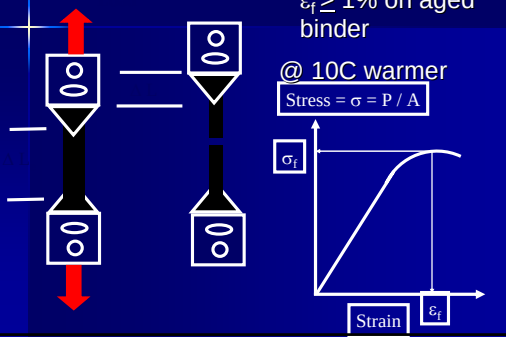


Direct Tension Test

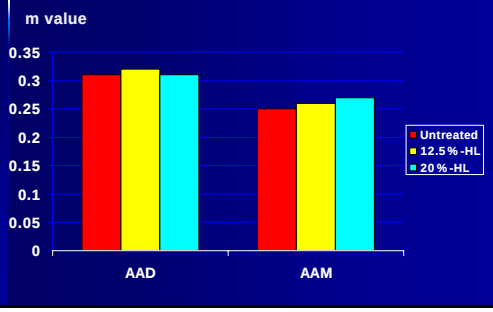
Addressed by:

$\varepsilon_f \geq 1\%$ on aged binder

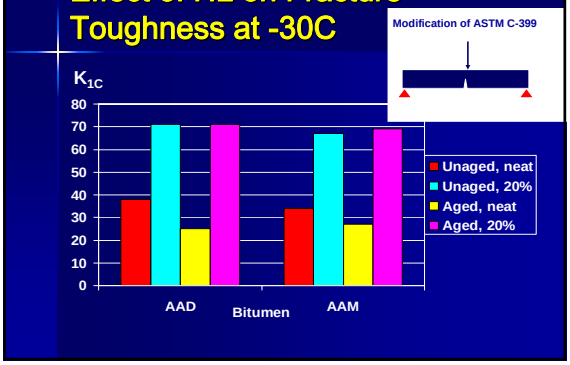
@ 10C warmer



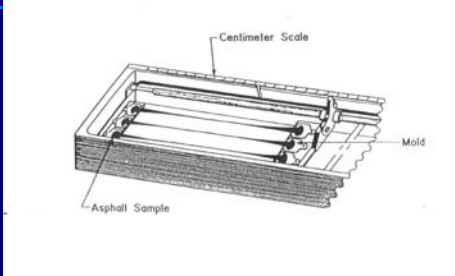
Effect of HL on low temp. BBR m-value (-18C)



Effect of HL on Fracture Toughness at -30C



Ductility



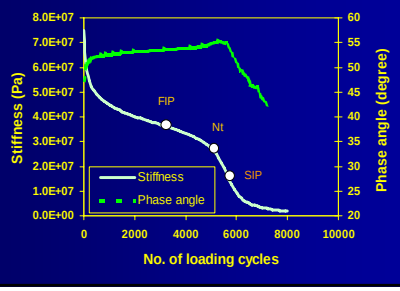
Tensile strain at 30°C (Direct Tensile Test), after Little and Petersen, 2005

Asphalt	Treatment	Temp., °C	Elongation, %	Tensile Stress, kPa
Boscan	None	-10	4.8	830
	20% Limestone	-10	2.8	1,680
	20% Ca(OH)2	-10	11.7	1,170
W. Texas - Maya	None	-10	4.4	1,340
	20% Limestone	-10	0.75	1,310
	20% Ca(OH)2	-10	8.3	2,170

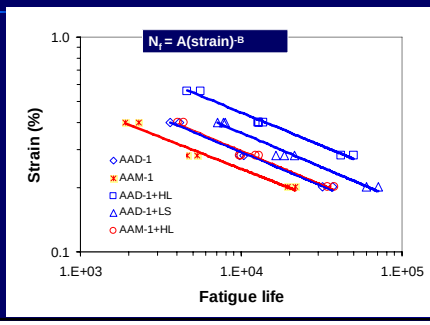
Effects of Moisture on DMA

DMA Testing Apparatus - Intermediate Temperature (25°C)

Normalized Nonlinear Dynamic Modulus and Phase Angle versus Number of Loading Cycles in Fatigue Testing

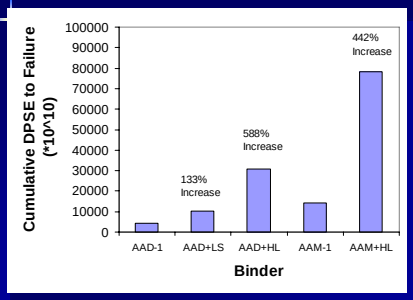


Fatigue Life
(Effect of Filler Addition)

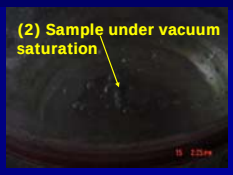


Comparison of CDPSE

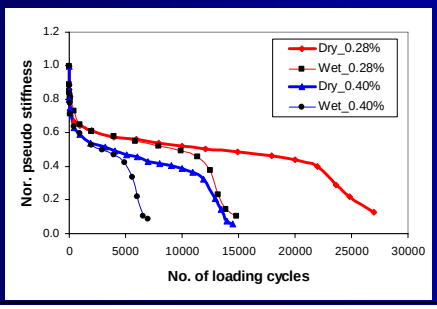
(@ Same Strain Level)



Fabrication of DMA Sample for Moisture Sensitivity Testing



Damage in DMA: Effect of Moisture



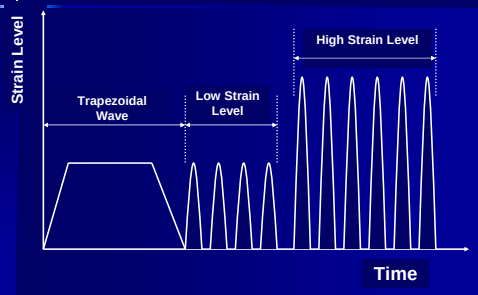
Impact of HL on Cycles to Failure (dry and wet)

Asphalt	Mineral Filler	N_f (dry)	N_f (wet)
AAM-1	Limestone	4,000	2,100
AAM-1	Hydrated Lime	8,200	6,200
AAD-1	Limestone	5,200	2,500
AAD-1	Hydrated Lime	10,000	8,500

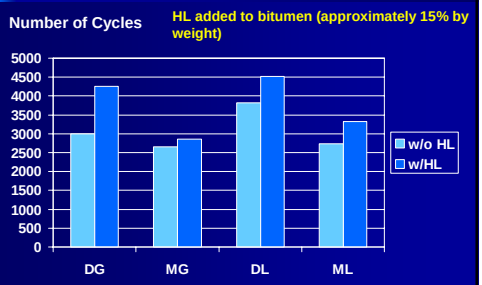
Superpave Shear Tester (SST) – Intermediate Temperature

Close-up of Test Setup

Input Strain Waveform



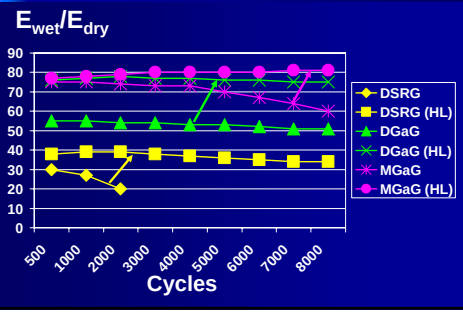
Effect of HL on Cycles to Direct Tensile Fatigue Failure



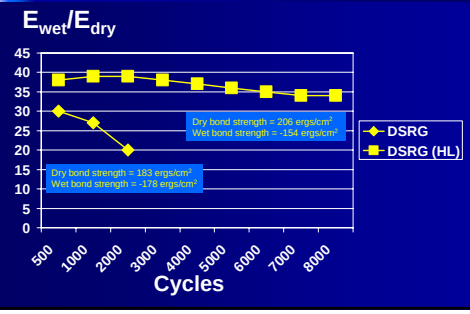
Effect of Moisture on Permanent Deformation

Repeated Load Permanent Deformation Testing (Dry and Near Saturation)

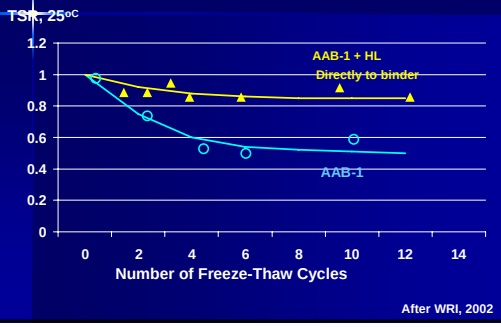
E_{wet}/E_{dry} in Repeated Load Testing (85% Saturation)



E_{wet}/E_{dry} in Repeated Load Testing (85% Saturation)

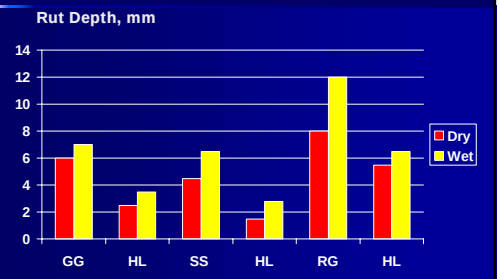


Impact of Freeze/Thaw Cycles on TSR



After WRI, 2002

Comparative APA Results



Conclusions

- HL is an active filler that substantially improves high temperature rheology - resistance to permanent deformation
- HL improves low temperature binder toughness without substantially reducing the ability of the binder to relax - resistance to low temperature cracking

Conclusions, cont'd

- When well-dispersed in the bitumen, HL acts to arrest or "pin" microcrack growth
- Resistance to microcrack growth promotes fatigue damage resistance
- HL improves moisture resistance by improving asphalt-aggregate bond and by improving mastic cohesive strength in the presence of moisture

Conclusions, cont'd

- Mechanisms of lime-asphalt interaction
  - strong base binds acids and related functionalities
  - interaction is reflected in remainder of binder (AAD - high amphoteric, RCOOH)
  - Ca-based organic salt - relatively insoluble
  - Ca reaction with carboxylic acids allows more moisture resistant bonds to form
  - Little and Petersen (2003)