

Nano Scale Organosilane Asphalt Applications

Virginia Asphalt Association

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Organosilane Chemistry

- Developed over 50 years ago by Dow Corning for Epoxy/Fiberglass systems
- Unique capability to form covalent bonds between inorganic and organic compounds.
- Inherent stability and flexibility of the siloxane (Si-O-Si) bond provides multiple benefits in bituminous applications.

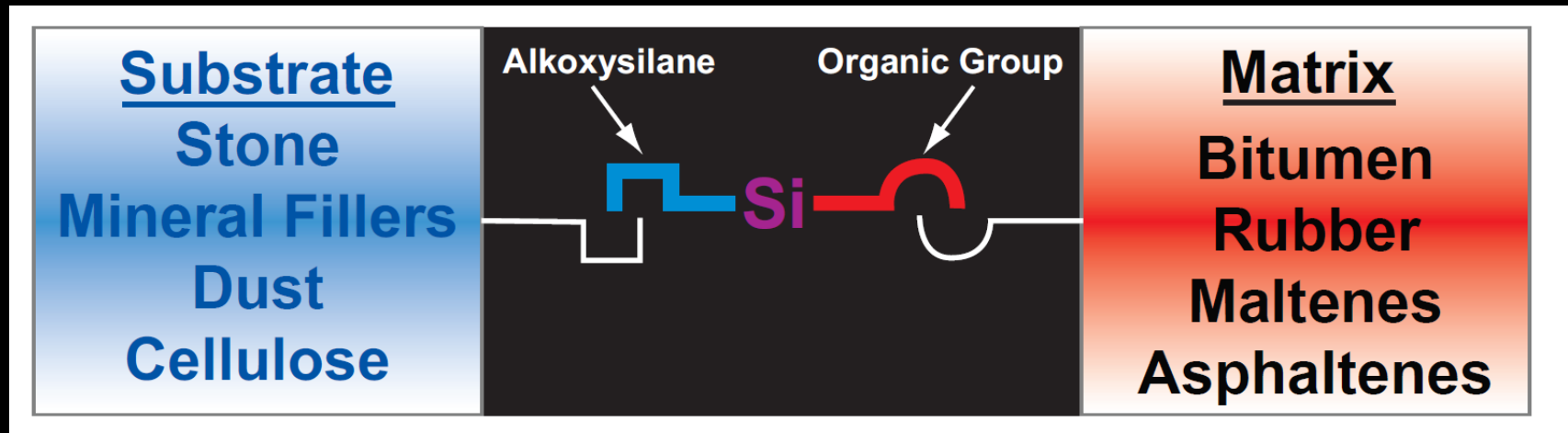
Organosilane Chemistry

By using the right organosilane, a poorly adhering coating can be converted to a material that will maintain adhesion even if subjected to severe environmental conditions (e.g., high temperature, underwater immersion or UV radiation).

Source: Organosilane Technology in Coating Applications: Review and Perspectives, Thierry Materne, Global Silane Technology, et. Al. Dow Corning Corporation

Nano Scale Organosilane Chemistry

- Nano Scale structures are under 100 nm
- Nanometer = 1×10^{-9} meters
- Comparable Dimensions
 - Sheet of paper = 100,000 nm
 - Human hair = 80,000 – 100,000 nm
 - 200 Sieve = 0.075 mm = 75,000 nm
- 1 kg of Nano-Scale Organosilane can contain 1×10^{17} reactive molecules



Asphalt Mix Applications:

- Nano Scale allows bonding to dust and fines
- Complete coating of the entire aggregate surface

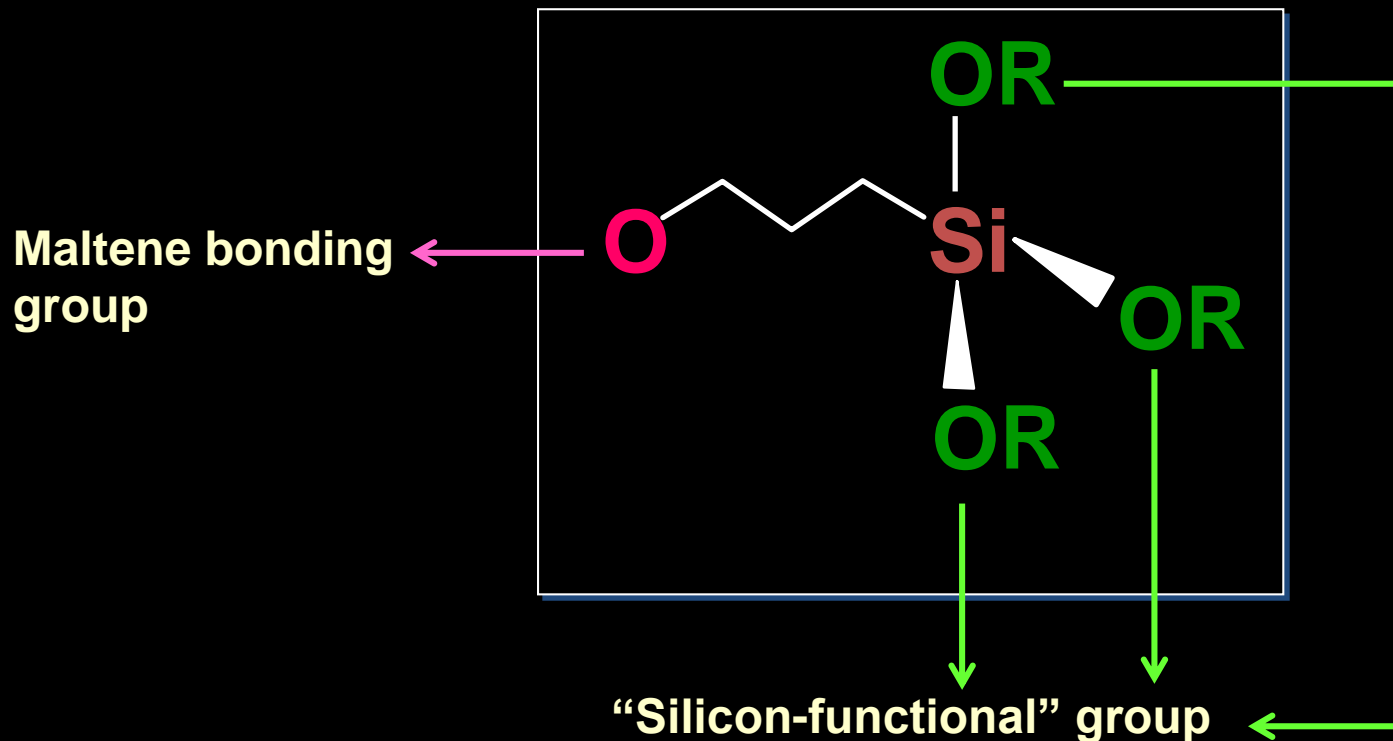
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Organosilane Chemistry

- Si forms four covalent bonds
- Silicon Functional Groups bond to aggregate
- Organofunctional groups bond to bitumen
- Chemical bonding of the bitumen-aggregate system decreases moisture susceptibility

Reactivity of Organosilane

Chemical Bi-Functional Structure – Dual Reactivity



Note that this is a solid molecule– will not evaporate or migrate and is heat stable in binder for 14 days.

Organosilane Effect on Asphalt Binder

- Does not change the Performance Grade of the binder
- Does not change the Rotational Viscosity AASHTO T 316 at 135 C
- Improves complex modulus $G^*/\sin\delta$ (binder stiffness) with the same visco-elastic response (phase angle) AASHTO T 315 DSR Test
- Penetration number goes down slightly
- Improves rut resistance (higher $G^*/\sin\delta$)
- Improved retention of elasticity as reflected by higher phase angle, in PAV aged asphalt binder
- Similar / Higher m-value at -12 °C (BBR Test AASHTO T 313), even though the G^* shows consistently higher values at 64 °C

Organosilane Function in Asphalt Mix

- Aggregates are naturally hydrophylic due to polar surfaces created by Si-OH^- hydroxyl groups
- Organofunctional alkoxysilane reacts at the aggregate–bitumen interface
- Forms Si-O-Si bonds that are non-polar
 - Aggregates repel water
 - Easily wetted by bitumen

Organosilane Function in Bitumen

- Polar organosilane molecules attracted to polar sites of asphaltenes
- Micellize and isolate asphaltenes
- Apparent viscosity reduction of bitumen
- Lower surface tension
- Pen number decrease

Organosilane Function in Asphalt Mixtures

- Binds asphaltenes to aggregate surfaces
 - Allows easier movement of aggregate
 - Decreases asphaltene build-up on plant
 - Acts as a compaction aid/WMA additive
- Lowers mixing temp 50 -6F
- Lowers compaction temp 95 – 105F
- Consistent compaction density over 190 – 215F range

PMA-Organosilane

- May be added to binder before polymer
- Reduced apparent viscosity
- Reduced stickiness
- Improved Compaction
- Enables increase of polymer % in the binder

CRMB-Organosilane

- Added to binder before CRMB
- Reduced Odor
- Fuel saving due to lower mixing temperature (50F)
- Improved Compaction
- Enables increase of crumb rubber % in the binder
- Stripping resistance at par with PMB

Organosilane Function in Asphalt Mixtures

- Decreased surface tension
 - Allows fines and dust to be coated
 - Frees trapped bitumen
 - Coats aggregate faster
 - Increases time for conductive heat transfer
- Minimizes uncoated aggregate surface
 - Eliminates trapped moisture
 - Increases stress transfer

Multiple applications in asphalt materials

- Asphalt Paving – antistripping / compaction aid
- PMA modification aid
- Foaming operations
- Emulsions - pre and post addition
- Crack sealants
- Adhesives
- Subgrade waterproofing

Organosilane Asphalt Binder Dose

- One molecule provides both antistrip and compaction aid properties
- 0.03% - 0.10 % of asphalt binder weight for antistrip
 - Higher Silica materials = higher dose
 - Higher fines – higher dose
 - Higher asphaltenes – higher dose
- 0.05% - 0.15% of asphalt binder weight for warm mix / compaction aid
 - Higher asphaltenes – higher dose
 - Higher PMA – higher dose
 - Higher Silica – higher dose
 - Higher fines – higher dose
- Aggregate may be treated directly

LIFE CYCLE EXTENSION

Organosilane Technology

- Improved oxidation resistance
- Reduced water damage
- Higher densities at lower compaction temperatures
- Improved fatigue resistance
- Improved bleed resistance





THANK YOU

Questions?

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