Nano Technology in Water Proofing of Building Materials  
(Long life, Economical & Eco-friendly)

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Abstract:  
Water intrusion in building materials has been a problem for the last 1000 years. Regrettably, this problem was never fully addressed due to a lack of understanding on a Nano scale. Fortunately, new developments in science and technology have incorporated the use of Nano technology to produce eco-friendly, Organo-Silicon products that can render most cementitious materials hydrophobic for cycles of 20 to 30 years or more at a very economical cost.

Introduction:  
Building materials are known to have water seepage and water leaks due to inherent porosity and micro cracks. Water repellency can be achieved through treatments, which are expected to render cementitious materials impervious to water. Over the last 50 years, a significant amount of technology has been developed utilizing various methodologies. One of the most common methods utilized a blend of basic polymeric chemistry and other materials to create products that are resistant to water intrusion.

Water Repellents:  
One of the primary objectives of water repellents is to maintain and preserve aesthetics, by protecting cementitious substrates from water related issues such as:

- Paint peel-off  
- Paint blisters  
- Fungus  
- Mold & Mildew  
- Efflorescence

In addition to aesthetic preservation, water repellents address more serious structural issues such as the loss of structural strength of concrete building materials due to ASR (alkali silica reaction), acid rain, and sulphate attack. Water repellents can also prevent chloride penetration, which often results in the corrosion of the reinforced steel bars.

Water related problems – Most cementitious building materials are very porous and have surface hydroxyl groups. These hydroxyl groups attract water because of the hydrophilic nature and similarity with the structure of water. Therefore, most cementitious building materials easily absorb water into the pores when water is present. The size of the water molecule is 0.18 nm (nanometer = 10^-9 meter, i.e. .00018 microns). The pore size in most cementitious building materials range from 5 to 200 nm. Most pollutants such as acids, chlorides, and sulphates range between 1 to 2 nm. Even the most dense concrete and stones and have pore sizes much larger than water which enable both water and other damaging chemicals to easily penetrate the pore structure of these materials.
As the world has started to pay more attention to aesthetics, the building industry has begun to rely on more often on water repellents as the primary mechanism to maintain and preserve the clean look of new buildings. As a result of this demand, many products are currently commercially available, however, it is important to recognize that the essential functions that these water repellents should address are:

- Resistance to water intrusion
- Prevention of water-soluble salts, particularly chloride salts
- Penetration of repellent treatment to a measurable depth
- Will not stain surface areas
- Long-term stability in an alkaline environment
- Low environmental and health risk
- UV stability (20+ years)

There are 2 classes of waterproofing products:

1. Film Formers
2. Penetrants / Repellents

**Film Formers:**
The economics and the ease of application have led to widespread use of film forming water repellents. Products like acrylic paint and silicon polymers are commonly used in the world for waterproofing applications. These film formers have a particle size greater than 100 nm, which will not allow them to penetrate inside the pores of the building materials but instead form a film covering and protecting the surface from water absorption. Generally, these polymer films are hydrophobic but they need to be continuous and defect-free and also must be UV resistant. It is found that during application, ensuring a continuous film on rough surfaces is difficult to achieve which leads to weak points in the film. Most typical polymer films tend to break down under UV exposure leading to cracking of the films in 2 to 5 year. This leads to failure in terms of losing the hydrophobic water resistant features of the film.

**Penetrants / Repellents:**
Most penetrants are solvent based, soluble monomeric materials less than 6 ηm in size which can easily penetrate inside the pores and sub-branches of the pores. There are two types of penetrants: (i) non reactive and (ii) reactive. Non-reactive penetrants are oils and other low viscosity hydrophobic materials, which coat the pores of the substrates and provide water repellency. However, these types of materials are also biodegradable and lose their hydrophobic characteristics within a year. Additionally, these products also provide food for mold or fungus growth on the substrate surfaces and into the pores.

Reactive penetrants chemically react with the substrate and provide molecular level hydrophobic protection 3 to 5 mm deep into the substrate. Therefore, these types of water repellent products provide protection for a long period. Additionally, the product is bound chemically on a molecular level to the substrate. As a result weathering (UV exposure) and natural abrasion have little impact on the ultimate waterproofing characteristics.
Table-1 summarizes the properties of various commercially available waterproofing.

**Waterproofing Products**

<table>
<thead>
<tr>
<th>Property</th>
<th>Organic</th>
<th>Acrylates</th>
<th>Epoxy</th>
<th>Siliconates</th>
<th>Silicone</th>
<th>Silane / Siloxane</th>
<th>Silane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Structure</td>
<td>Monomeric Compounds</td>
<td>Organic Polymer</td>
<td>Organic Polymer</td>
<td>Na salt of Silicic acid (Sodium Silicate)</td>
<td>Poly dimethyl silicone</td>
<td>Poly dimethyl silica polymer</td>
<td>Mixture of low molecular weight alkoxy silanes and Silane</td>
</tr>
<tr>
<td>Particle size (nm)</td>
<td>0.5 to 1.5**</td>
<td>100 to 1000</td>
<td>100 to 1000</td>
<td>2 to 5</td>
<td>50 to 2000</td>
<td>50 to 2000</td>
<td>Alkoxy silane</td>
</tr>
<tr>
<td>Mechanism of waterproofing</td>
<td>Hydrophobation by organic film</td>
<td>Hydrophobation by coating and closing of the substrate</td>
<td>Hydrophobation by coating and closing of the substrate</td>
<td>Hydrophobation by coating silicate formation and tighter packing</td>
<td>Hydrophobation by coating and closing of the substrate</td>
<td>Hydrophobation by changing surface property by reacting with surface with some penetration</td>
<td>Hydrophobation by changing surface property through a chemical bonding with polar groups of the substrate surface</td>
</tr>
<tr>
<td>Requirements</td>
<td>Need surface wetting</td>
<td>Need good adhesion and continuous film</td>
<td>Need good adhesion and continuous film</td>
<td>Porous surface</td>
<td>Need good adhesion and continuous film</td>
<td>Need reactive site (OH) with alkoxy poly mers</td>
<td>Need reactive group (OH) on the surface</td>
</tr>
<tr>
<td>Solvent</td>
<td>None</td>
<td>Hydrocarbon water</td>
<td>Hydrocarbon water</td>
<td>Water</td>
<td>Hydrocarbon</td>
<td>Hydrocarbon</td>
<td>None</td>
</tr>
<tr>
<td>Solvent Compatibility with surface</td>
<td>Not Applicable</td>
<td>Not Compatible</td>
<td>None</td>
<td>Compatible</td>
<td>Not Compatible</td>
<td>Not Compatible</td>
<td>Compatible</td>
</tr>
<tr>
<td>UV Stability</td>
<td>Not Stable</td>
<td>Not Stable</td>
<td>Not Stable</td>
<td>Stable</td>
<td>Not Stable</td>
<td>Somewhat Stable</td>
<td>Stable</td>
</tr>
<tr>
<td>Accelerated Abrasion test</td>
<td>Fails</td>
<td>Fails</td>
<td>Fails</td>
<td>Fails</td>
<td>Fails</td>
<td>Fails</td>
<td>Fails</td>
</tr>
<tr>
<td>Breathability</td>
<td>Not Breathable</td>
<td>Not Breathable</td>
<td>Not Breathable</td>
<td>Breathable</td>
<td>Not Breathable</td>
<td>Somewhat Breathable</td>
<td>Breathable</td>
</tr>
<tr>
<td>10 Year Stability Test</td>
<td>Loses 99% Protection</td>
<td>Loses 99% Protection</td>
<td>Loses 60% Protection</td>
<td>Loses 99% Protection</td>
<td>Loses 90% Protection</td>
<td>Loses 40% Protection</td>
<td>Loses only 2% Protection</td>
</tr>
<tr>
<td>Depth of Penetration</td>
<td>1 to 3 mm</td>
<td>None</td>
<td>None</td>
<td>1 to 3 mm</td>
<td>None</td>
<td>Less than 0.5 mm</td>
<td>3 to 7 mm</td>
</tr>
<tr>
<td>Vapor Permeability</td>
<td>Permeable</td>
<td>Not Permeable</td>
<td>Not Permeable</td>
<td>Permeable</td>
<td>Not Permeable</td>
<td>Somehow Permeable</td>
<td>Permeable</td>
</tr>
<tr>
<td>Alkaline Resistance</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Resistance to Biological Growth</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Good for 3 to 5 years</td>
<td>Good for 3 to 5 years</td>
<td>Excellent 10+ years</td>
</tr>
<tr>
<td>Durability</td>
<td>Less than 2 years</td>
<td>Less than 3 years</td>
<td>Less than 5 years</td>
<td>Less than 1 year</td>
<td>Less than 5 years</td>
<td>Less than 5 years</td>
<td>More than 20 years</td>
</tr>
</tbody>
</table>

The data clearly suggests that Silane water repellent technologies offer optimum long-term performance. Silanes and Silane / Siloxanes are recognized as a new class of water repellent technology that uses two methods to suppress water intrusion.

Solvent based silane water repellent compounds have been proven to provide long lasting performance and are used widely in USA and Europe. The two alkyl silanes most often used for waterproofing are: (i) isobutyltrialkoxysilane (ii) n-octyltrialkoxysilane.
The silanes used with water repellent technologies are monomeric materials known as alkylalkoxysilane. Alkylalkoxysilane has two types of groups (a) alkyl group, R’ and (b) alkoxy groups, (OR) which are reactive with most cementitious building materials.

Alkyl Group

\[ \text{R'} \quad \text{Si} \quad \text{OR} \quad \text{R} \quad \text{OR} \quad \text{R} \]

Alkoxy Groups

Organosilicon Waterproofing Products

Alkylalkoxysilane

Most cementitious building materials contain hydroxyl (OH) groups. These OH groups can chemically react with alkoxy groups of Silane to form permanent siloxane bonds with the substrate. The alkyl group R’ provides hydrophobicity (water repellency) on the surface. Therefore, these types of products impart water repellency by modifying surface characteristics from hydrophilic to hydrophobic.

Although solvent based silanes can provide superior performance, usage is often limited because of its high cost, flammability and toxicity related to the solvent content limiting its usage to more critical structures.

Recently, Zydex Industries in India developed a water repellent technology known as Zycosil, which provides the four most desired properties (Eco Friendly, Easy to apply, Long lasting, Affordable) based on nano technology. Zycosil provides molecular level hydrophobicity to inorganic substrate and is eco-friendly because it is applied in water solution and the VOC per
applied square meter is less than 20% of solvent based silanes. The product is based on organosilane chemistry; hence it reacts with the inorganic substrate surface and provides service life of 20 to 30 years service.

**Eco-Friendly Water Based Nano Technology – Zycosil:**
Zycosil is an organosilane product, which forms a particle size of 4-6 nm in water and penetrates deep into the building material pores (3-5 mm depth). The product becomes part of the building material and makes it highly water repellent.

The product has shown 4 major attributes:

- **Long Life*** 20+ years
  (*abrasion, UV resistant)
- **Easy to Apply**
- **Affordable**
- **Eco friendly**

- ZYCOSIL has a long expected life of 20 to 30 years, confirmed by weathering test data conducted with ASTM test methods.
- ZYCOSIL is diluted 1:10 or more with tap water, and emits an extremely small amount of organic solvent into the atmosphere, making it eco-friendly and non flammable.
- ZYCOSIL can be applied by brush, spray or roller techniques, making it user friendly.
- ZYCOSIL provides water repellency at a material cost lower than existing technology and products, which can give a similar initial performance.

**Zycosil Treated Substrate Testing**
**Rilem Test:**
The Rilem tube was affixed on the substrate surface. Water was filled up to the 5ml mark. The drop in water level was observed over a 20-minute period. The hydraulic pressure generated on the surface was equivalent to 140 Km/hr wind driven rain.
The water level did not drop for a 24 hour period on the Zycosil treated cement block. The water level of untreated cement blocks dropped to about the 2.5 ml mark after 20 minutes. The Rilem test is also used for water absorption rate. The absorption rate is determined and compared with the untreated samples.

Zycosil treated samples (brick, concrete, cement sheet, plaster, stone, etc.) reduced water absorption rates by over 99%.

**Accelerated weathering:**

Weathering Cycle: The UV exposure was set according to ASTM G-154 (21 hours), followed by rain showers (1 hour) and drying at 110°C (2 hours).

The Zycosil treated samples (Concrete blocks, Bricks, Plaster, Sand stone, and Cement Sheet) have undergone over 80 cycles.

All the Samples retained over 98% of water repellency, after 80 cycles.

**Water uptake test:**

This test was carried out according to ASTM 6489 method. The Zycosil treated samples were weighed to the nearest 0.01 grams, and then placed with treated or exposed surface only, in a tank containing several inches of tap water for a period of 24 hours. The samples were then removed from the water, towel dried and reweighed. The initial and final weights were used to calculate the 24-Hour Treated Water uptake values. These values were compared with the untreated samples.

Zycosil treated samples showed over 90% reduction in water uptake of water.