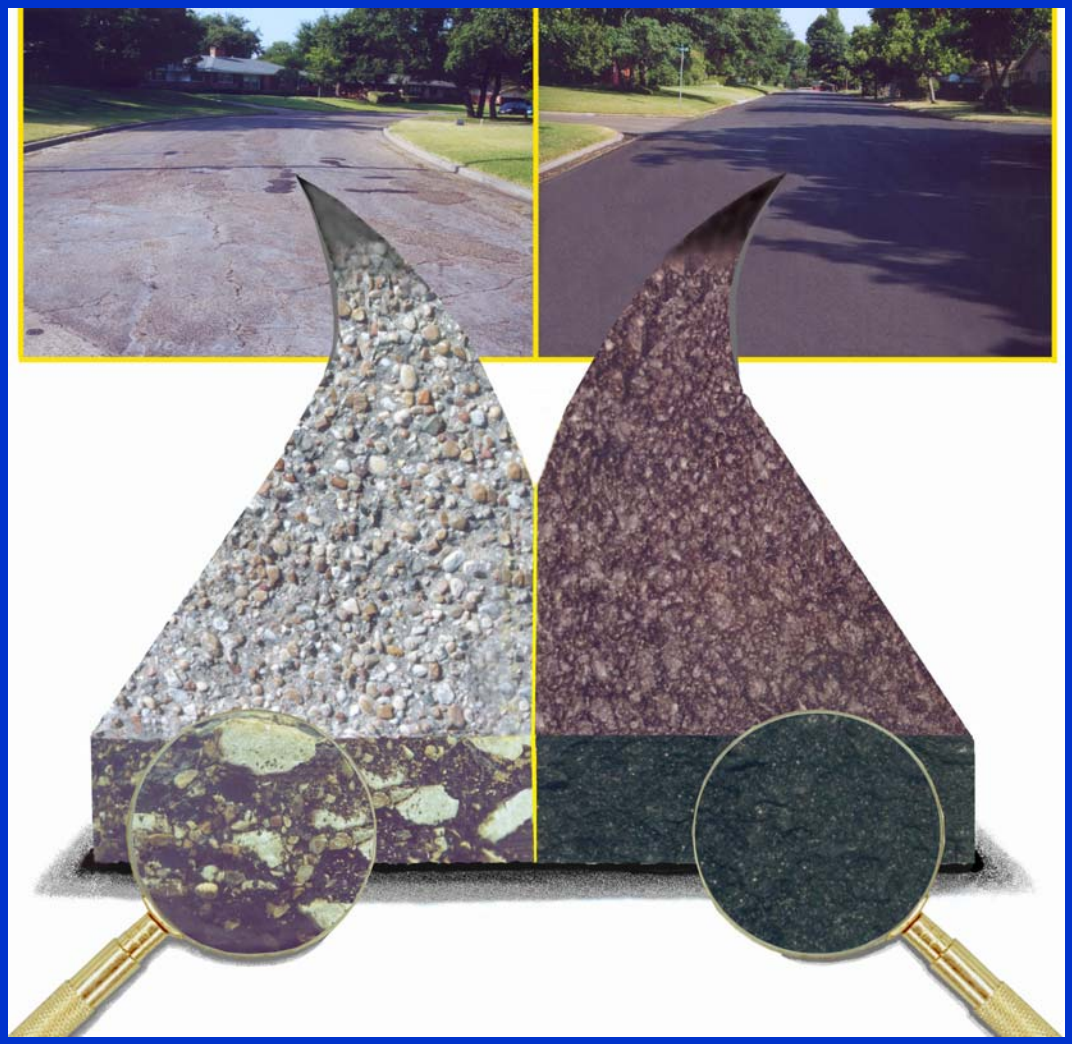
Chemistry of Asphalt Aggregate Interaction

SL April 14, 2002

AI Spring meeting

Stripping in Asphalt pavements

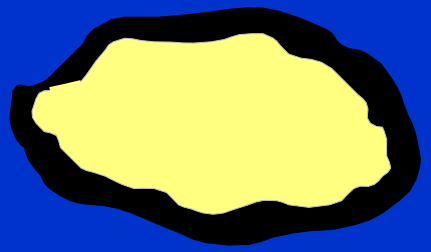
Stripping due to lack of chemical interaction between asphalt and aggregate/bonding (Adhesion)



Scope

- *Analyze in chemical terms the*
  - *Nature of asphalt and aggregate interaction*
  - *What is stripping and reasons for stripping*
  - *Possible ways to correct the problem*
- *Initiate discussion about what is being measured by the common stripping tests*

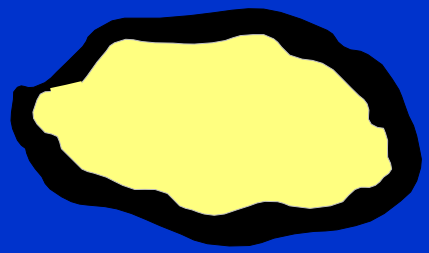
Adhesion and active adhesion

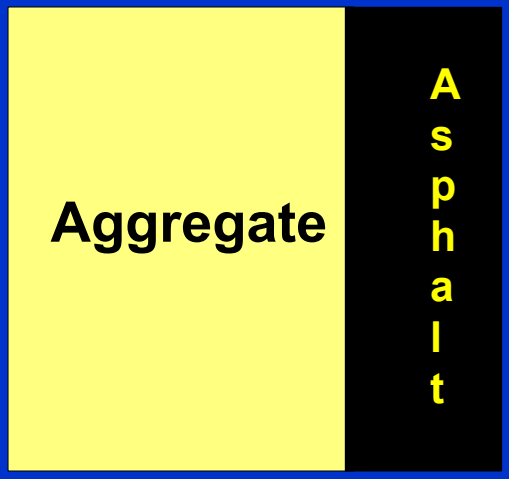


- Adhesion:
  "The process of forming chemical bond between the asphalt film and the aggregate surface"

- Active adhesion:
  "Coating and formation of chemical bond in the presence of water"

Stripping





"Stripping is the breaking of the bond between aggregate and asphalt by the action of water"

Adhesion and Stripping

- *Definition indicate that it is a Surface phenomenon*

- *The surface or interface is between asphalt and aggregate*

General Asphalt Composition

Asphaltenes : polar condensed aromatics MW 1000-100 000 (5-25%)

- Maltenes

  Resins : polar aromatics MW 500-50 000 (15-30%)

  Aromatics: non-polar aromatics MW 200-3000 (40-65%)

  Saturates: aliphatic hydrocarbons and alkyl substituted cyclics MW 200-5000 (5-20%)

AKZO NOBEL

Presence of acidic organic compounds in Asphalt

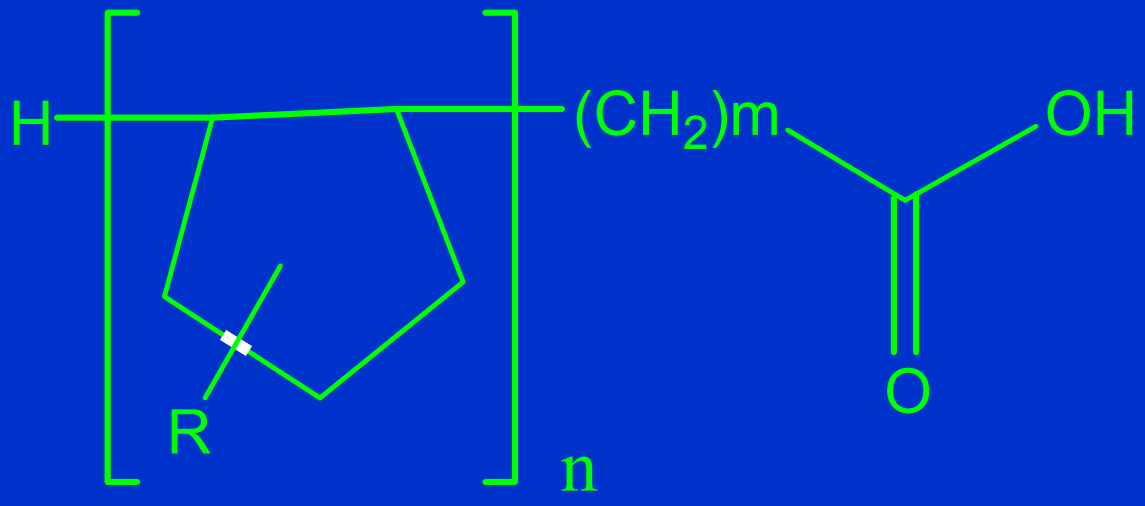
- *Carboxylic acids (RCOOH) and anhydrides*

- *Acid Value*
  - *0 to 4 mg KOH/g*

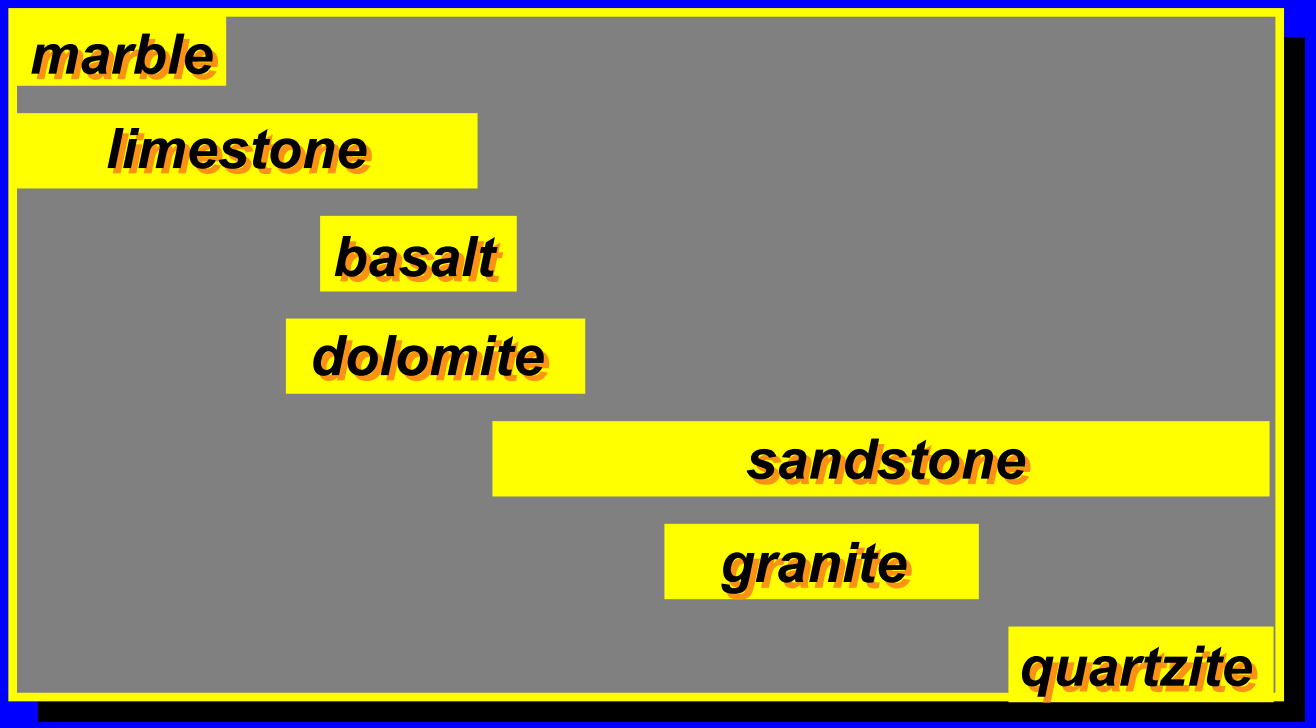
H. Plancher et.al., Proceedings of AAPT volume 46 (1977), pp.151-175

A. Seive, M.F. Morizur, B. G. Koenders, G. Durand, J.E. Poirier., Proceeding of AEMA (1999), pp. 256-263

Possible presence of compounds related to naphthenic acids

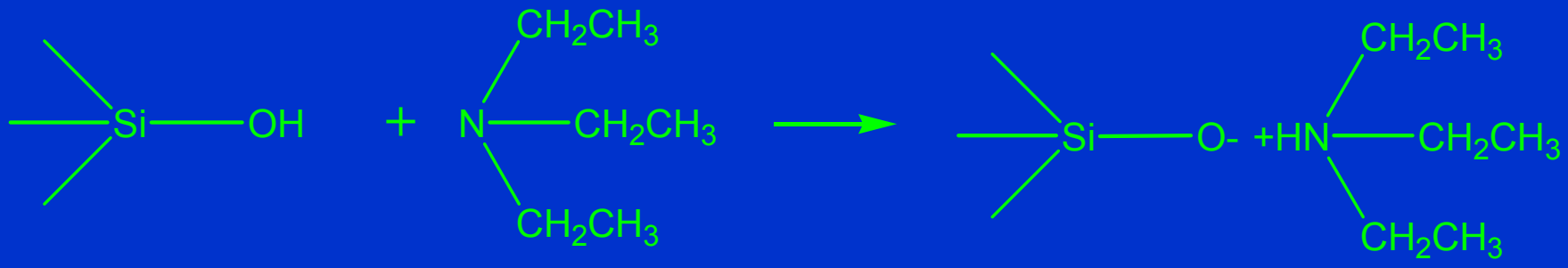


Chemical Nature of Road Aggregates



AKZO NOBEL

Evidence for acidic surfaces on siliceous aggregates



Silica, Triethylamine compound

Stable >900^{o}F in Vacuum

Titova et. al., Langmuir. 1987, **3**, 960

Aggregate and Asphalt Properties

Aggregate	Surface Properties	Asphalt Properties
Quartzite	Acidic	**Basic Ingredients** Not usually present in significant amounts
Granite	Acidic	
Sandstone	Acidic	
Limestone	Alkaline	**Acidic Ingredients**

Depending on the asphalt

Asphalt Aggregate Interactions

Acidic Siliceous Aggregate	*No Adhesion or Chemical Bonding*
Alkaline Aggregates such as limestone	*Adhesion or bonding depending on the type of asphalt (acidic organic compounds)*

- *Aggregates with a high $CaCO_3$ content will not pass polish test*
- *Fines are siliceous material (sand) and the stripping in the fines is more of a problem.*

Interaction of alkaline aggregates and asphalt with acidic components

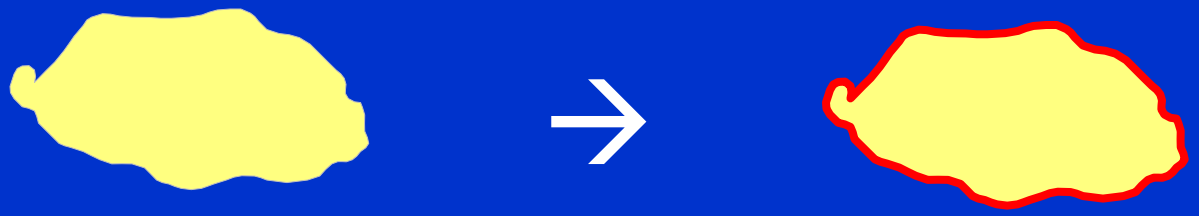
$CaC0_3 + 2RC00H \rightarrow (RC00^-)_2\, Ca + CO_2 + H_20$

$CaC0_3 \rightarrow CaO + CO_2$

At high temp possible coating of quick lime on the surface

$CaO + 2RC00H \rightarrow (RC00^-)_2\, Ca + H_20$

Possible coating of quicklime on the surface of a limestone



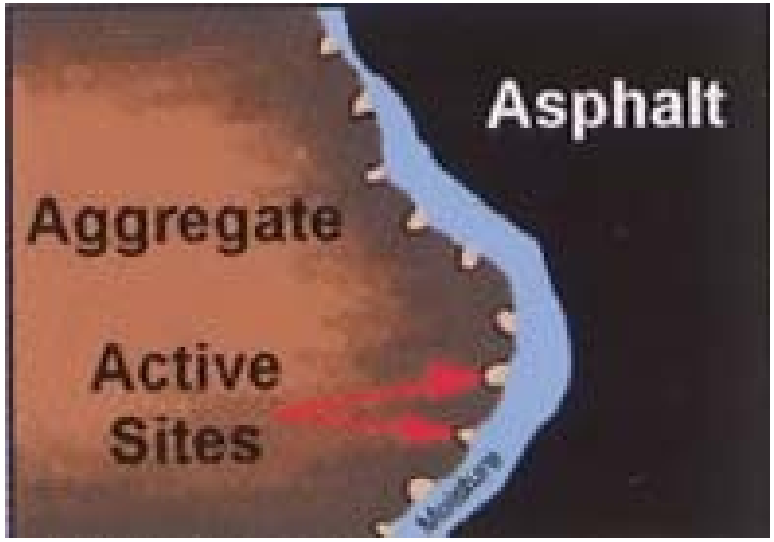
~ 700 °C

This is not possible in siliceous aggregates

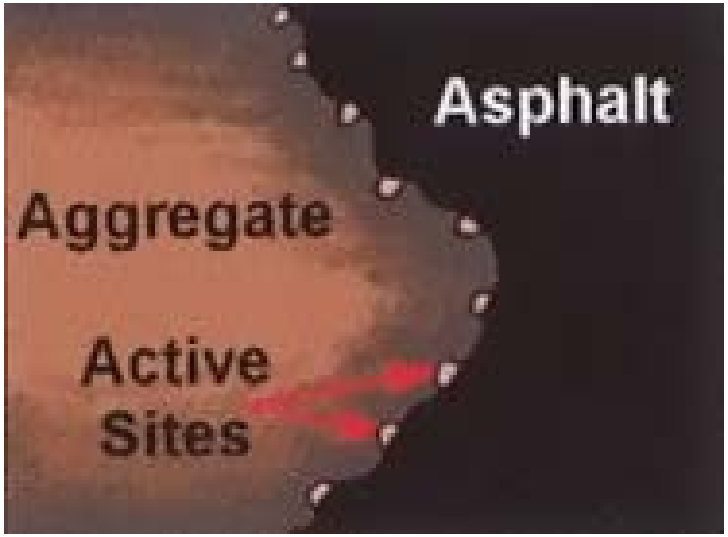
Stripping in asphalt pavements

Coating without chemical bonding

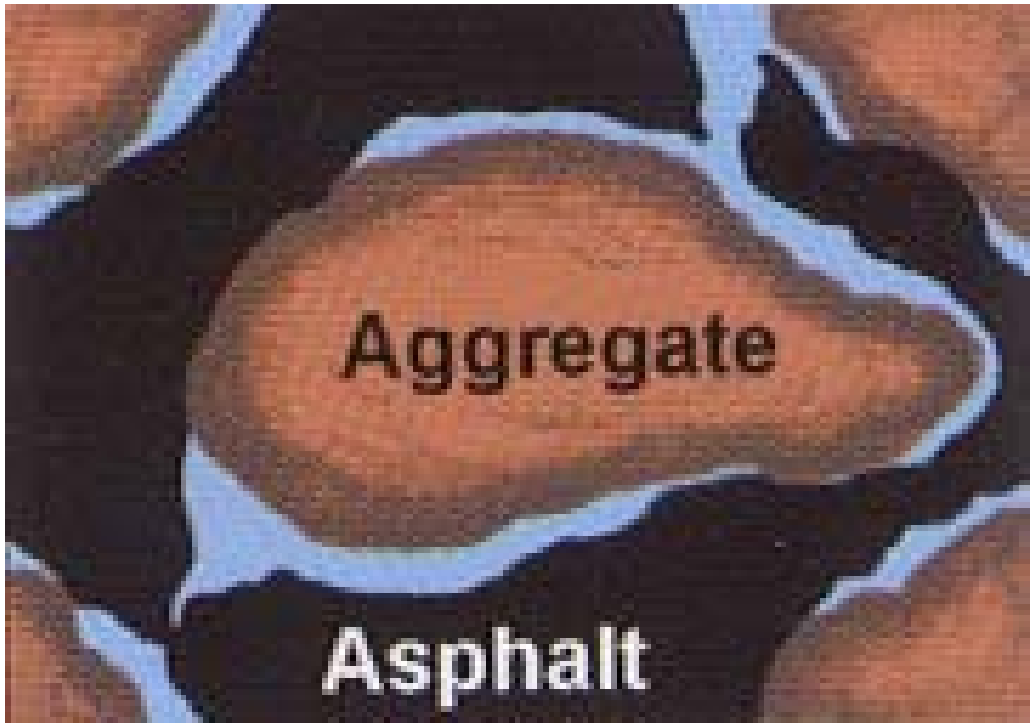
Moist Aggregate



Dry Aggregate



Stripping

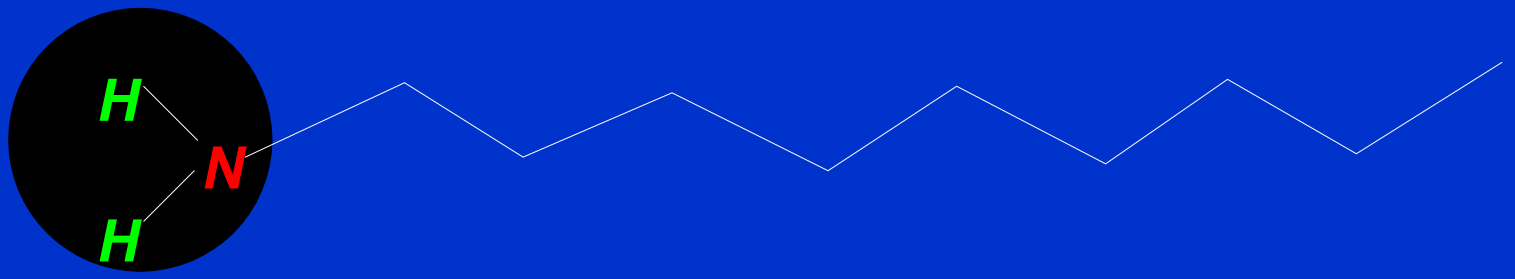



Static immersion test at 60°C
Nynas B 180

Possible ways to improve Surface interaction (adhesion)

Interaction of acidic aggregates and asphalt with alkaline amine components

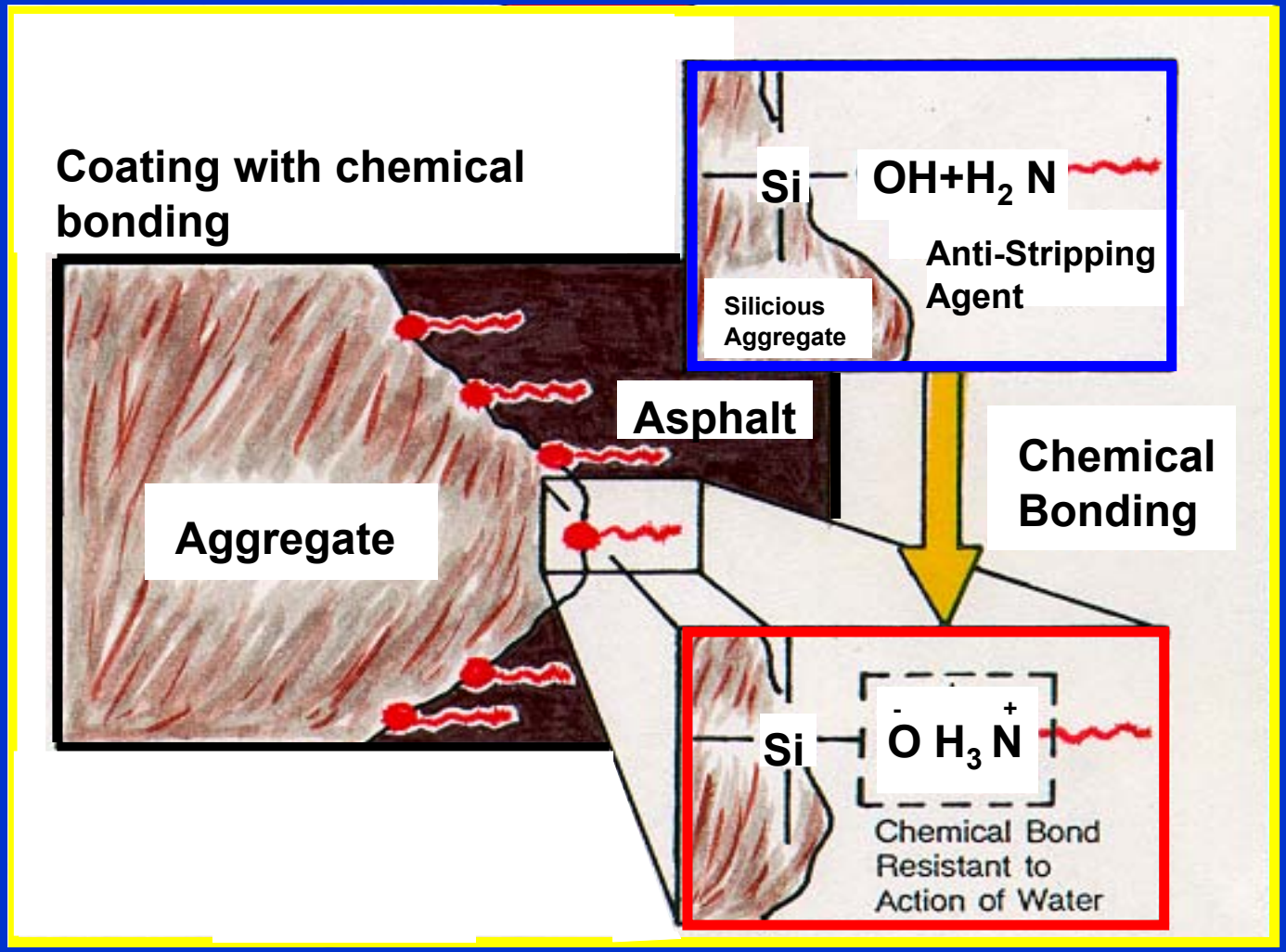
$$--SiOH + RNH_2 \rightarrow --SiO^- RN^+H_3 + H_20$$



Polar End Group

Non-Polar Hydrocarbon Chain

Asphalt aggregate interaction in the presence of suitable compounds in asphalt



Asphalt Aggregate Interaction

- *All discussions about surface interactions*
- *Stripping tests*
  - *What are we measuring?*

Stripping tests

- *Boiling Water - ASTM D3625*
- *Static-Immersion - AASHTO T182 or ASTM D1664*


Static immersion test at 60°C
Nynas B 180

Other Tests

- *Modified Lottman - AASHTO T283 or ASTM D4867*
- *Georgia Wheel Rutting Device*
- *Hamburg Wheel Rutting Device*

Typical Appearance

Fail *Pass*

Modified Lottman test results

Additive + Gilsonite

Additive	Gilsonite	Additive*	St. psi Dry	St. psi Wet	TSR %	Property
Control	0	0	137	64	47	
Additive	0	1	119	92	77	SI
Control with Gilsonite	0.47	0	203	100	49	Harder asp
Additive + Gilsonite	0.47	1	188	154	82	SI + Harder asp
Additive + Gilsonite	0.24	1	153	131	85	SI + Harder asp

1.0 by the weight of the asphalt

Asphalt + Gilsonite = 4.7% (10% and 5% by the weight of asphalt)

Lottman test and it's variations

- *Surface Interaction (Adhesion and Stripping) + other parameters?*
- *Other parameter – hardness?*
- *Lottman type tests*
  - *Weakening of specimen during freeze-thaw Expansion caused by water becoming ice?*
  - *Harder asphalts and Mix can resist this expansion better*

Hamburg Wheel Tracking Test

- *Known that harder (high softening point) asphalts give better results*
  - *Polymer modified*
  - *Oxidized (air blown) asphalts*

- *Surface interaction + rutting*
  - *Harder asphalts resist rutting better*

Important test methods for Hot-mix
And Possible properties evaluatedby various tests

Test methods	***Observed properties***
Boil test, *Static immersion*	*Surface interaction between aggregate and asphalt*
Lottman type tests And Wheel tracking tests	*Surface interaction* + *Hardening effect of the asphalt and mix*

Summary

1. *Asphalt Aggregate interaction (Adhesion and Stripping) depends on the type of aggregate and asphalt composition*

2. *There is a lack of interaction (Adhesion) in most mixes*

3. *Adhesion and stripping is a surface phenomenon*

4. *May be a combination of stripping tests should be used to evaluate both surface interactions and the mix properties?*