Effect of
Hydrated Lime
&
Liquid Antistrip
on Stripping of HMA Mixtures

Dallas N. Little – Texas A&M University

Presented by: Amit Bhasin

Introduction

- Stripping – most easily visualized form of moisture damage at asphalt aggregate interface
- Moisture Damage:
  - loss of strength and durability due to effects of moisture
  - also includes weakening of mastic in due to moisture

Outline

- Adhesion mechanisms – background to understand effect of Hydrated Lime (HL) and liquid antistrip (LA)
- Effect of HL
- Effect of LA
- Physical tests for evaluation

Adhesion Mechanisms

Detachment

Pore pressure

pH instability

Spontaneous emulsification

Displacement

Hydraulic scour

Environmental

Two classes:

- Mechanical
- Chemical

Adhesion Mechanisms

Chemical Reactions:

- Nitrogen compounds from asphalt adhere strongly to aggregate surface
- Carboxylic acids (COOH) adhere to aggregate surface – easily removed in water

(Robertson 2000)

Adhesion Mechanisms

Chemical Reactions:

- Monovalent cation salts at interface – easily removed
- Divalent cation salts at interface – more difficult to remove

(Plancher 1977, Scott 1978, Petersen 1987, Robertson 2000)

Adhesion Mechanisms

pH Instability:

- Adhesion decreases as pH of water is increased from 7 to 9
- Different bitumen aggregate environment create different pH levels of water

(Scott 1982, Yoon & Tareer 1988)

Adhesion Mechanisms

Surface Energy:

- Relative wettability of aggregate by asphalt and water
- Distribution of polar groups in both asphalt and aggregate surface impacts adhesion and debonding

Effect of Hydrated Lime

Absence of HL:

SiOH from aggregate surface react with COOH from bitumen…

Resulting bond is weak and easily broken in water

Effect of Hydrated Lime

Presence of HL improves stripping potential via 3 main mechanisms:

1. Ca^{++} from HL react with COOH to form Ca salts

   Relative low solubility of Ca salts in water – improves moisture resistance

(Plancher 1977, Hicks 1991)

Effect of Hydrated Lime

2. Ca^{++} from HL react with COOH

   Reaction between SiOH from aggregate surface and COOH is prevented

   Leaves SiOH sites “open” for Nitrogen compounds (pyridines) from bitumen to interact & form strong adhesive bonds

(Petersen 1987)

Effect of Hydrated Lime

3. Ca^{++} salts migrate to aggregate surface and displace Na and K cations

Easily soluble Na and K cation sites are replaced with low solubility Ca sites

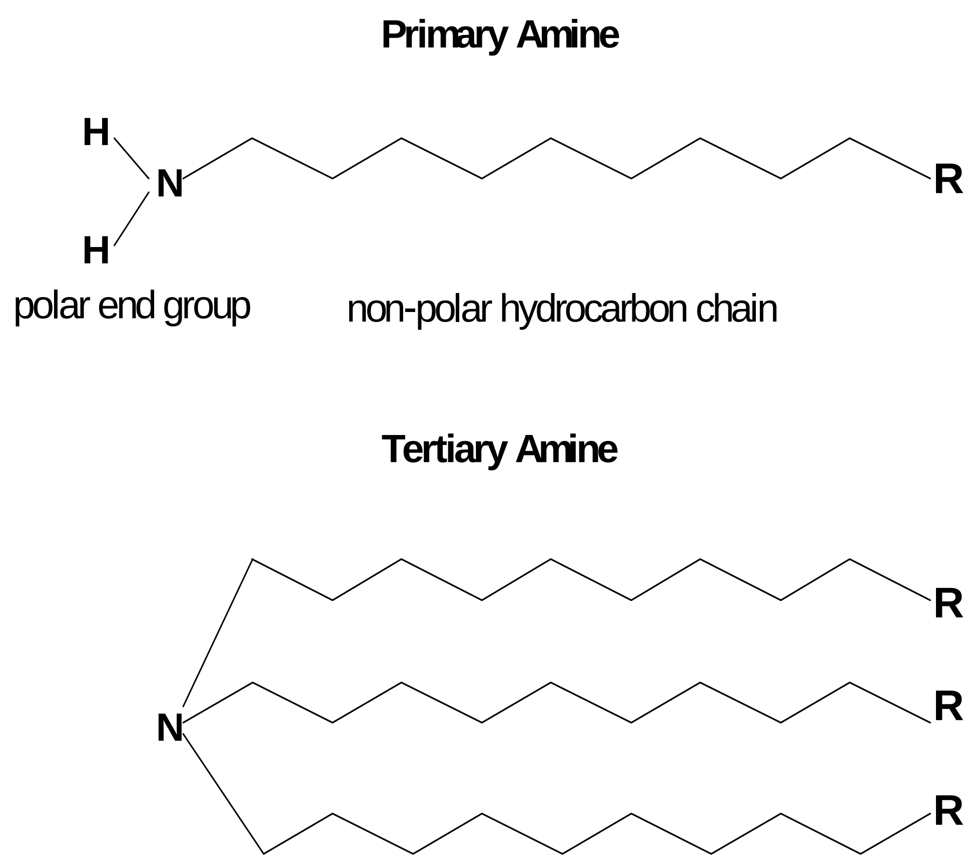
(Schmidt and Graf 1972)

Effect of Liquid Antistrip

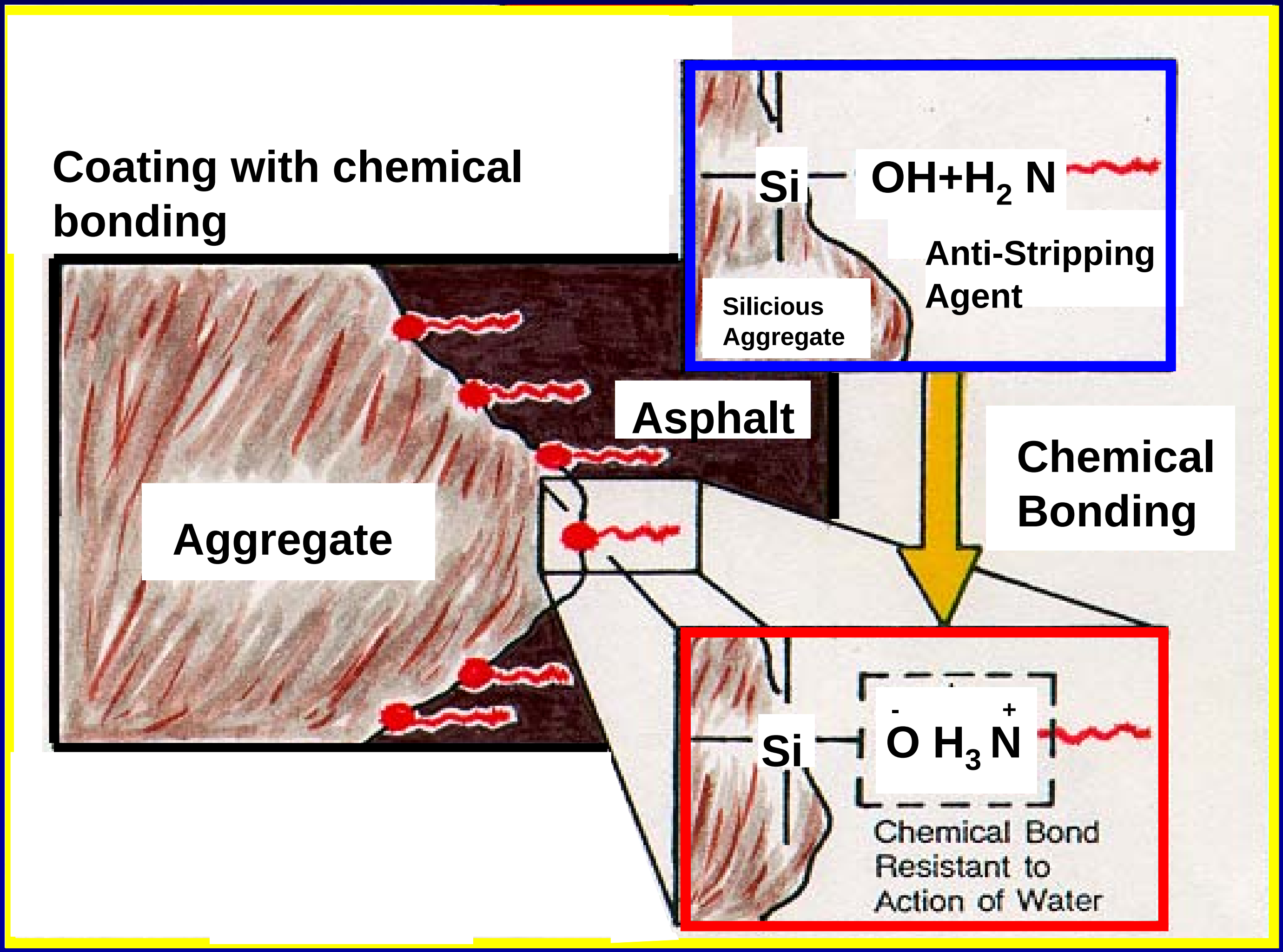
Characteristic:

1. Polar amine end group – bond with siliceous aggregate surface
2. Hydrocarbon chain – part of bitumen

(Logaraj 2002)



Effect of Liquid Antistrip



(Logaraj, 2002)

Effect of Liquid Antistrip

- Length of hydrocarbon chain (R) and number of amine groups influence adhesion
- Fatty amines enable asphalt to wet aggregate surface
- Hydrophobic, hydrocarbon chain of the fatty amine is anchored in bitumen (bridge)

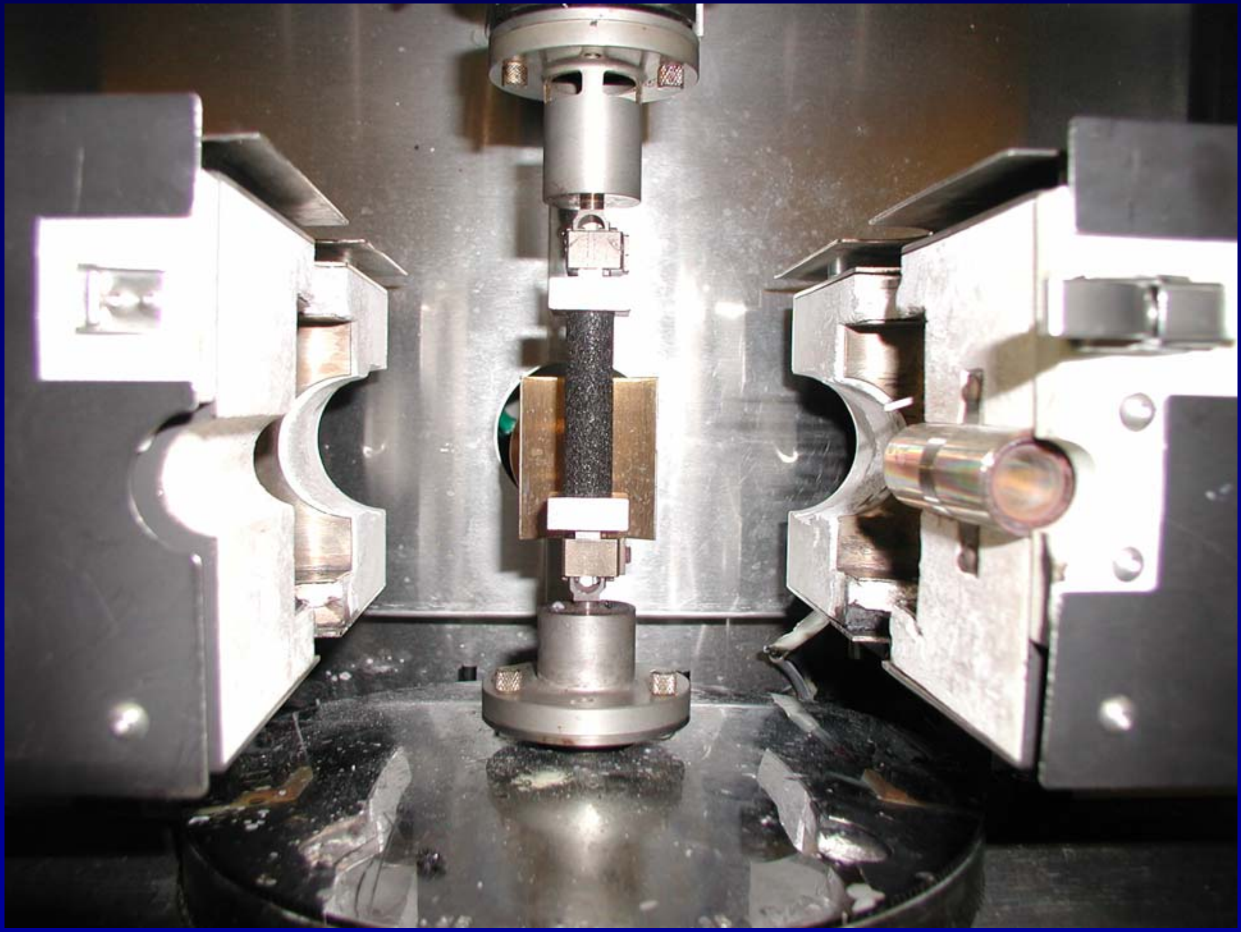
Surface Energy

- Addition of HL & LA increases polar component of bitumen surface energy
- Increased polar component
  - higher adhesive bond strength at bitumen aggregate interface
  - higher wettability of bitumen on aggregate surface

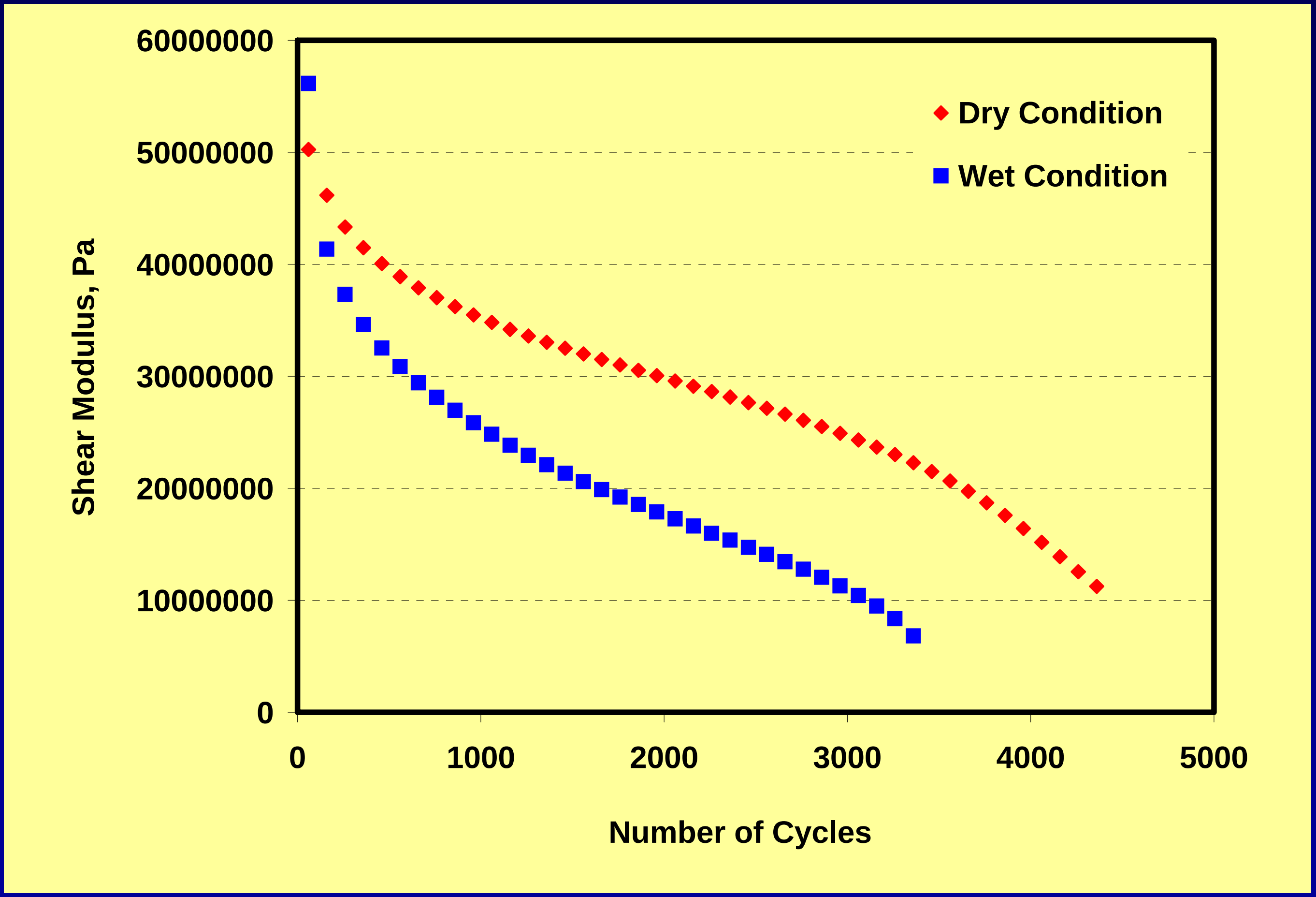
Physical Tests - DMA

- Fast effective test
- Useful for evaluating performance of mastic – fatigue and moisture damage

Physical Tests - DMA



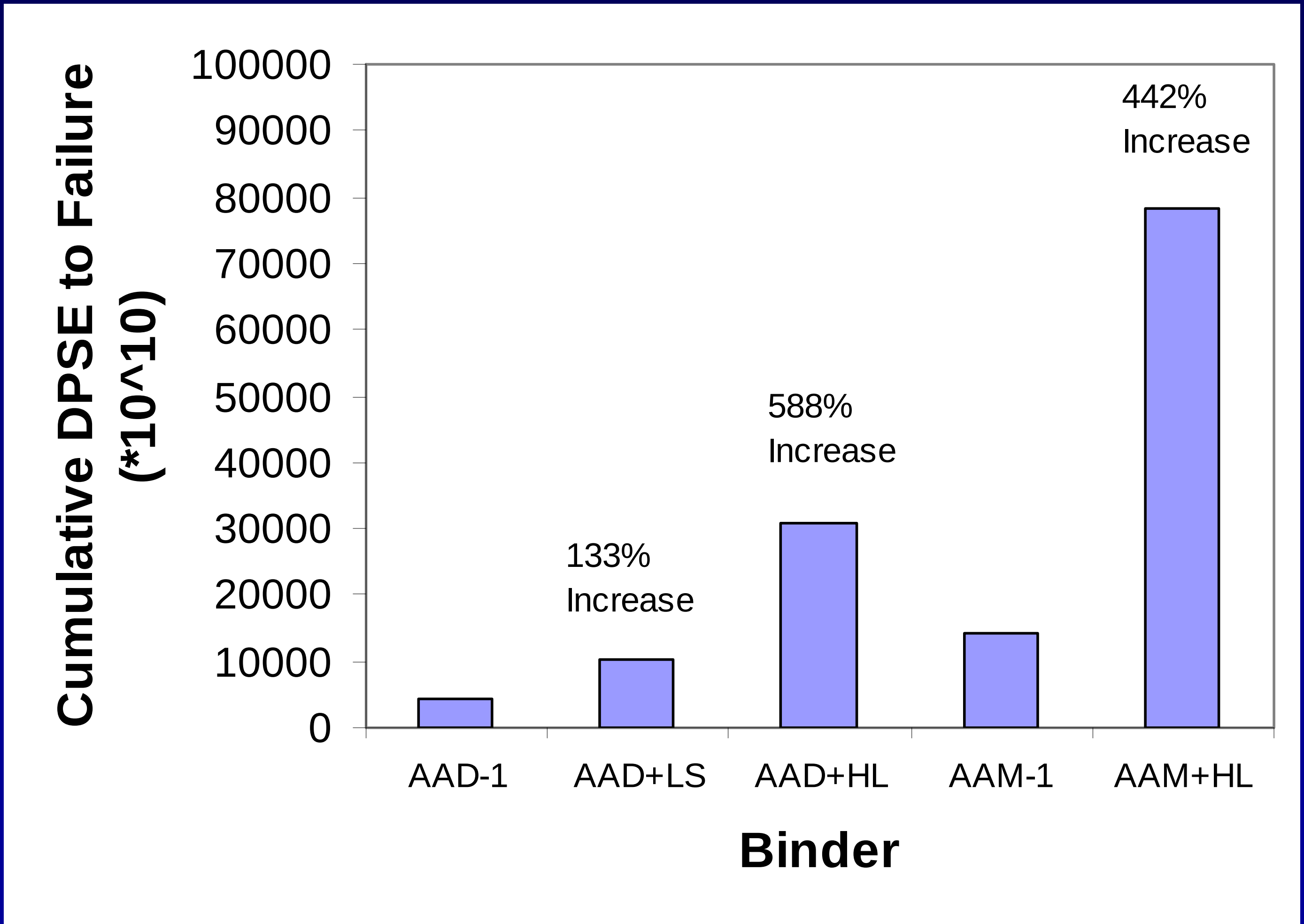
Physical Tests - DMA



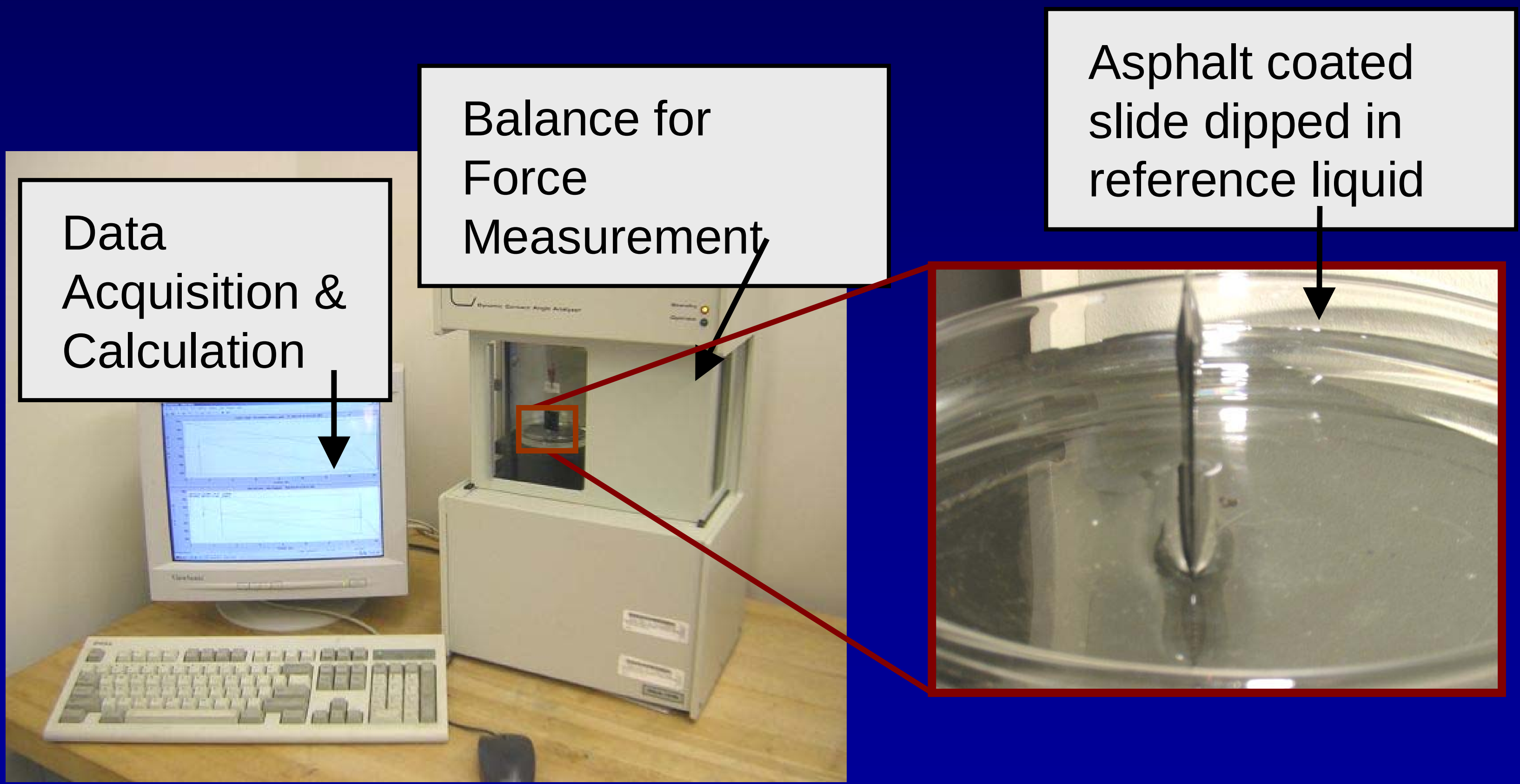
Physical Tests - DMA

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

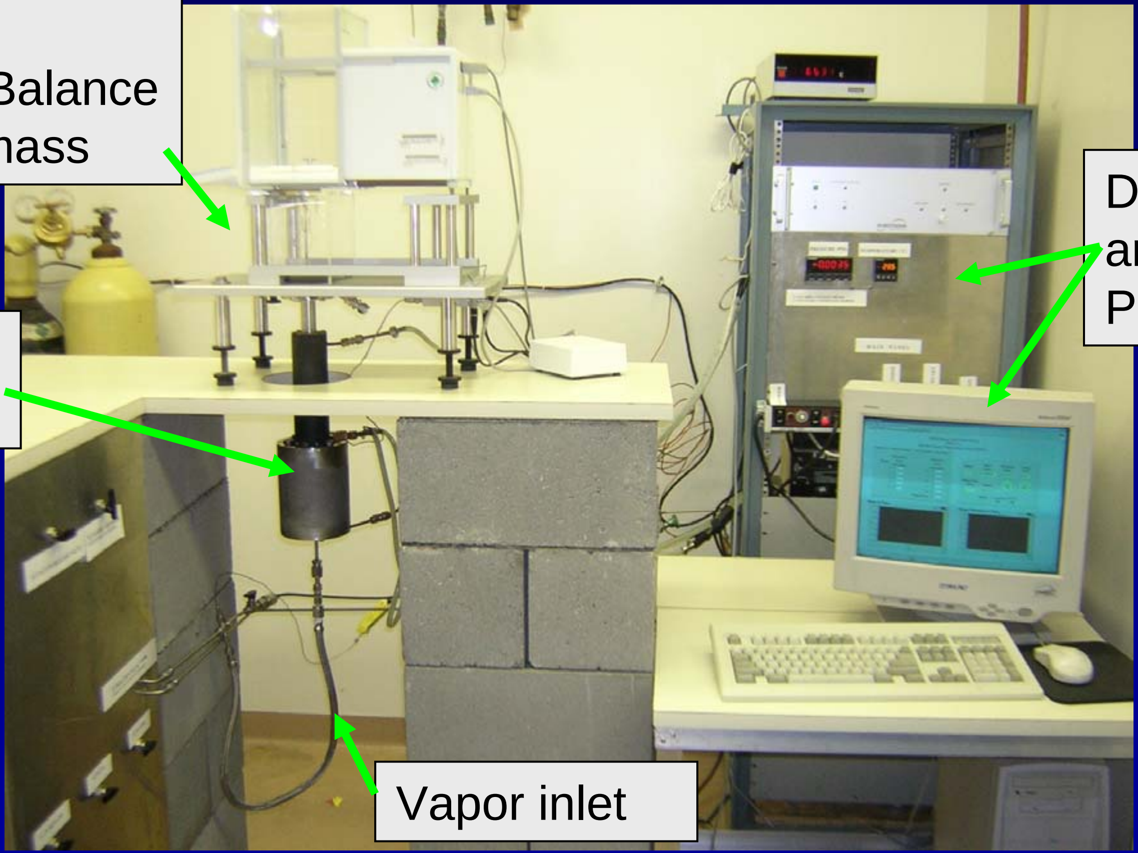
Physical Tests - DMA



Physical Tests – Surface Energy



Physical Tests – Surface Energy



Magnetic Suspension Balance to measure mass

Sample chamber

Data Acquisition and Automatic Pressure Control

Vapor inlet

Physical Tests – Surface Energy

Typical Aggregate Values

Aggregate	Surface Energy Components (ergs/cm^2)			
	Γ^{LW}	Γ^{+}	Γ^{-}	Γ^{Total}
Gravel	61	20	1067	350
Limestone	58	6	340	144
Granite	50	0.1	400	60

Physical Tests – Surface Energy

PG 64-40 + Gravel System

Asphalt (Abbreviation) PG 64-40	**Surface Energy Components (ergs/cm^2)**			
	Γ^{LW}	Γ^{+}	Γ^{-}	Γ^{Total}
Neat	14.6	3.3	0.2	16.3
+ HL	10.7	5.4	0.1	12.3
+ LA	18.7	4.0	1.7	24.0

Physical Tests – Surface Energy

PG 64-40 + Gravel

Mix	Total		Moisture Damage		Bond Strength (ergs/cm^2)	
	Passes (x1000)	Rut Depth (mm)	Passes (x1000)	Rut depth (mm)	Dry	Wet
Neat	4.5	9.5	3.1	5.8	183	-178
+ HL	20.0	9.3	none	none	206	-154
+ LA	20.0	8.9	none	none	211	-166

Physical Tests – Surface Energy

PG 64-22 + Limestone

Asphalt (Abbreviation) PG 64-22	Surface Energy Components (ergs/cm^2)			
	Γ^{LW}	Γ^{+}	Γ^{-}	Γ^{Total}
Neat	13.3	3.7	0.1	14.6
+ HL	25.2	0.8	0.1	25.8
+ LA	25.6	0.7	6.0	29.8

Physical Tests – Surface Energy

PG 64-22 + Limestone

Mix	Total		Moisture Damage		Bond Strength (ergs/cm^2)	
	Passes (x1000)	Rut Depth (mm)	Passes (x1000)	Rut depth (mm)	Dry	Wet
Neat	15	11	9.7	2.5	128	-64
+ HL	7.5	8.3	4.3	2.6	112	-83
+ LA	6.5	8.3	3.5	2.7	120	-96

Conclusions

- Different levels of improvement in stripping properties by addition of HL and LA
- Improvements can be explained based on:
  - chemical mechanisms
  - adhesion theories
  - mechanical mechanisms (HL)

Conclusions

- Synergetic effect of various mechanisms
- Impact of filler will differ from case to case basis
- DMA as a tool for mastic durability
- Surface energy as a tool for selecting “right” filler for a system

Conclusions

- Not all PG grades are alike! – Need to better understand mechanisms to control physical properties
- Further research:

  - Optimal dosing of fillers using tools such as surface energy

  - Influence of pH and fillers in improving stripping resistance