Federal Lands Highway Polymer-Modified Emulsion Program

NEPPP Meeting
October 21, 2008

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Summary

- **Sponsored by FHWA (~2006)**
  - Administered by NCPP
  - G. King – Program manager
- **Extensive PME literature review completed**
  - J. Johnston – NCPP – White paper
- **Deliverable – Proposed spec for PME's**
  - Field projects – Central Bureau Fed Lands
  - Report-only data – BASF, PRI, Paragon

PME Specification Targets

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- **Low temperature recovery method**
  - Preserves polymer morphology/structure
  - **Requires Supplier Certification Program**
- **All residue testing completed on DSR**
- **Includes performance testing**
  - Chip seal
  - Polymer-modified slurry
  - Micro surfacing

Strawman PME Specification
Recovery Method + High T Testing

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Testing Protocol for 2008 Evaluations

PROPERTY	TEST METHOD		SPEC	RESULT
Asphalt Emulsion as Received				
Standard AASHTO or ASTM tests:	AASHTO M-140 Emulsified Asphalt or AASHTO M-208 Cationic Emulsified Asphalt			
Field Viscosity Test	WYDOT 538.0		Report	
Residue Recovery (24 hours @ 25℃, 24 hours @ 60℃, For ced Draft Oven)				
Frequency Sweep (25 mm, 0.1 – 100 rad/sec, 10% Strain)	HTG*	AASHTO T 315	Report	Frequency Sweep (G*, δ, etc…)
Multiple Stress Creep Recovery (100, 1000, 3200 & 10,000Pa)	HTG*	TP 70-08	Report	% Recovery & Jnr at each stress level
Frequency Sweep (25 mm, 0.1 – 100 rad/sec, 10% Strain)	HTG - 6℃	AASHTO T 315	Report	Frequency Sweep (G*, δ, etc…)
Multiple Stress Creep Recovery (100, 1000, 3200 & 10,000Pa)	HTG - 6℃	TP 70-08	Report	% Recovery & Jnr at each stress level
Frequency Sweep (25 mm, 0.1 – 100 rad/sec, 10% Strain)	HTG -12℃	AASHTO T 315	Report	Frequency Sweep (G*, δ, etc…)
Multiple Stress Creep Recovery (100, 1000, 3200 & 10,000Pa)	HTG -12℃	TP 70-08	Report	% Recovery & Jnr at each stress level
Test Strain Sweep, 1 – 50% strain, 10 rad/s	25ºC		Report	• Resistance to Deformation: G*/sind @ 12% Strain • Strain Tolerance: Strain Level at which G* < 90% G* initial • Failure Properties: Strain Level at which G* <50% G* initial

Strawman PME Specification Intermediate and Low T Testing

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Pressure Aging Residue (100℃, 300 psi, 20 hours)   R 28
(PAV run on residue obtained by Forced Draft Oven Method run in PAV pan)

Frequency Sweep (25 mm, 0.1 – 100 rad/sec,1% Strain)	HTG*	AASHTO T 315		Frequency Sweep (G*, δ, etc…)
Multiple Stress Creep Recovery (100, 1000, 3200 & 10,000Pa)		TP 70-08		% Recovery & Jnr at each stress level
Frequency Sweep (25 mm, 0.1 – 100 rad/sec,1% Strain)	HTG - 6℃	AASHTO T 315		Frequency Sweep (G*, δ, etc…)
Multiple Stress Creep Recovery (100, 1000, 3200 & 10,000Pa)		TP 70-08		% Recovery & Jnr at each stress level
Frequency Sweep (25 mm, 0.1 – 100 rad/sec,1% Strain)	HTG -12℃	AASHTO T 315	Report	Frequency Sweep (G*, δ, etc…)
Multiple Stress Creep Recovery (100, 1000, 3200 & 10,000Pa)		TP 70-08		% Recovery & Jnr at each stress level
Frequency Sweep (8 mm, 0.1-100 rad/sec, % Strain (TBD))	0℃			Frequency Sweep (G*, δ, etc…)
Frequency Sweep (8 mm, 0.1-100 rad/sec, % Strain (TBD))	10℃	AASHTO T 315		Frequency Sweep (G*, δ, etc…)
Frequency Sweep (8 mm, 0.1-100 rad/sec, % Strain (TBD))	20℃			Frequency Sweep (G*, δ, etc…)
Test Strain Sweep, 1 – 50% strain, 10 rad/s	25ºC			• Resistance to Deformation: G*/sind @ 12% Strain • Strain Tolerance: Strain Level at which G* < 90% G* initial • Failure Properties: Strain Level at which G* <50% G* initial
Bending Beam Rheometer	-12℃ + -18℃	AASHTO T 313		Stiffness + m-value

Strawman PME Specification Performance Testing

Performance tests for Chip Seals		
Sweep Test	Modified ASTM D-7000	Report
Performance tests for Polymer Modified Slurry Seals and Micro-Surfacing		
Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal Surfaces	ISSA A105	ISSA
Recommended Performance Guidelines for Polymer Modified Micro-Surfacing	ISSA A143	ISSA
Tests recommended by Caltrans Slurry/Micro-Surface Mix Design Procedure Project /Contract 65A0151	TBD	

* High Temperature Performance Grade as selected for local climate (LTPPBind version 3.1)

Central Bureau Fed Lands Projects Strawman – Report-Only Data

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Project	Date	System(s)
Utah Parks	September, 2008	Chip Seal - CRS-2P (SBR) Micro Surfacing (NRL, Ralumac)
Dinosaur Natl. Monument	September, 2008	Chip Seal - PASS - CRS-2P (Latex)
Death Valley	November, 2008	Chip Seal (SBR, SBS?)
Crater Lake	Spring 2009	Chip Seal (TBD)

- **Testing Labs (Third Party + Industry):**
  - PRI Asphalt Technologies, Inc (Tampa, FL)
  - Paragon Technical Services, Inc. (Richland, MS)
  - BASF Corporation (Charlotte, NC)

Emulsions 101
Polymer-Modified Emulsions for Surface Treatments

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Outline

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- Asphalt emulsion primer
- What are polymers?
- Why polymers for asphalt emulsions?
- Modification of asphalt emulsions
- Polymer networks in asphalt emulsions
- Impact on performance + properties

Asphalt Emulsions - Formulation

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- **Components**
  - Asphalt
  - Surfactant (surface active agents, emulsifiers)
  - Water
  - Mechanical energy (colloid mill)
- **Other Ingredients**
  - Additives (calcium chloride, cutback agents,…)
  - Modifiers – *Polymers*

Asphalt Emulsions – Component Distribution

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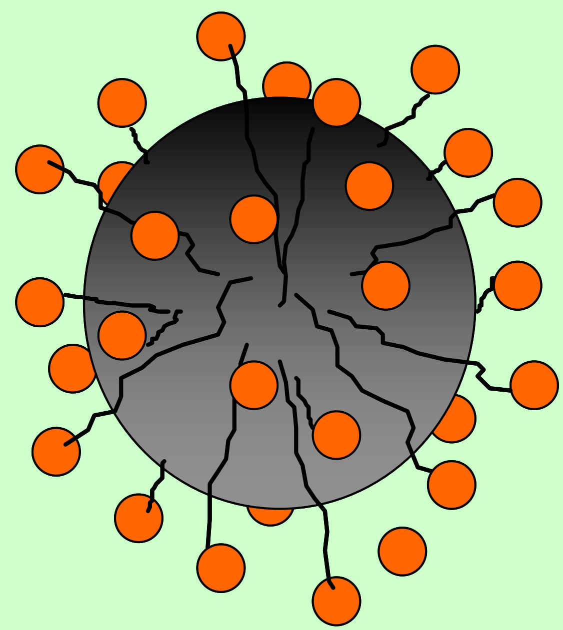
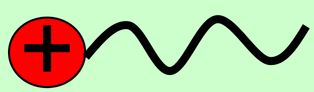
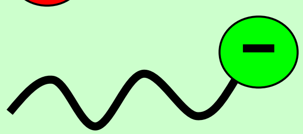
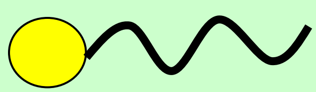
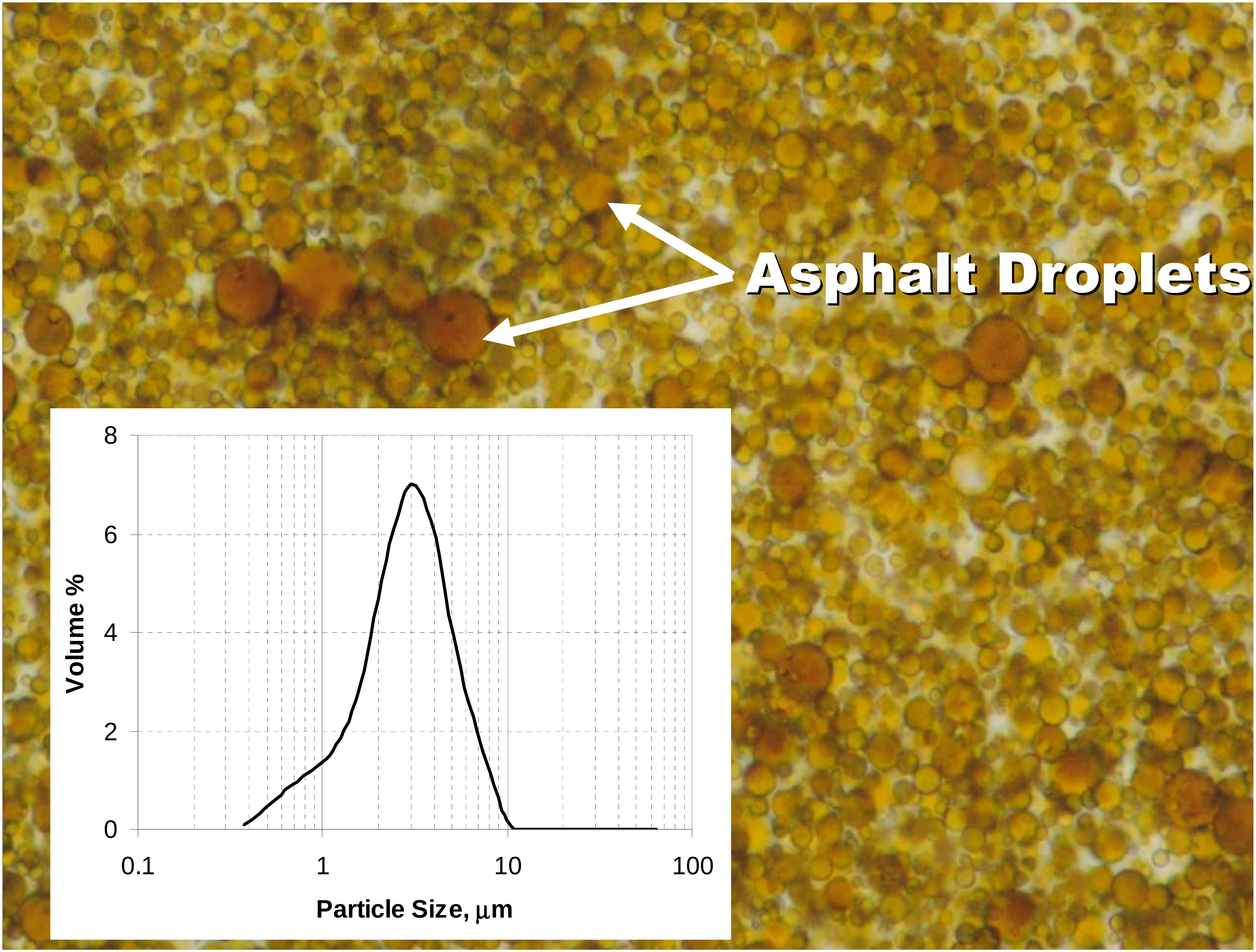
Dispersion of asphalt in water

- Water – continuous phase
- Asphalt – non-continuous or dispersed phase
  - Stabilized by surfactant



Surfactant → emulsion class.

- Cationic 
- Anionic 
- Nonionic 


Asphalt Droplets
Volume %
8
6
4
2
0
0.1
1
10
100
Particle Size, µm

What are Polymers?

- **Comprised of many small molecules**
  - Poly = many
  - Monomers = small molecules or repeat units
- **Monomers chemically react ⟶ larger molecules**
  - Water-based polymers – latex form (SBR)
  - Solvent-based polymers – pellets, bale (SB-,SBS)
- **Properties are determined by:**
  - Types and sequence of monomers
  - Molecular weight

Polymer Types for Asphalt Mod.

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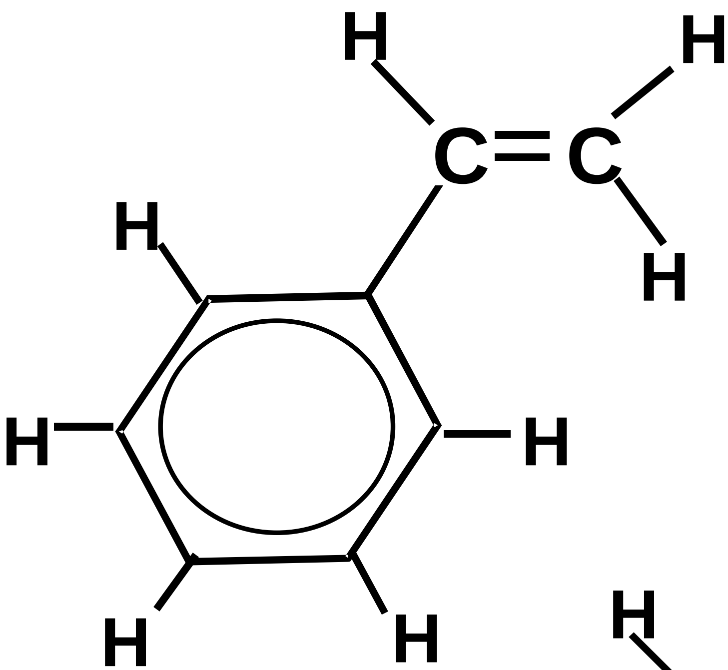
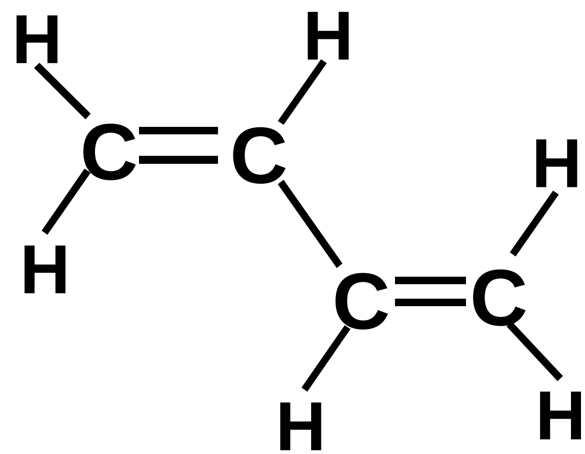
- SBR Latex – Chip Seals, Slurry and Micro Surfacing
- SB/SBS – Chip Seals
- Natural Rubber Latex – Ralumac (Micro Surfacing)
- Other – Neoprene, EVA, GTR (REAS), Fibers

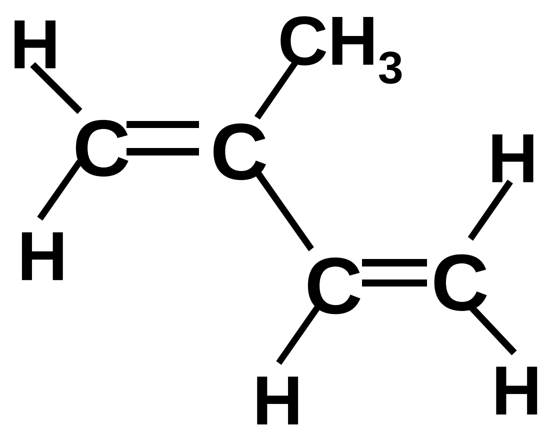
Typical Monomers



Styrene



Butadiene



Isoprene
(NR)

Viscoelastic Behavior
Cured Latex Modified Asphalt Emulsion

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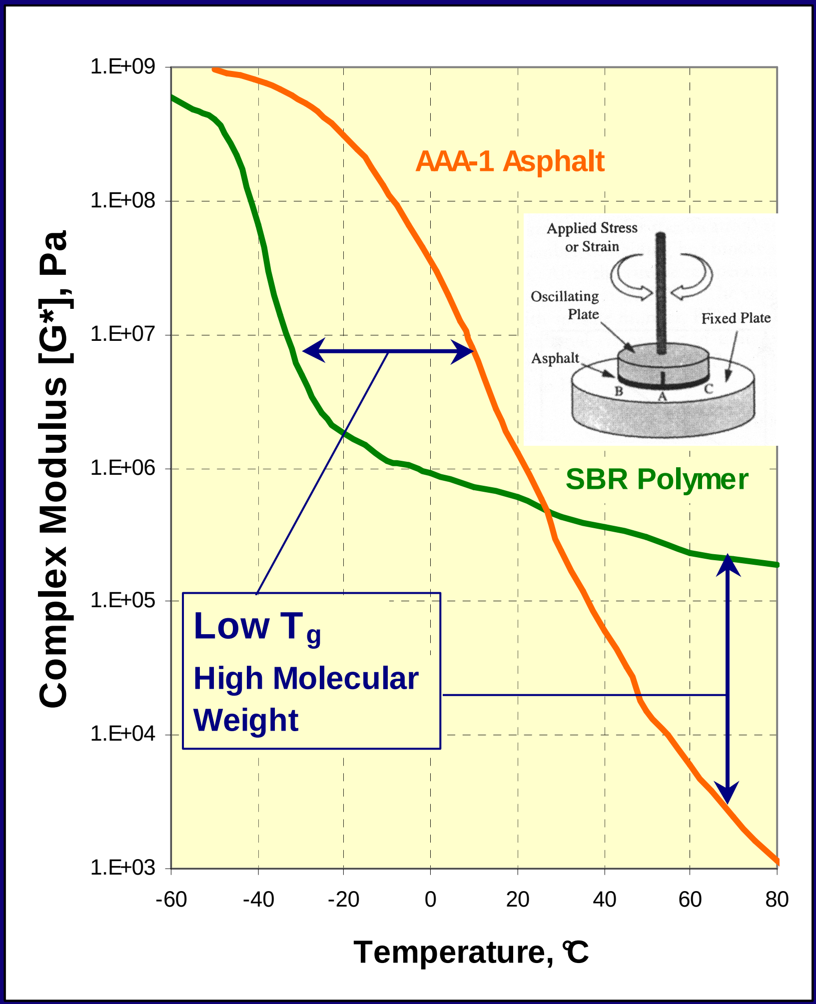

- G* = f(T) = deform. resist.
- Asphalt
  - High G* at low T – brittle
  - Low G* at high T – viscous
  - ΔG*(80ºC – 20ºC) = 1000x
- SBR Polymer
  - Lower G* at low T – flexible
  - Higher G* at high T – elastic
  - ΔG*(80ºC – 20ºC) = 10x

Polymer Modification of Asphalt Emulsions

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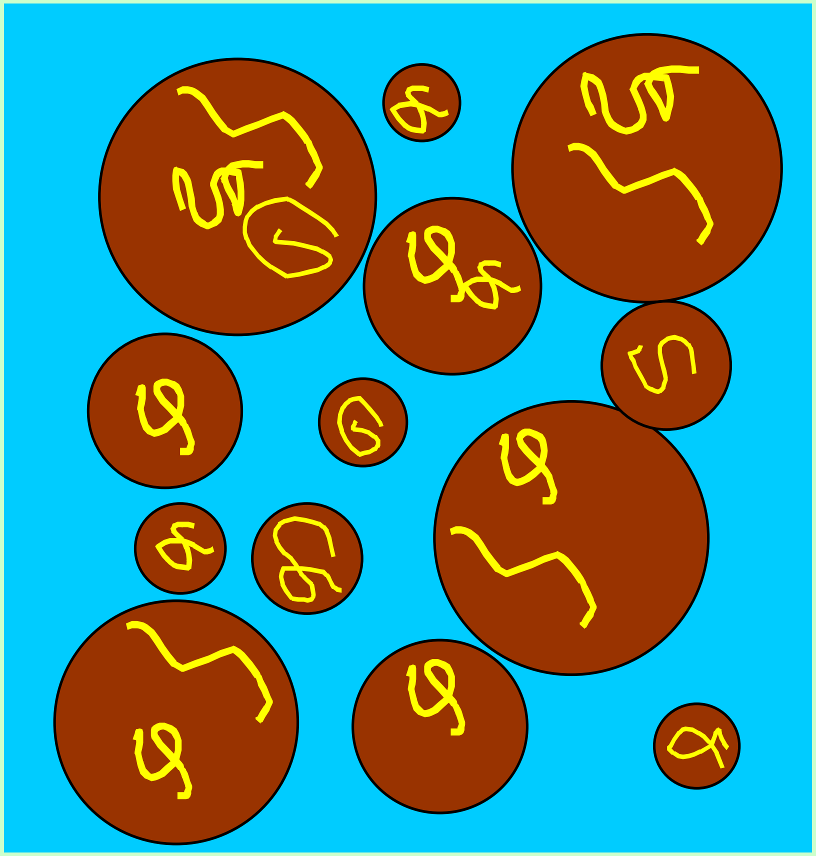
- **Emulsify polymer modified asphalt**
  - "Pre-modified" emulsion
  - Polymers – SBS, SB-
  - Higher mod. asphalt viscosity
    - higher asphalt + mill temp.
  - Exit temp. > 100ºC
  - Heat exchanger, back press.



- **Polymer inside asphalt droplet**

Polymer Modification of Asphalt Emulsions

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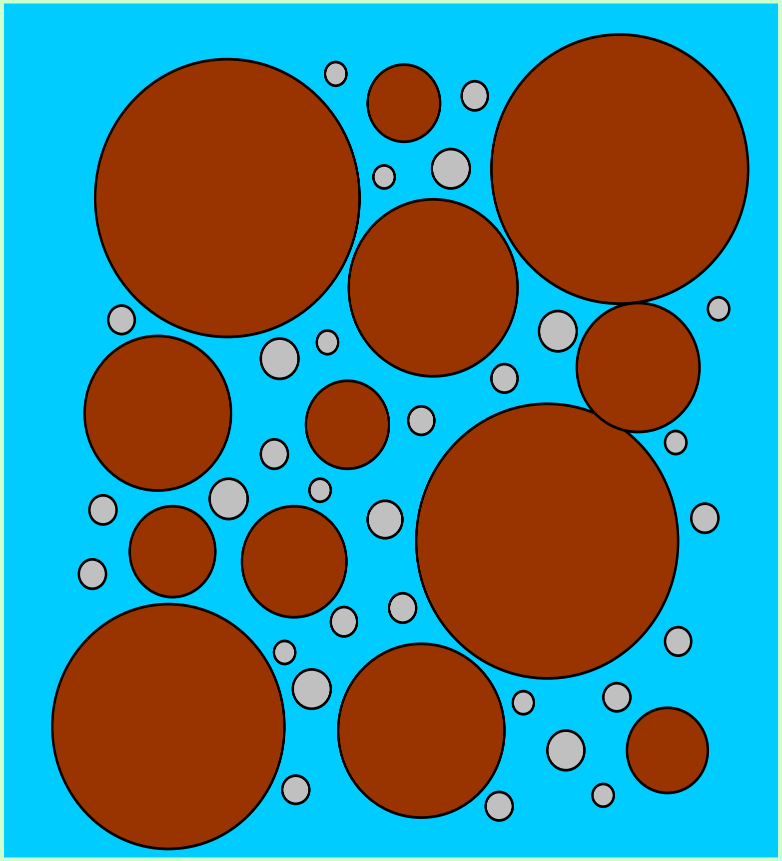
- **Add latex external to asphalt**
  - Methods
    - soap batching
    - co-milling – asphalt line
    - co-milling – soap line
  - Polymers – SBR, NR latex
  - Lower asphalt process T
  - No special mill, handling
- **Polymer in water phase**
- **Continuous polymer film formation on curing**



Latex Polymer-Modified Asphalt Emulsion

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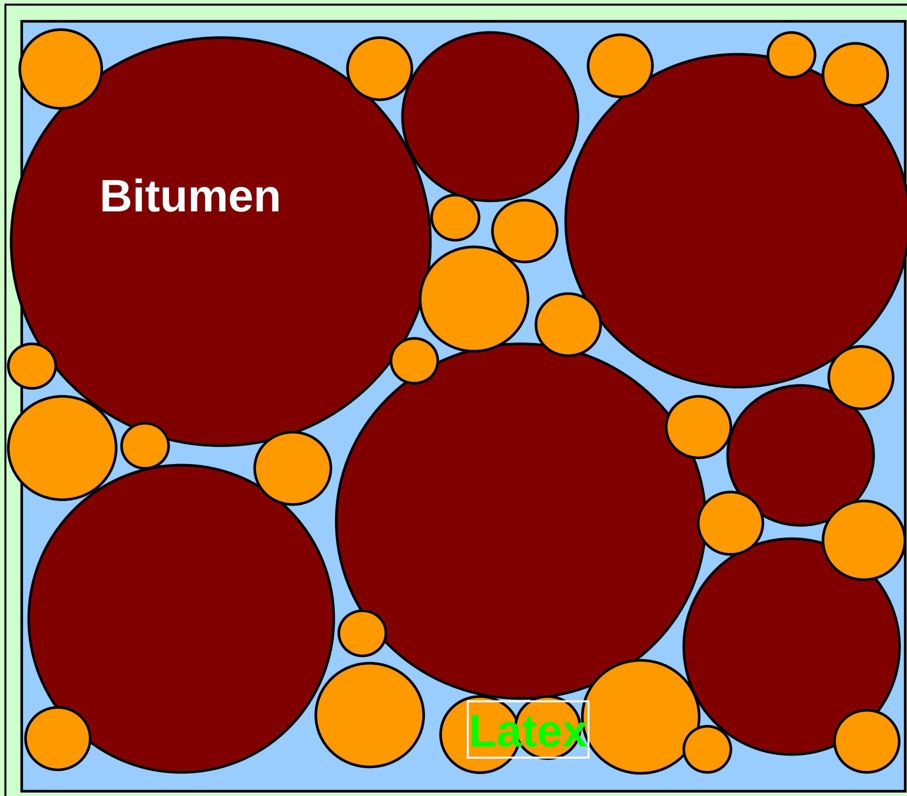

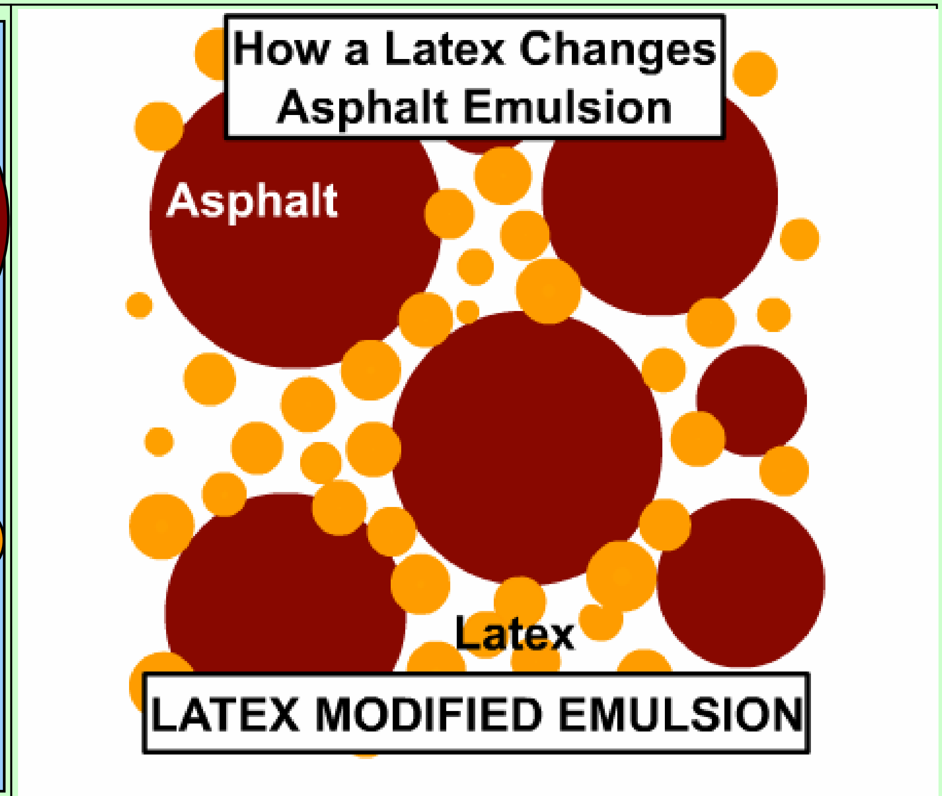

Latex Modified Emulsion	Cured Bitumen Emulsion

- **Optimum for Fine Polymer Network Formation**

Chip Seal – Field Application

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Chip Seal Surface Treatment

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Near Taos, NM

CRS-2 vs.CRS-2P(LM) – Physical Props.

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	Test Method	CRS-2	CRS-2P
R&B Softening Point (^{o}F)	**ASTM D 36**	115	128
Ductility (4^{o}C, cm)	**ASTM D 113**	21	150+
Elastic Recovery (10^{o}C, %)	**AASHTO T 301**	5	60

3 wt.% SBR latex polymer (on asphalt)

- **Residue**
  - ASTM D 6934 - Oven evaporation at 163^{o}C
- **Polymer**
  - Raises SP, drastically increases ductility and ER

Sweep Testing – CRS-2P vs CRS-2 ASTM D7000 - 04

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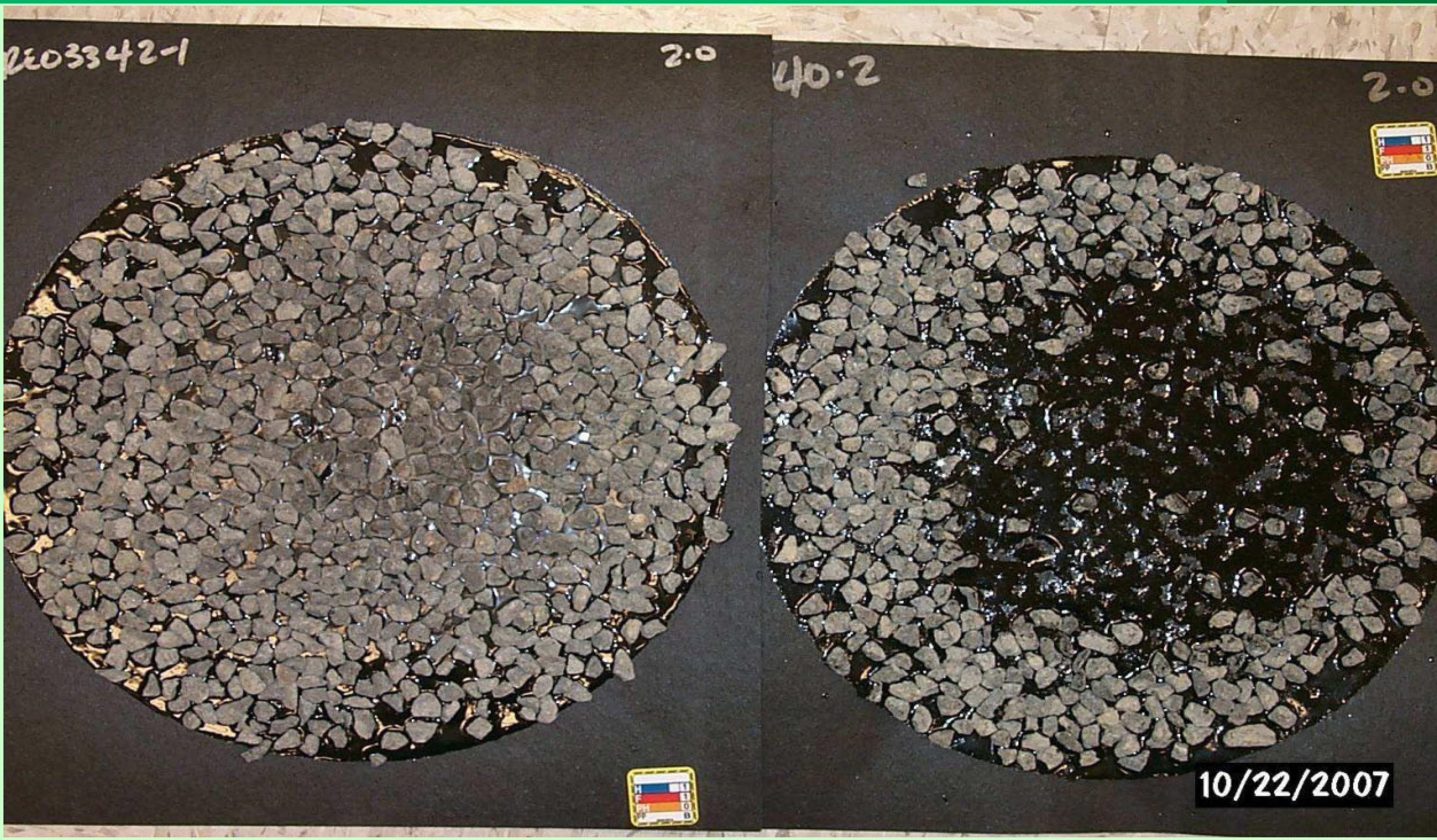

Chip Seal with Latex Modified CRS

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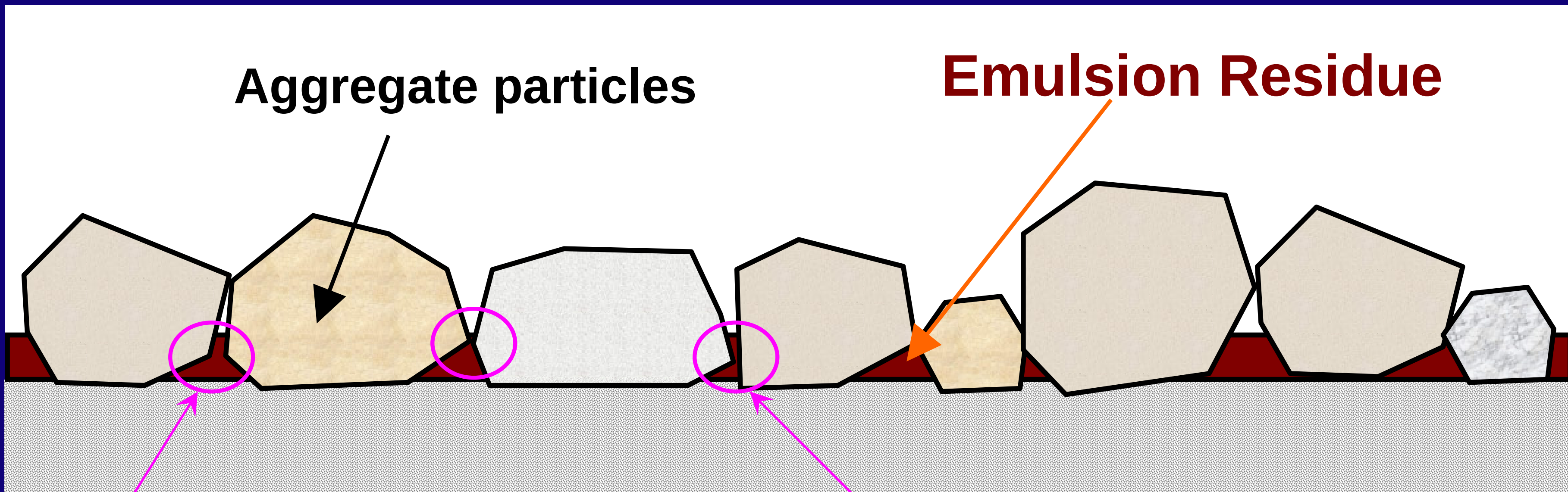

- **Latex polymers accumulate at optimum location**
  - Act to glue aggregate together!!!

Curing of CRS-2LM Emulsion

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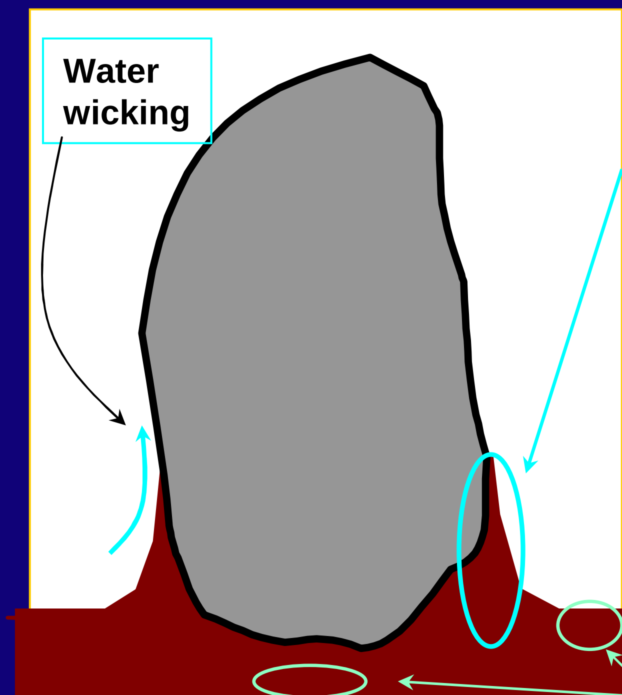
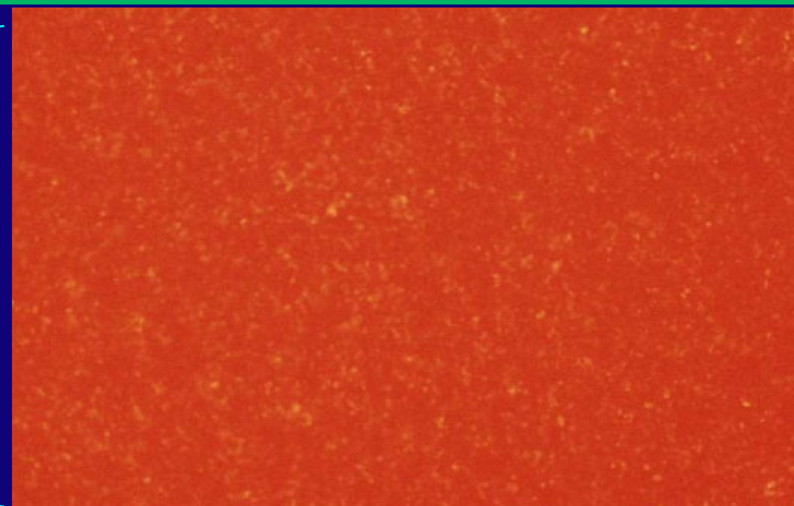
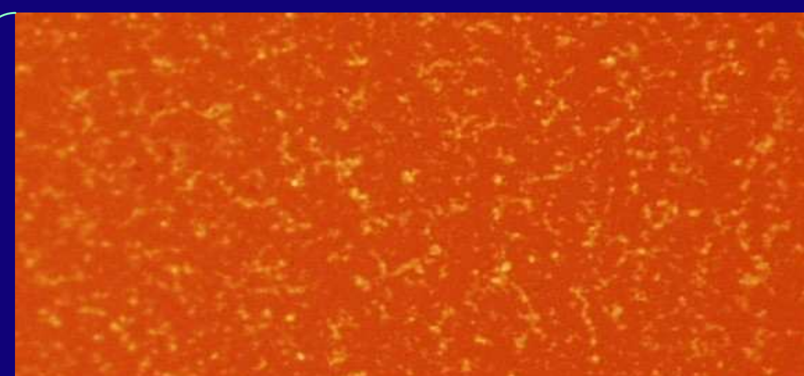
- **Water in asphalt emulsion wicks the aggregate surface.**
  - Order of migration = Water, latex particles, asphalt droplets

Latex Polymer Distribution – Unstable CRS-2L Emulsion



CRS-2LM with Surfactant A





- **Latex particles migrate together with water???**
  - Polymer rich regions around aggregate = NO

Latex Polymer Distribution – Stable CRS-2L Emulsion

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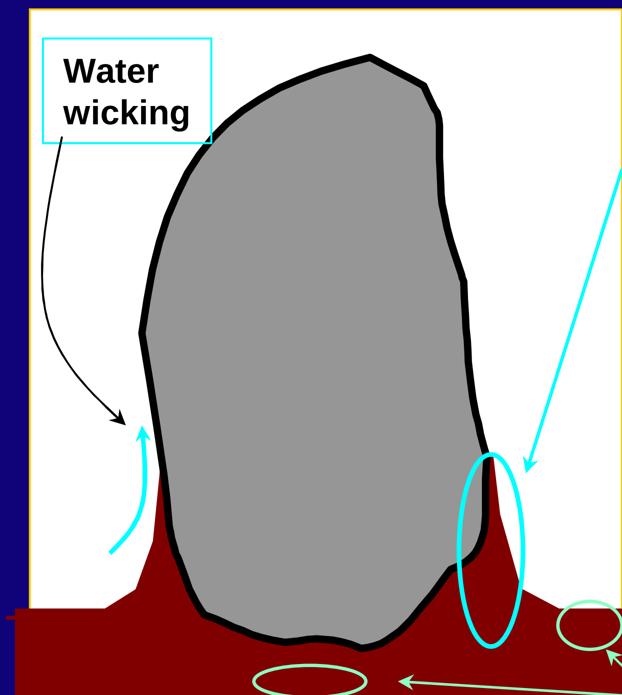
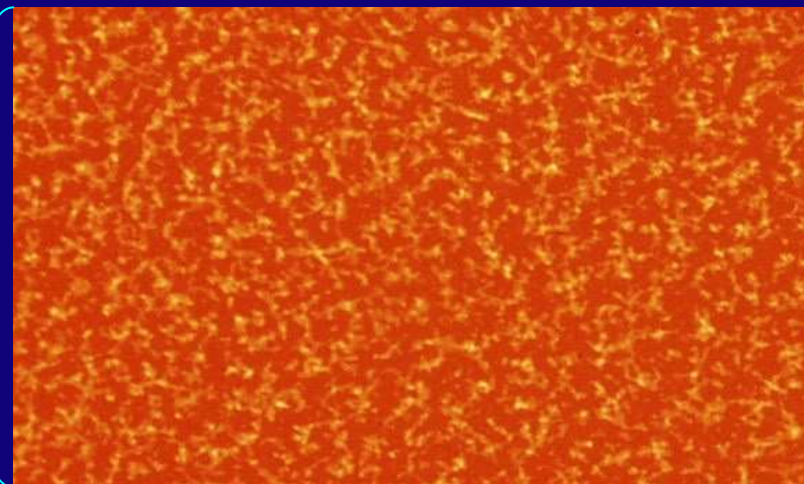
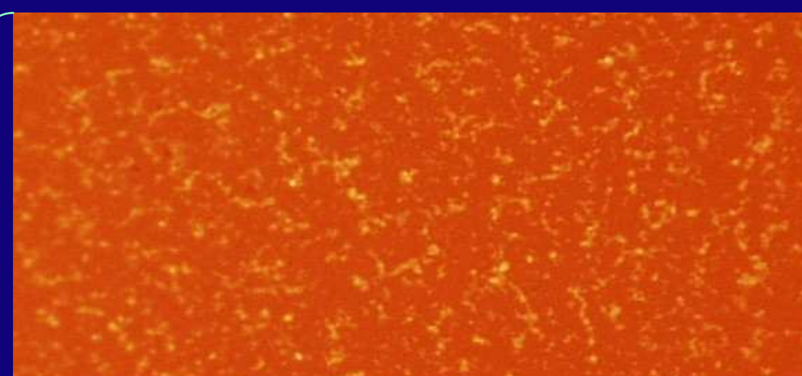


CRS-2LM with Surfactant D





- **Latex particles migrate together with water!**
  - Polymer rich regions around aggregate = YES

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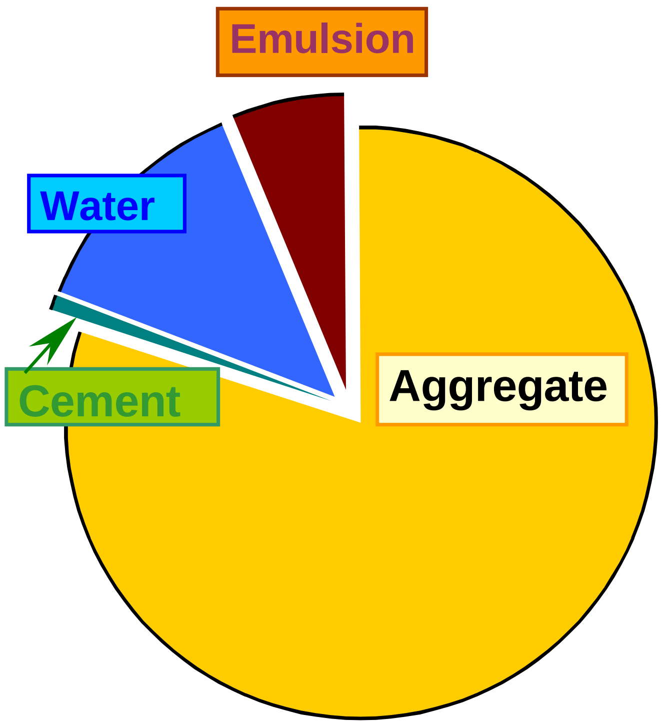
Micro Surfacing Operation

1min<Mix Time<3 min

Cohesion Development<1 hr

Micro Surfacing – High ADT + ESAL's

Micro Surfacing Mix Formulation



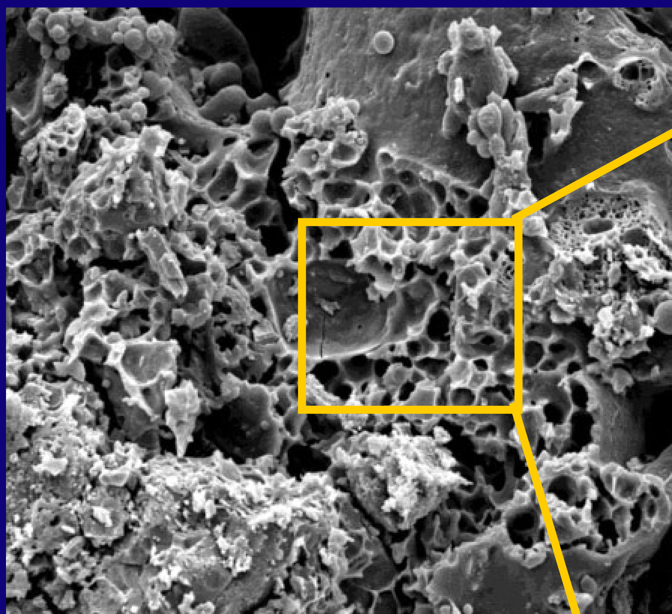
Latex Polymer =

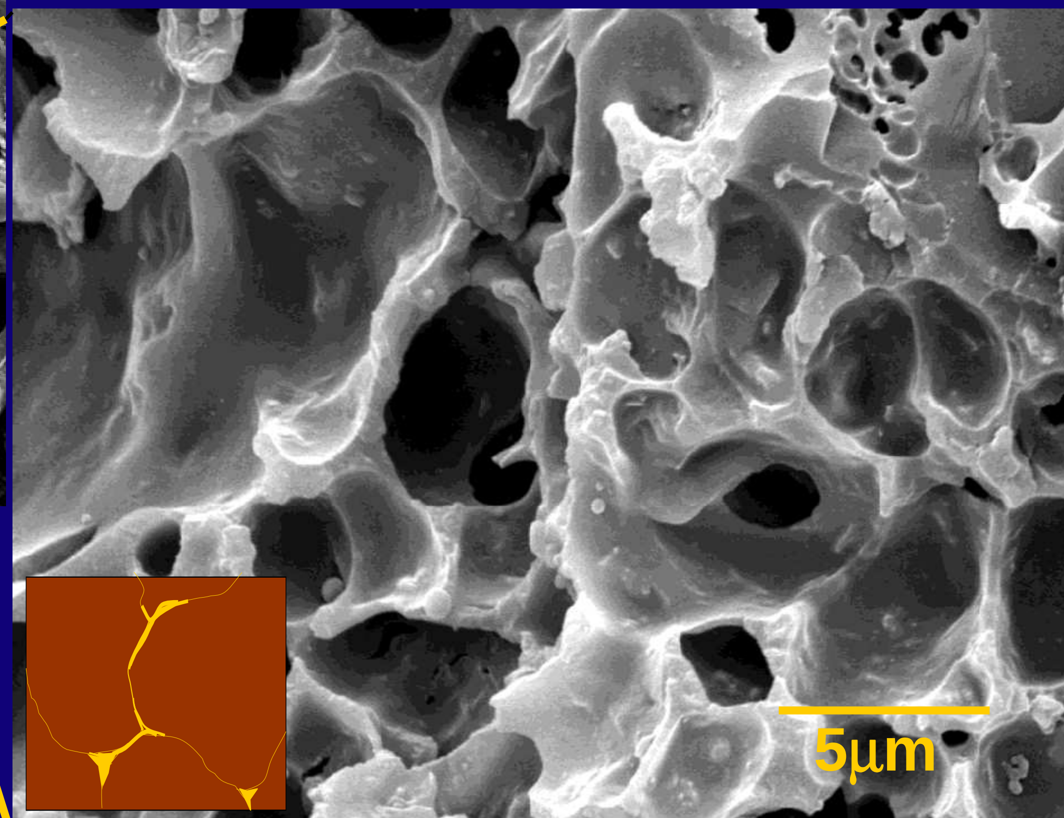
3% of Asphalt

- **Blade Coating Operation**
  - **2 m wide + <1 cm thick**
  - **4-5 km/hour**
  - **Traffic within 1 hour**
- **Latex Polymer Binds**
  - **Asphalt**
  - **Fines**

  to Aggregates

Micro Surfacing – Polymer Morphology Field Application





Texas State Highway 84

- Near Waco,TX
- Paved in 1998
- Samples taken in 2001

Cured Latex Polymer Network

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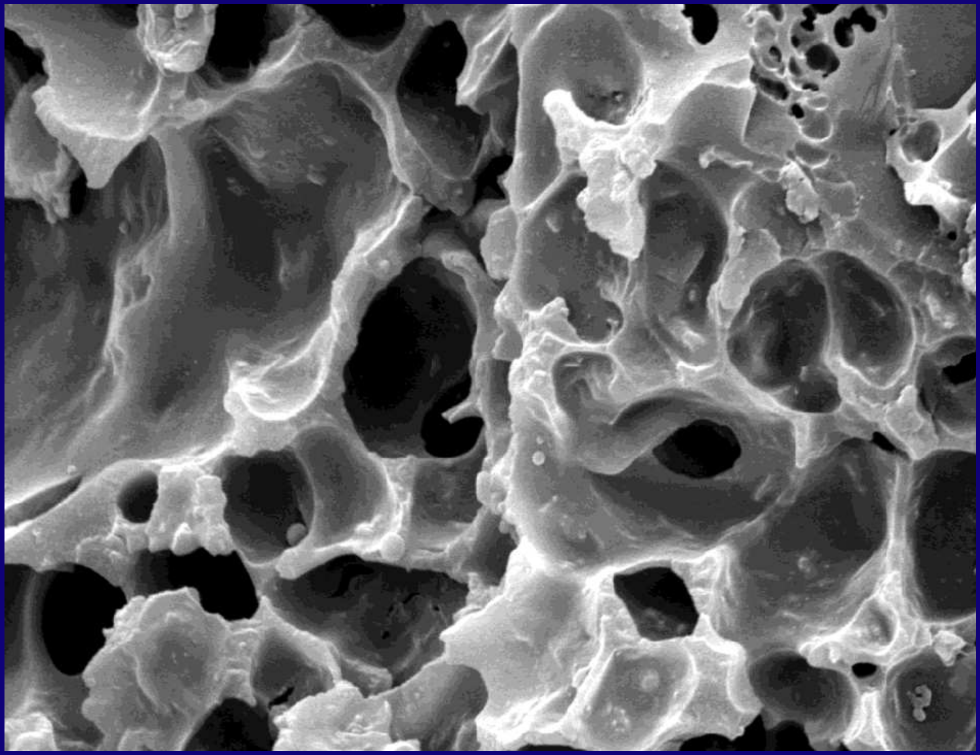
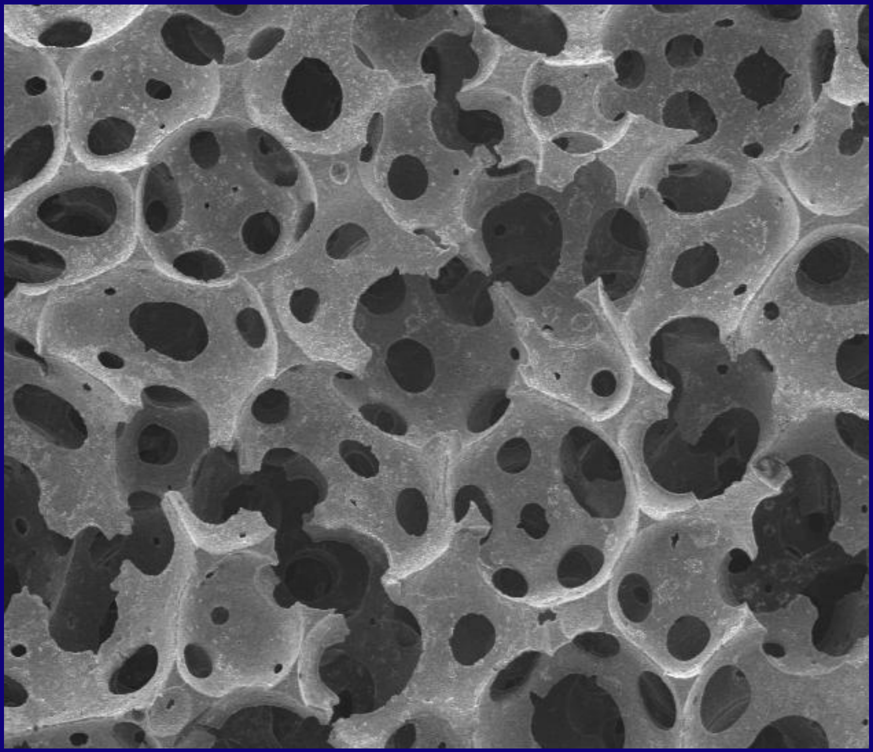


Micro Surfacing



Latex Foam

Wet Track Abrasion Loss – ISSA TB-100

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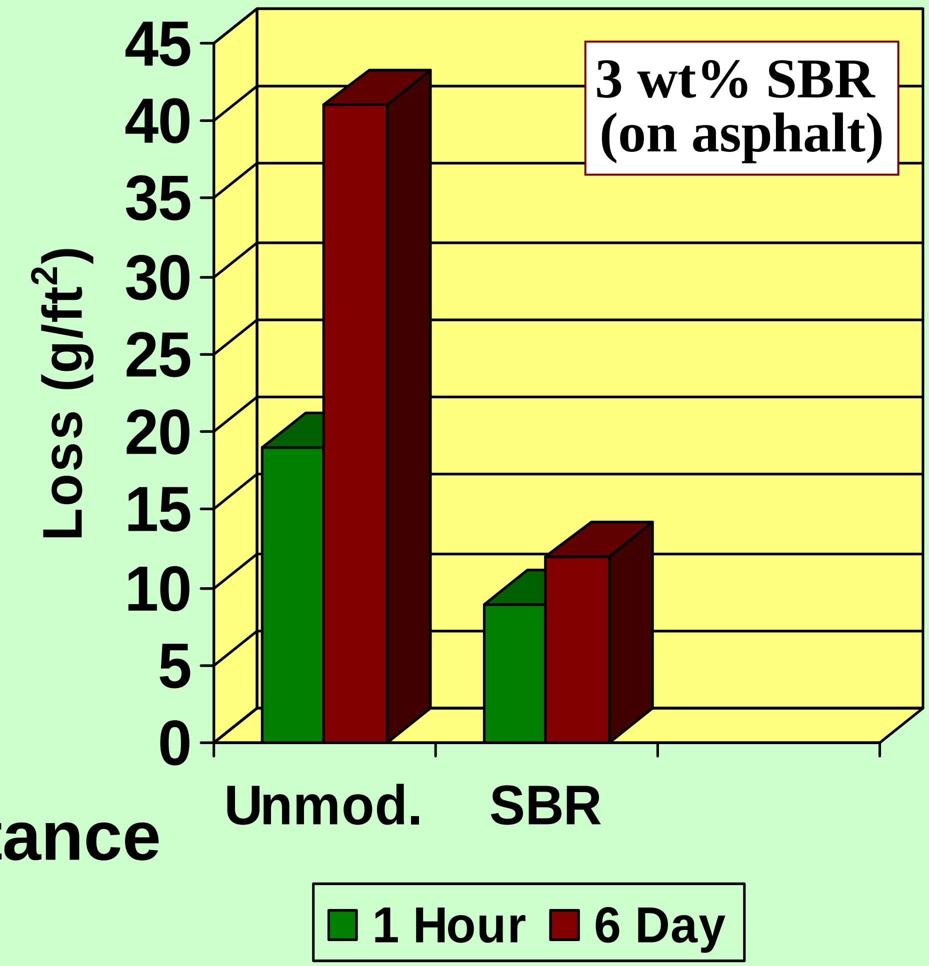
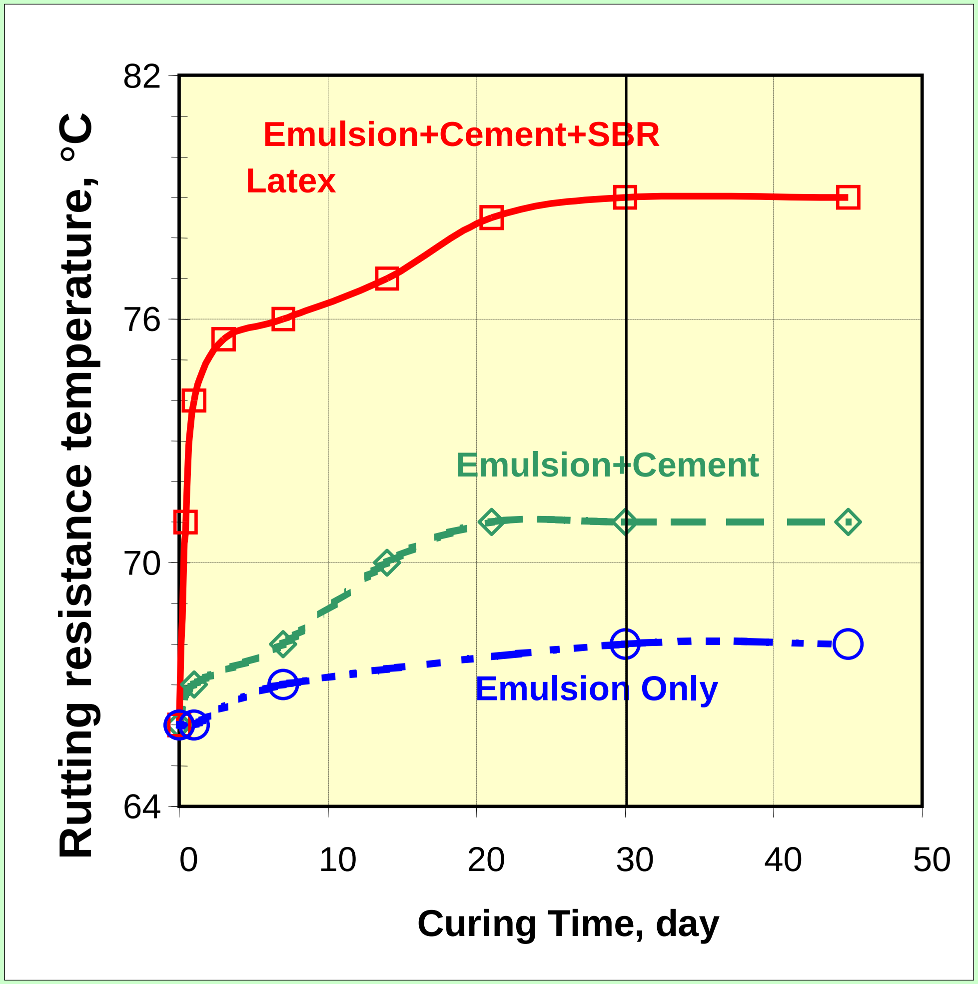
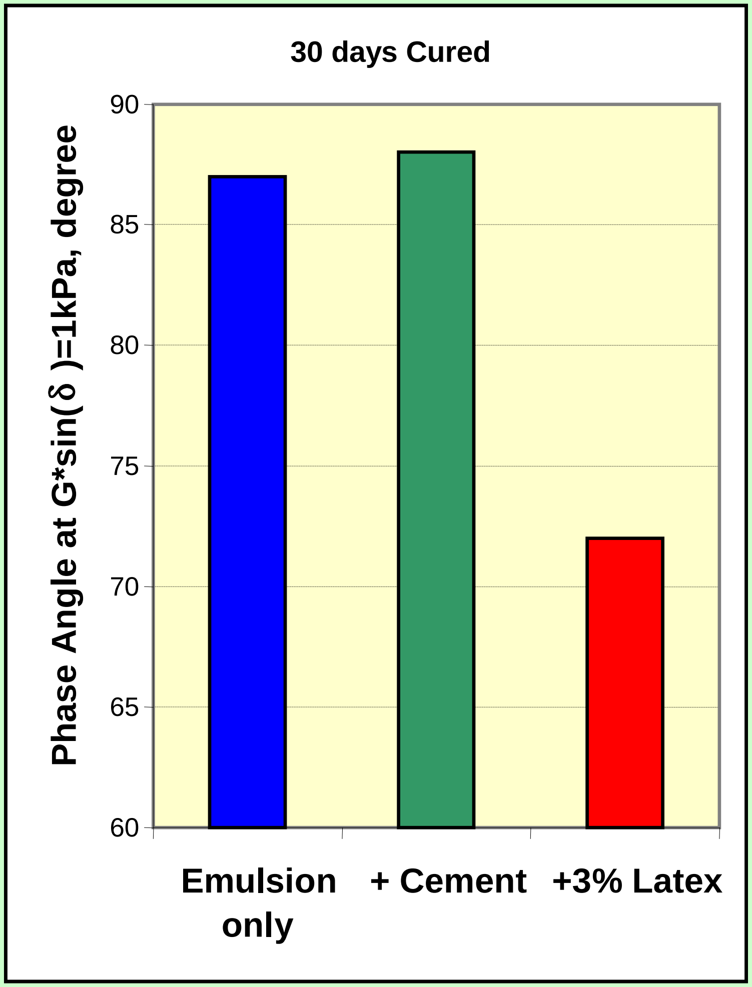
SBR latex polymer

- **50% reduction in loss**
  - one hour soak
- **67% reduction in loss**
  - six day soak
- **Surface of mix**
  - tougher
  - more abrasion res.
- **Adhesion + water resistance**
  - improved



Micro Surfacing Residue – SHRP Grade





Summary – Polymer Modified Emulsions

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- **Chip seals**
  - Early and long term chip retention
  - High temperature strength
  - Low temperature flexibility
- **Slurry seal and micro surfacing**
  - Improved mix cohesion
  - Reduction in abrasion loss of aggregate
  - Resistance to deformation