Nanotechnology for asphalt modification

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Association of Modified Asphalt Producers

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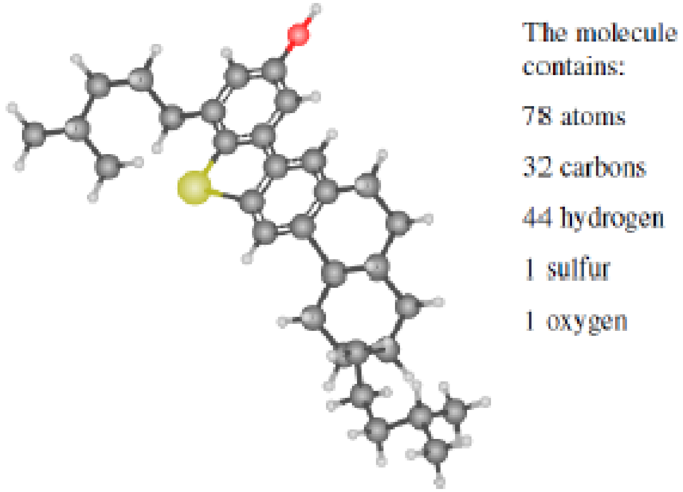
Objectives

- To present some definitions relating to nanotechnology
- Work being conducted around the world
- Some new materials
  - Many introduced to the market in last few years

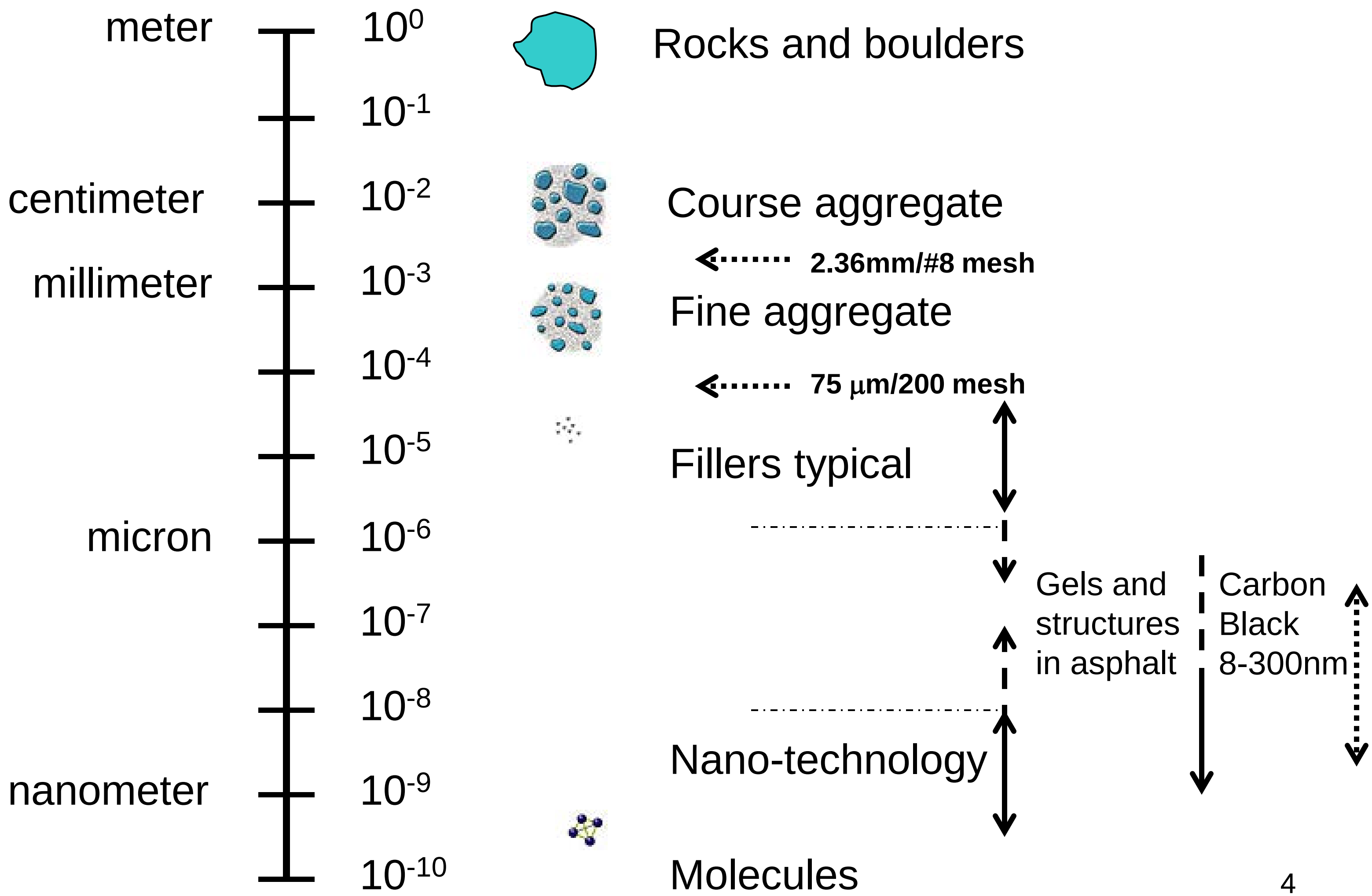
What is it?

- Technologies being developed at a scale at or above the atomic scale but significantly below what we normally consider as fillers

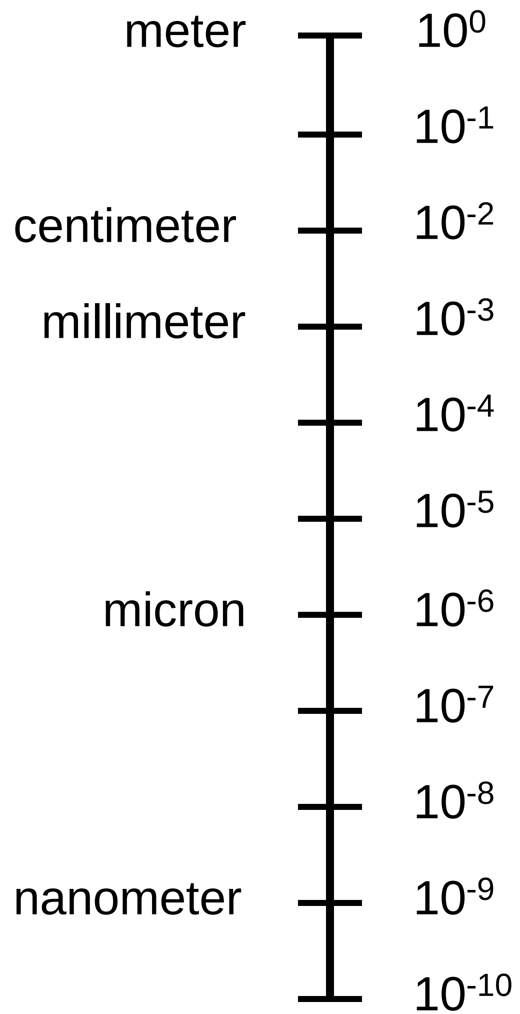


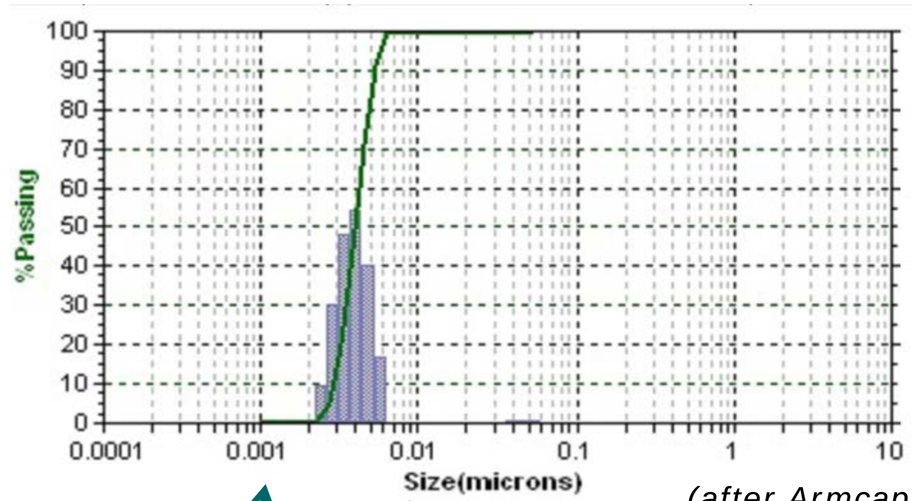
(P. Redelius)

Relative scales



Typical size range



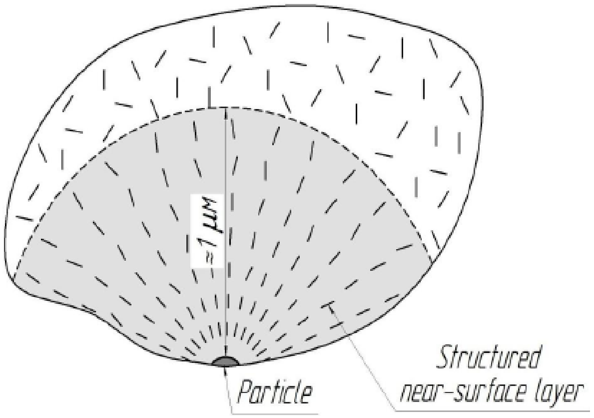


(after Armcap)

Nano-modification is at a very small scale

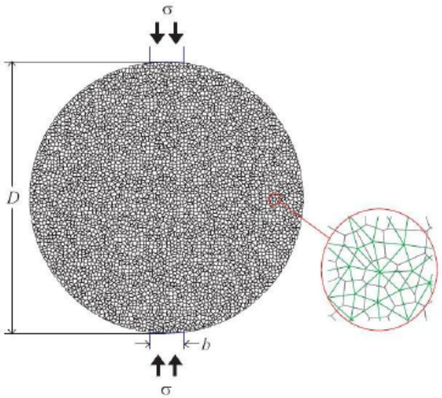
Asphalt and nanotechnology

- Work being conducted in two major area
  - Understanding behavior at nano range
    - Modeling
    - Observations
  - Development of new material technologies
    - Many being develop from nano-diamonds to nano-modified silica

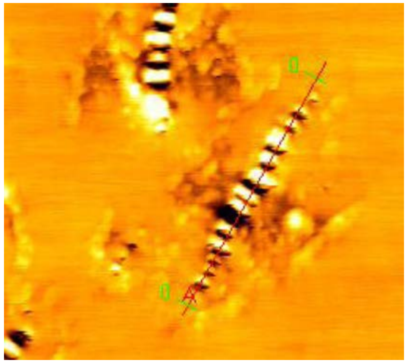


Understanding behavior

- Various meeting/groups
  - RILEM meeting 2011
    - Modeling – Kringos
  - ISAP
    - Meeting on various aspects
- Work being conducted to understand structures /chemistry



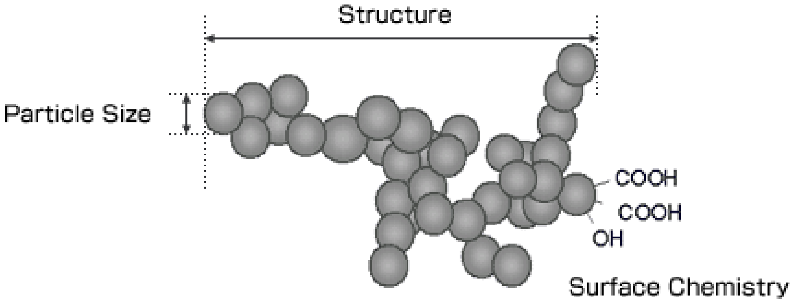
(Modeling - H. Herrmann)



(Morphology - E. Chailleux)

New material technologies

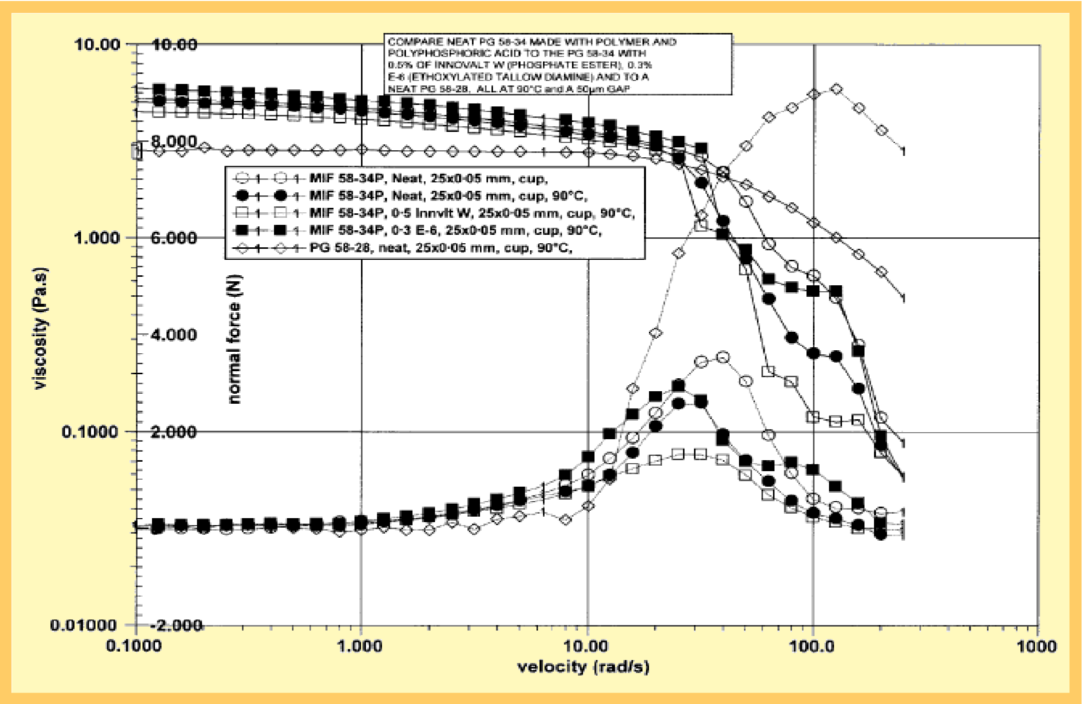
- Note – many of our older materials could be considered as nano-modification
  - PPA
  - Amines
  - Carbon black
  - Etc, etc.



- Some new products being proposed for asphalt
  - Terms and materials

Warm mix technologies

- Materials being added to effect interface conditions
  - Lubricity – introduced by Reinke and Baumgardner
  - Material introduced as warm mix technology



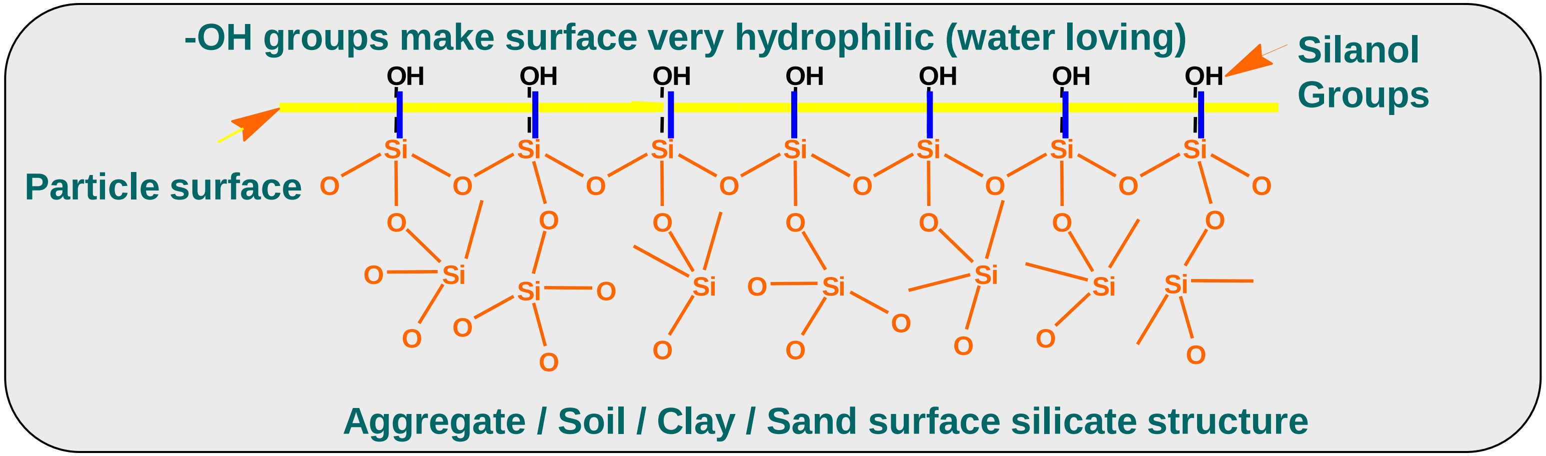
Some new technologies

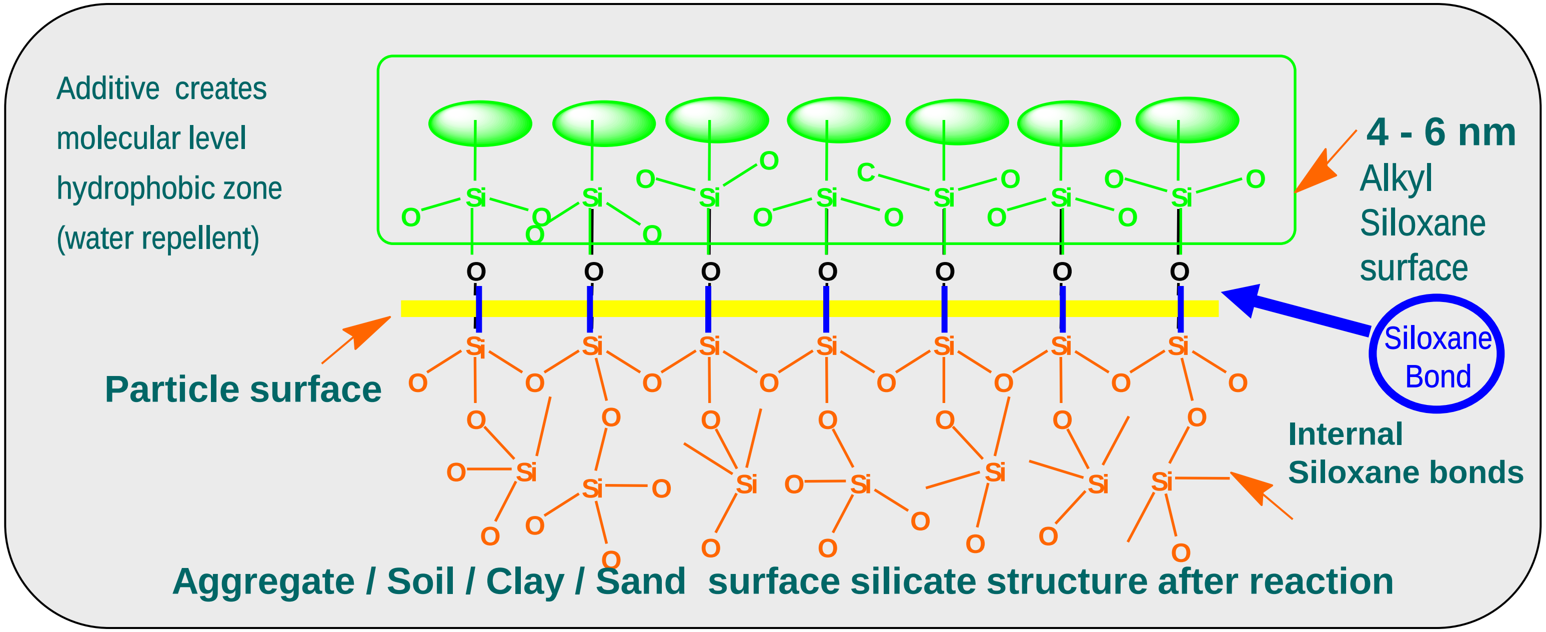
- 3 examples
  - Adhesion promotion
  - Tack coat application
  - Drain down prevention

1 - Adhesion promotion

- Bonding technology based on Siloxane bonds
  - Modifier dispersed in ethylene glycol
- Bond is very strong once established
- Good experience with contractors in Washington State

Anti-strip (and warm mix)





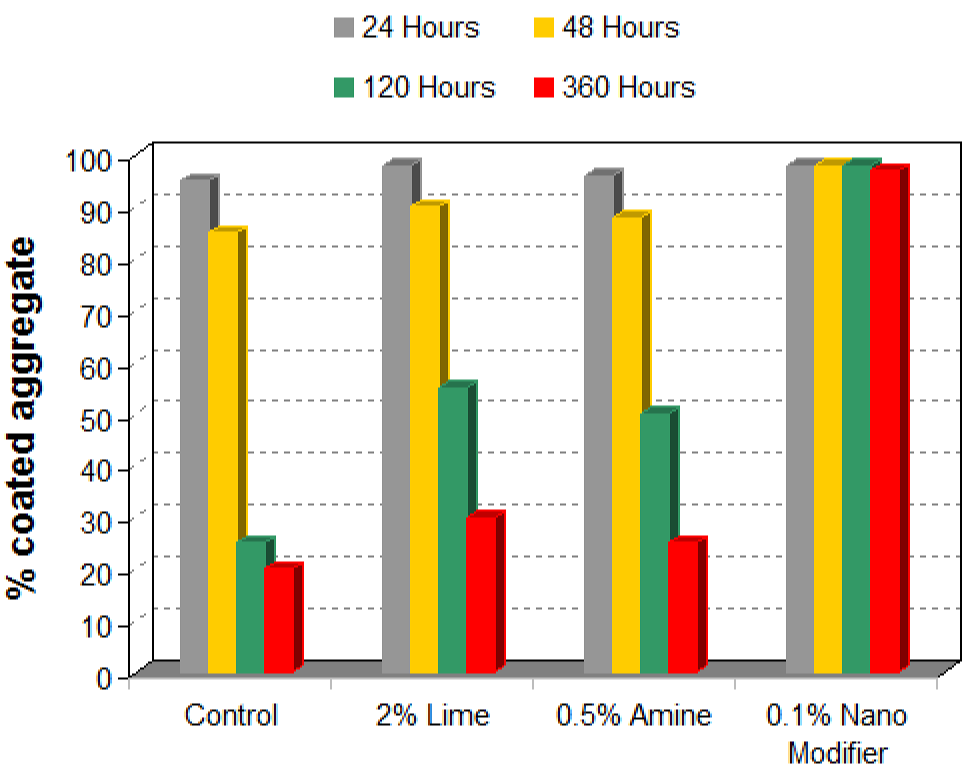
Siloxane bond

- Siloxane bond is very strong
  - “mothers nature’s strongest bond”
  - 90-140 Kcal/mole
  - Stable to 300°C
  - Water repellent

Evaluation of stripping potential

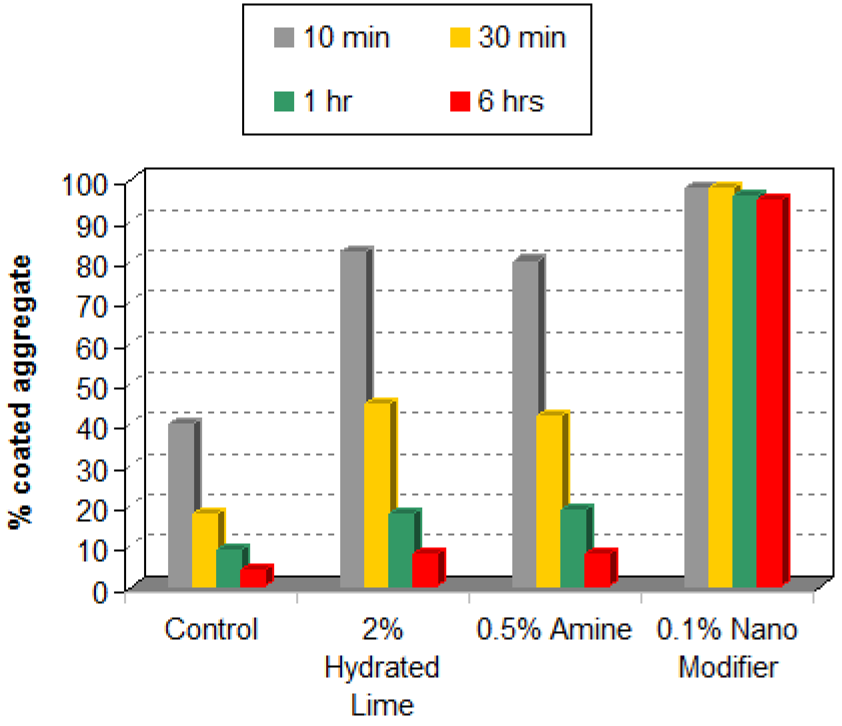
- AASHTO T 182 - Standard Method of Test for Coating and Stripping of Bitumen-Aggregate Mixtures
  - 60ºC static immersion test

- Basalt Aggregate (DBM) : 45% 20 mm, 10% 10 mm, 45% less than 6 mm with stone dust
- Asphalt Grade: AC-20 (VG-30, 60-70 penetration grade)
- Specified standard typically less than 85% coating considered as failure



Evaluation of stripping potential

- ASTM D3625 - 96(2005) Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using Boiling Water
- Basalt Aggregate (DBM) : 45% 20 mm, 10% 10 mm, 45% less than 6 mm with stone dust
- Asphalt Grade: AC-20 (VG-30, 60-70 penetration grade)
- Specified Standards – typically less than 75% considered as failure

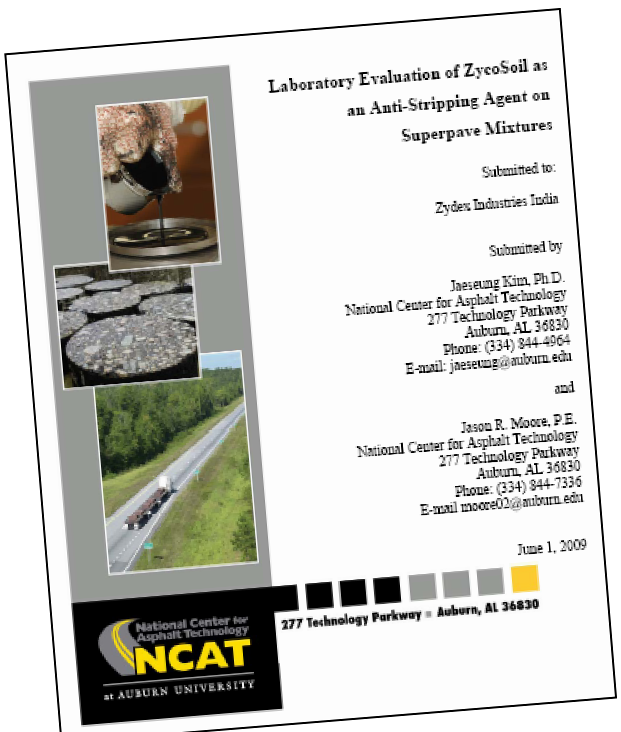


Boil test results

- Boiling test – some of the modifiers have a very significant impact on the performance

Tensile strength ratio

- Work conducted by NCAT on Georgia aggregate



Laboratory Evaluation of ZycoSoil as an Anti-Stripping Agent on Superpave Mixtures

Submitted to:

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June 1, 2009

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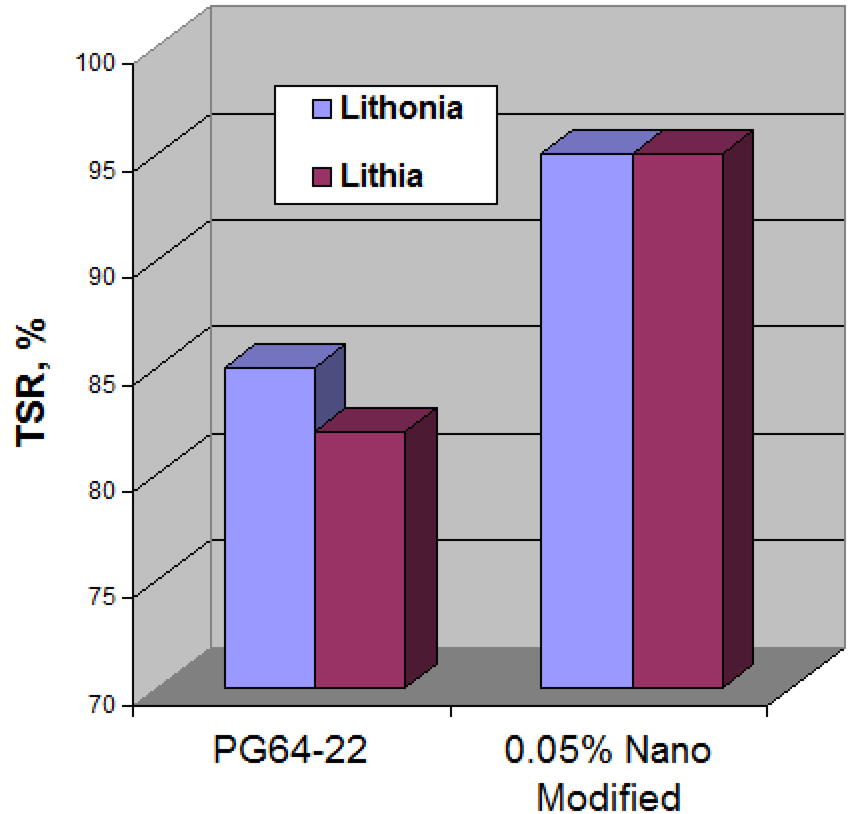
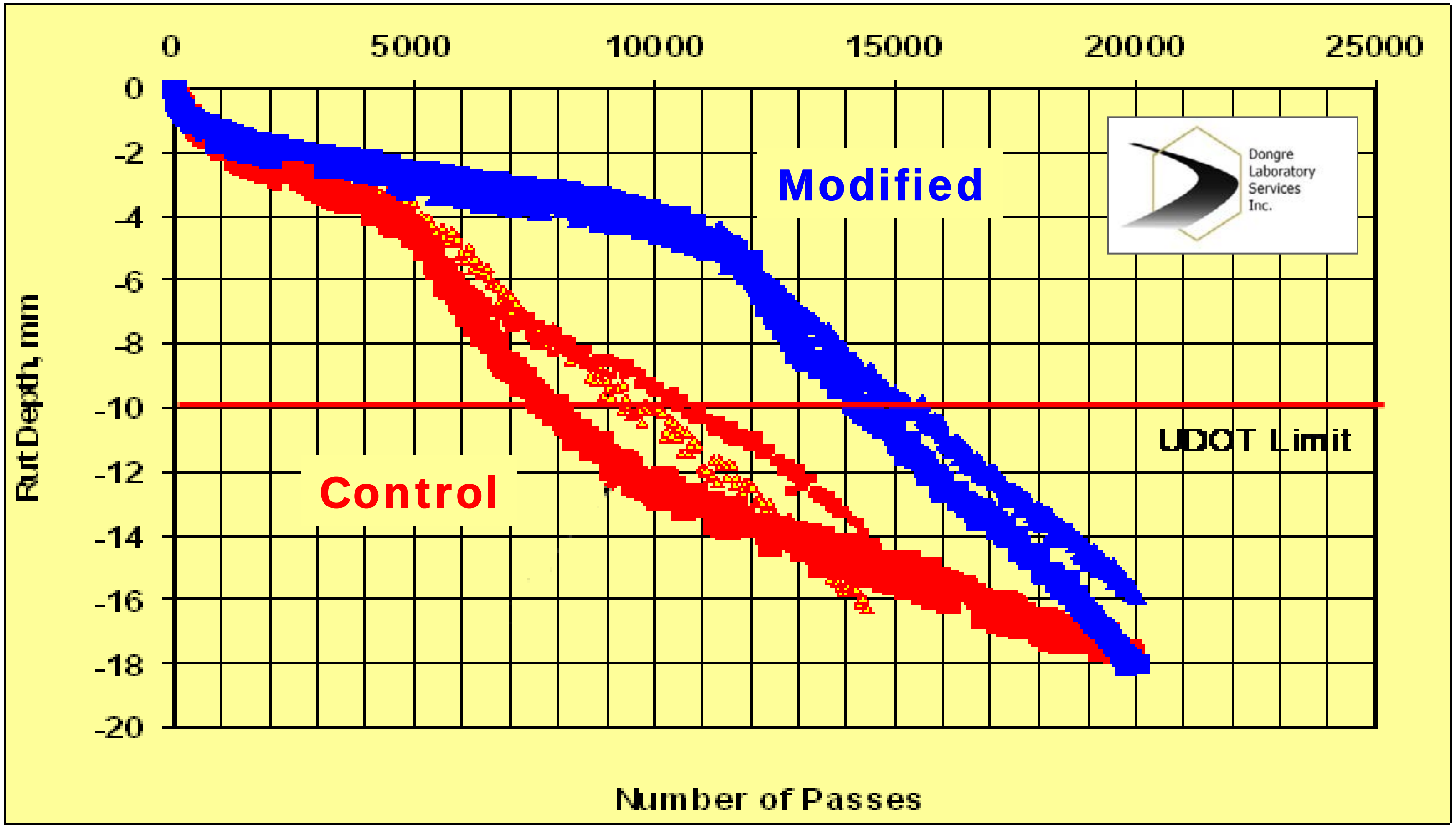
National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY



Hamburg wheel tracking



Implementation

- Materials being used extensively in Washington state
- Claims by contractors is that better coating is achieved
- Materials being added both a terminals and HMA plants

2 – tack coat application

- Tack Coats suffer from issues of poor / insufficient bonding, leading to decreased structural bearing capacity of pavement
- Slippage cracks, Top-down cracking & fatigue cracks

Hadleigh, Suffolk, England (1982)

Tack coat application

- Similar Siloxane technology used in non-tracking tack coat
  - Modifier dispersed in ethylene glycol
- Bond is very strong once established

Tack coat issues

- Poor spreading
- Inadequate bond
- Industry needs improvements
- Development of “trackless” tack or non- tracking – non-pickup tack coats needed

Design of emulsion

- Typical
  - 100 gals - 60% emulsion
  - Dilute 100 gals of water
  - Add 1.4 gals of modifier

- Process
  - Start re-circulation of emulsion
  - Add water followed with modifier, continue re-circulation for 10-15 minutes
  - Spray the Mix

NCAT study – rates of spread

- NCAT study

Surface	Material	Residual Mass (%)	Spray Application Rate-gal/sy (L/m2)		
			Low	Medium	High
HMA	Control	30	0.067 (0.303)	0.133 (0.602)	0.200 (0.906)
	Nano modifier	10	0.067 (0.303)	0.133 (0.602)	0.200 (0.906)
Milled Surface	Control	30	0.133 (0.602)	0.267 (1.209)	0.400 (1.811)
	Nano modifier	10	0.133 (0.602)	0.267 (1.209)	0.400 (1.811)

Bond strength data comparison

New Surface (3-day curing)

Sample	Residual Asphalt (%)	**Bond Strength (PSI)** Application Rate		
		Low	Medium	High
Control	30	225	160	150
Nano modifier	10	175	125	160

Milled Surface (3-Day curing)

Sample	Residual Asphalt (%)	**Bond Strength (PSI)** Application Rate		
		Low	Medium	High
Control	30	250	175	190
Nano modifier	10	1180	180	190

Bond Strength Ratio (AASTO 230)

Sample	BSR* One Freeze Thaw Cycle		BSR* Two Freeze Thaw Cycles	
	New HMA	Milled HMA	New HMA	Milled HMA
Control	0.55	1.0	0.50	1.1
Nano modifier	0.65	1.1	0.80	1.18

*** Ratio of conditioned and unconditioned Bond Strength**

NCAT study, 2012

Bond strength data comparison

- The nano modified emulsion (10% AC residual) with a lower residual AC content provided equivalent bond strength to that of a control emulsion (30% AC residual) on an unmilled (new HMA) surface

NCAT study, 2012

Claims

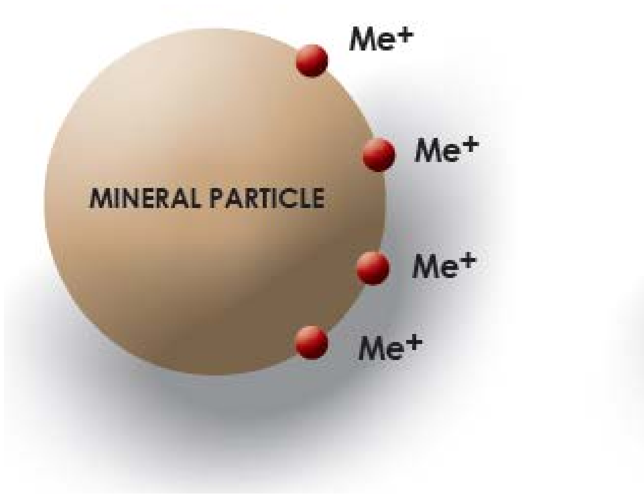
- Nano modified tack coat keeps nozzles clean by improving stability of cationic bitumen emulsion
- Ensures uniform spraying at room temperature
- Heating of the emulsion not required, saving energy & time
- Allows substantial reduction in asphalt thickness due to better wetting & spraying
- Wets, penetrates & sets quickly (5-10 minutes)
- Reduces tackiness on the surface
- Eliminates Tire Pick-Up

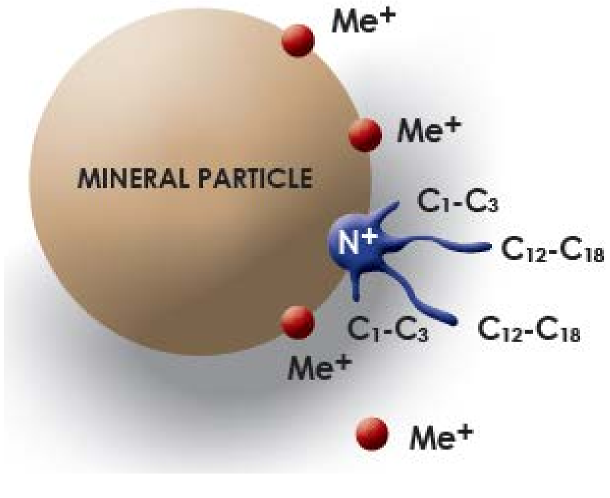
3 – Drain down prevention

- In this example a amorous silica is reacted with a surface active agents
- Amorous silica is around 5 to microns – no not in the nano range
  - Modification to surface in nano range
- Product is Activated Mineral Bitumen Stabilizer

AMBS process and mechanism

- The raw silica mineral is ground to powder and activated by surface-active agents using a cation exchange mechanism
- The surface metal cations (Me) in the mineral particles are exchanged by the organic cations with long chains
- Activated by organic compound, mineral particles have the ability to swell organic liquids, like asphalt, due to the long chain molecules

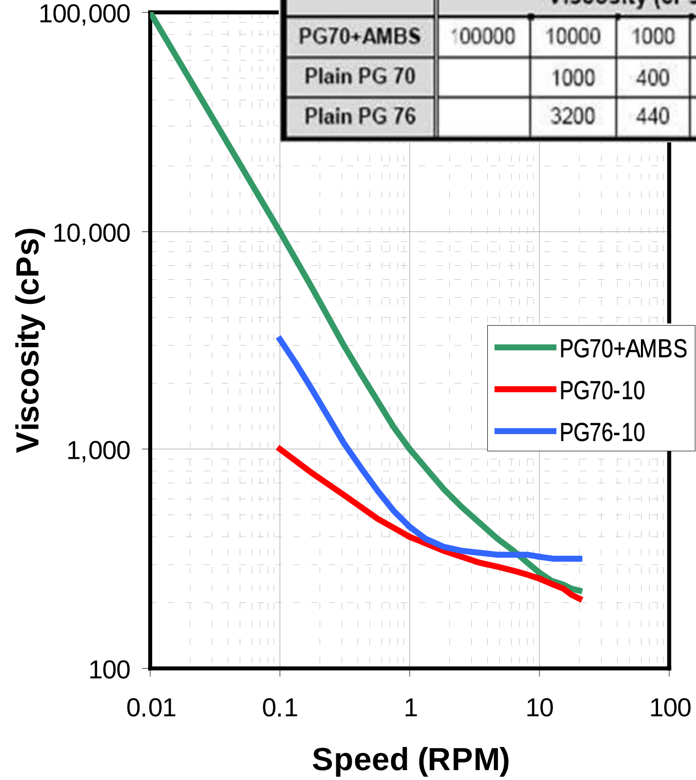




Viscosity variation

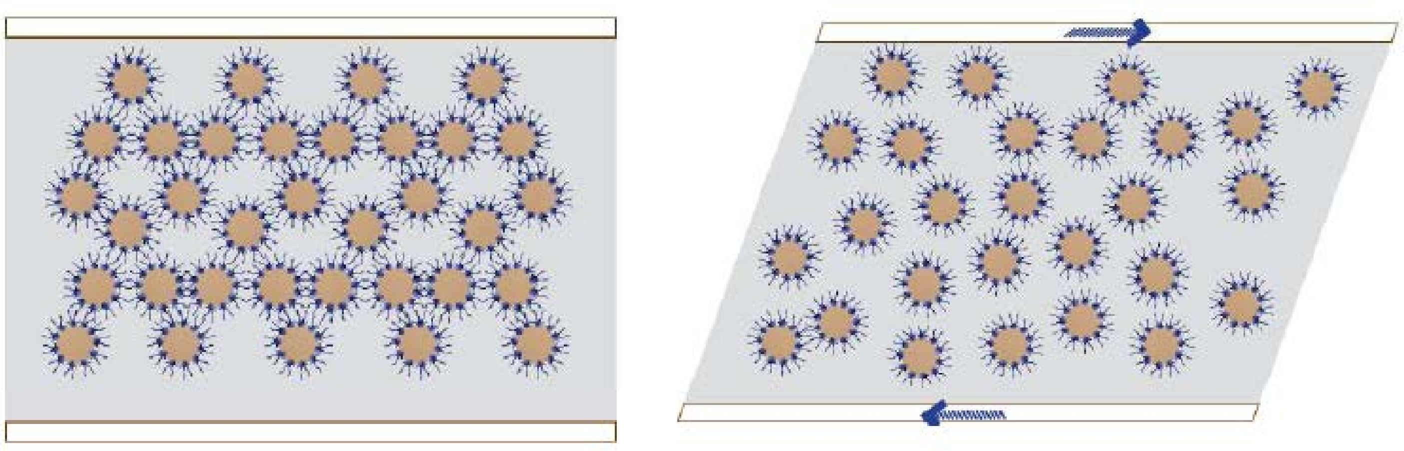
- Brookfield viscosity is significantly more rate dependent when AMBS is added to a neat PG70-10 binder grade
- Material is shear thinning at high shear rates
  - At low rates more viscous than modified grade
  - At high rate viscosity similar to unmodified grade

	Speed (RPM) 0.01	0.1	1	10	20
	Viscosity (cPs)				
PG70+AMBS	100000	10000	1000	275	225
Plain PG 70		1000	400	256	210
Plain PG 76		3200	440	324	316



AMBS rheological behavior

- This rheological mechanism of asphalt stabilization by the Shear Thinning effect is schematically described follows:



Stabilizer Net at Rest ("Card House")   Stabilizer Particles in Movement

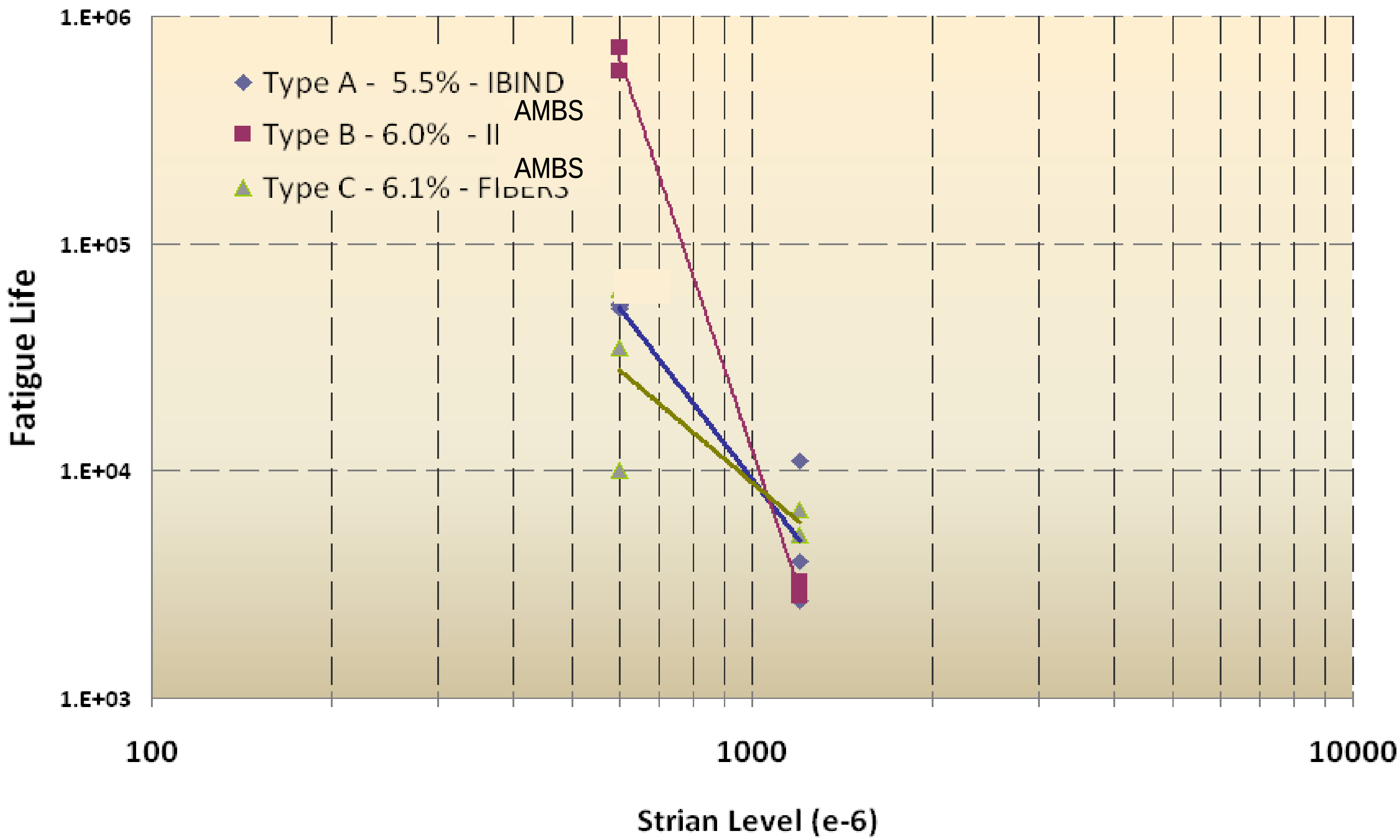
Example of implementation

Paving and compaction

Work conducted

Large volume of work conducted – not included here…

AMBS Investigation – CHINA Sample Results – Fatigue Test



Claims

- Prevents excessive draindown
- Improves resistance to water damage
- Creates better mechanical stability
- Strongly improves wearing resistance
- Greatly improves rutting & fatigue resistance
- Improves durability
- Lowers mixing & compaction temperatures
- Makes SMA/OGFC easier to produce & lay
- Reduces energy & emissions of greenhouse gases
- Makes SMA/OGFC more cost effective

Summary

- Many materials are being developed
- For our industry we must consider these as tools in our toolbox
  - Agencies will have different needs and the design tools that we have for our materials help us to target agency needs
- Nano-technologies provide an interesting avenue to explore and will help us develop better modified asphalt pavements

Thank you for your attention

Studies of water damage to sand!