Nano Technology in Water Proofing Building Materials For achieving goals of Long life, Economical & Eco-friendliness

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Abstract:

Waterproofing of building materials has been a problem since last 1000 years. The problem has not been addressed completely due to lack of understanding at nano level of the building material. The new development in science & technology has allowed using the latest nano technology to produce eco-friendly Organo-Silicon products to waterproof practically all the different kinds of building materials. The nano technology has ensured that service life of this approach will lead to life cycles beyond 20 to 30 years at very economical cost of 4-9 US cents/sq feet

Introduction:

Building materials are known to have water seepage, water leakages due to inherent porosity and micro cracks. Waterproofing is a treatment, which is expected to make the material impervious to water. Lot of technology and product development has taken place in various waterproofing products for the last 50 years, particularly using polymeric backbone and variety of other materials.

Waterproofing:

One of the objectives of waterproofing is to maintain and preserve aesthetics –

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

Another serious issue waterproofing addresses is to prevent loss of structural strength of concrete building materials, particularly due to ASR (alkali silica reaction), acid rain, sulphate attack, etc. It also prevents chloride penetration which can result in corrosion of the reinforced steel bars.

Water related problems – Most of the 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 of the building material easily wet and absorb water in the pores. The size of the water molecule is 0.18 ηm (nanometer 10^{-9} meter i.e. .00018 microns. The size of the pores in most of the building materials, range from 5 to 200 ηm. The size of most of the pollutants like acids, chlorides & sulphates would range between 1 to 2 ηm. Even with the dense concrete and stones the pore size is much larger than water allowing easy entry with the hydrophilic nature of the building material. As the world has started to pay attention to the aesthetics with labour cost going up, the building industry is looking at waterproofing as a mechanism to maintain and preserve look of new buildings. Many products are available in market and the essential requirements waterproofing materials should address are

- Resistance it can impart to water absorption
- Preventing of water soluble salts, particularly chloride salts
- Penetration of waterproofing treatment to a measurable depth
- Non-staining of treated 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

Film Formers:

The economics and the ease of application have led to widespread use of film forming water repellents. The products like acrylic paint, silicon polymers are commonly used in the world for waterproofing application. These film formers have particle size greater than 100 ηm, which will not allow them to penetrate inside the pores of the building materials but form a film covering and preventing 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 continuous film on rough surface is not easy which leads to weak points for film former. All the typical polymer films tend to break down under UV leading to cracking of the films in 2-5 years, which leads to failure in terms of losing of hydrophobicity and water repellency.

Penetrants:

Most penetrants are solvent based, soluble monomeric material with less than 6 ηm size. They 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 material, which coats the pore of the substrates, and provide water repellency. However, these types of materials are also biodegradable and loose hydrophobicity within a year. Additionally, these products also provide food for mold or fungus growth.

The reactive penetrants chemically react with the substrate and provide molecular level hydrophobicity to the treated surface and 3-5 mm deep in the substrate. Therefore, these types of waterproofing products provide protection for a very long period. Additionally, the product is bound chemically on a molecular level to the substrate as a result; weathering (UV radiation) and natural abrasion have virtually no effect and hence very limited effect on the waterproofing characteristics.

Table-1 summarizes the properties of various commercially available waterproofing.

Waterproofing Products Facts Table

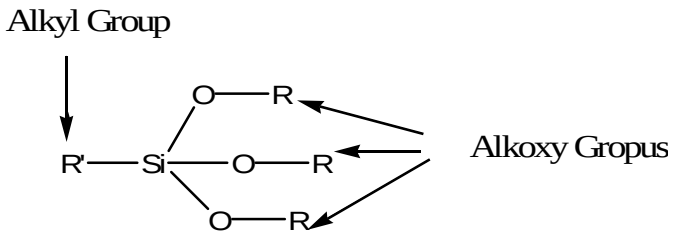
Property	Organic*	Acrylates	Epoxy	Siliconates	Silicone	Silane/Siloxane	Silane
Molecular Structure	Monomeric compounds	Organic Polymer	Organic Polymer	Na salt of Silicylic acid (Sodium silicate)	Polydimethyl silicone Silicone polymer	Mixture, Low molecular weight alkoxysiloxanes and Silane	Alkylalkoxysilane
Particle size (mm)	0.5 – 1.5 **	100 – 1000	100 – 1000	2-5	50 -2000	Siloxane 100-500 Silane 3-5	3-5
Mechanism of Waterproofing	Hydrophobation by organic film	Hydrophobation by coating and closing pores of the substrate	Hydrophobation by coating and closing pores of the substrate	Hydrophobation by silicate formation and tighter packing	Hydrophobation by coating and closing pores of the substrate	Hydrophobation by changing surface property by reacting with surface and provide some penetration	Hydrophobation by changes surface property by chemical bonding with the polar groups of the substrate surface
Requirements	Need wetting of the surface	Need good adhesion and continuous film	Need good adhesion and continuous film	Porous surface	Need good adhesion and continuous film	Need reactive sites (OH) with alkoxypolymers	Need reactive groups (OH) on the surface
Solvent	None	Hydrocarbon water	Hydrocarbon	Water	Hydrocarbon	Hydrocarbon	None Alcohol Water
Solvent Compatibility with Surface	Not Applicable	Not Compatibles	None	Compatible	Not Compatible	Not Compatible	Compatible
UV stability	Not Stable	Not Stable	Not Stable	Stable	Not Stable	Some what Stable	stable
Accelerated Abrasion test	Fails	Fails	Fails	Fails	Fails	Fails	Passes
Breathability	Not breathable	Not breathable	Not breathable	Breathable	Not breathable	Some what breathable	Breathable
10 Years Stability test	Looses 99 % Protection	Looses 99 % Protection	Looses 60 % protection	Looses 99 % Protection	Looses 90 % protection	Looses 40 % Protection	Looses only 2% protection
Depth of Penetration	1-3 cm	None	None	1-3 cm	None	Less than 0.5 mm	3-7 mm

Vapor Permeability	Permeable	Not permeable	Not permeable	Permeable	Not permeable	Some what permeable	Permeable
Alkaline Resistance	Poor	Poor	Poor	Poor	Good	Good	Excellent
Resistance to Biological Growth	Poor	Poor	Poor	Poor	Good for 3-5 years	Good for 3-5 years	Excellent 10 + years
Durability	Less than 2 years	Less than 3 years	Less than 5 years	Less than 1 years	Less than 5 years	Less than 5 years	More than 20 years

The data clearly suggests that Silane based waterproofing products are desirable for long-term performance. Silanes and Silane/Siloxanes are known as new class of waterproofing products. These products are used in USA and Europe for last 30 years. However only last few years they became available in India.

The solvent based silane waterproofing compounds are proven to provide long lasting performance and are used very widely in USA and Europe. The various alkyl silanes that are used for waterproofing are (i) isobutyltrialkoxysilane (ii) n-octyltrialkoxysilane.

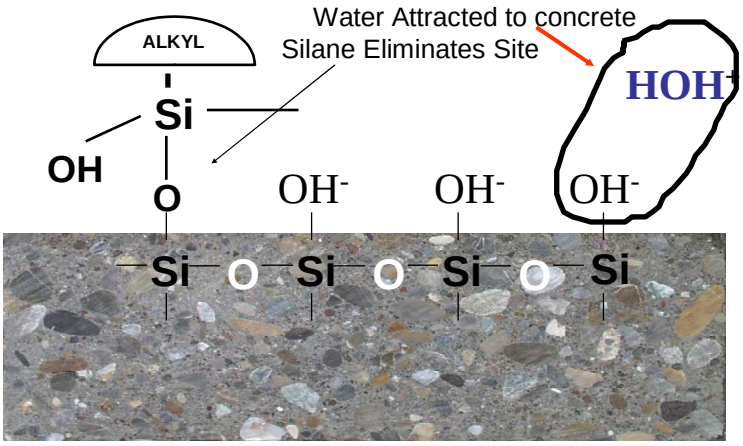
Silanes are monomeric materials. The products used for waterproofing are known as alkylalkoxysilane. Alkylalkoxysilane has two types of groups (a) alkyl group, R' and (b) alkoxy groups, OR, which are reactive to the most building materials.



Organosilicon Waterproofing Products
Alkylalkoxysilane

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

Reactive Silanes Cap Off Silanol Sites



Beside superior performance silanes, usage is limited on a worldwide basis because of high cost 35 to 60 US cents per sq.ft. Also, solvent's flammability and toxicity imposes limitations to easy applications.

Recently Zydex Industries in India has developed a waterproofing product that is known as Zycosil which provides all three most desired properties. It is based on nano technology; it provides molecular level hydrophobicity to inorganic substrate. It is eco-friendly, because it is applied in water solution and VOC per applied M^2 is less than 20%compared to solvent based silanes. The product is based on organosilicon chemistry, hence reacts with the inorganic substrate surface and provides long service life of 20-30 years.

Eco-Friendly Water Based Nano Technology – Zycosil:

Zycosil is an organosilicon product, which forms a particle size of 4-6 ηm in water and penetrates deep into the building material pores 3-5 mm. The product becomes part of the building material and makes it highly water repellent.

The product has shown 4 major attributes:

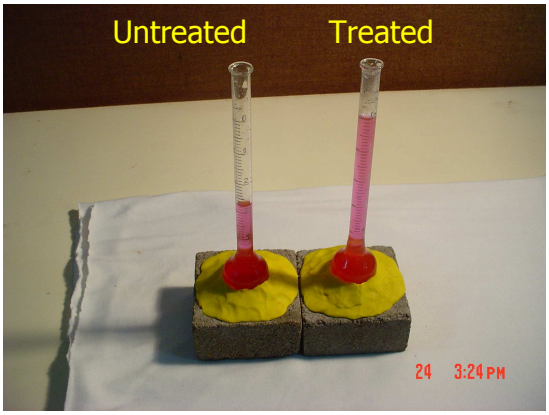
- It is a long expected life of 20 to 30 years confirmed by weathering test data by ASTM methods.
- It is diluted 1:10 and more with tap water and emits extremely small amount of organics in the atmosphere making it eco-friendly.

- The product can be applied by brush, spray or roller techniques makes it user friendly.
- The product will be providing water repellency at a material cost of US cents 4 to 9 per sq.ft.
- The product is non flammable

Zycosil Treated Substrate Testing

Rilem Test

The Rilem tube was affixed on the substrate surface. Water was filled up to 5ml mark. The drop in water level is 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 24 hours for Zycosil treated cement block. The water of untreated cement blocks level dropped to about 2.5 ml mark after 20 minutes.
The Rilem test is also used for water absorption rate. The absorption rates is determined and compared with the untreated samples.

Zycosil treated samples (brick, concrete, cement sheet, plaster, stone ,sand, gravel 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 ^{o}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 80cycles

Water uptake test

This test is carried out according to ASTM 6489 method. The Zycosil treated samples were weighed to the nearest 0.01 grams, and then placed treated or exposed surface only, in a tank containing several inches of tap water for a period of 24 hours. The samples 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 sample showed over 90 % reduction in water uptake of water.