

Durability of Cement based Building Materials

ABSTRACT

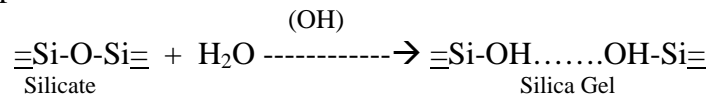
Cement based building material undergo destructive chemical reactions. Some of the reactions involve water as reactant. However in the majority of the reactions water acts as a solvent and the reaction medium. These materials can be protected from intrusion of water by various waterproofing technology. Selection of the technology that provide long term protection is essential. Film former or barrier technology (coating) has been used very widely. However due to weathering and UV exposure the coating has limited life (3-5 years) and periodic reparative applications are required. Only organosilane based technology is appropriate for long term protection.

INTRODUCTION

The building materials mostly based on cement. These include Reinforced Concrete, Mortar, Cement Plaster, Cement Building Blocks, Cement Roofing Sheets, Cement Pipes, etc. Durability of these materials depends on weathering and environmental factors. Field experience with deterioration suggested that major cause for deterioration is chemical in nature. Cementitious material undergoes chemical reactions due to weathering and environmental factors. These can be summarized as follow:

ASR (Alkali-Silica-Reaction)

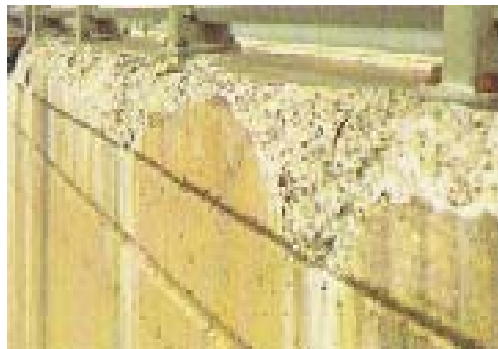
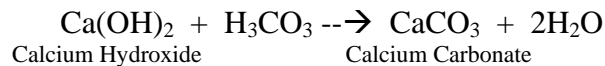
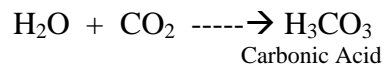
Normal cement based building materials are very basic in nature (pH over 13). This is due to presence of $\text{Ca}(\text{OH})_2$. The major component of the concrete structure is Silicate bond (Si-O-Si). Silicate bond can under go chemical reaction with water in highly basic environment. As a result, Si-O-Si bond converts in to two Silanol groups (Si-OH). The silica containing Si-OH is known as Silica Gel. Silica Gel has four times volume than normal Si-O-Si containing material and imparts additional pressure. As a result, concrete develops cracks. Additionally silica gel absorbs more water than the parent materials and accelerates ASR reactions.



ASR Cracks Formation

Carbonation

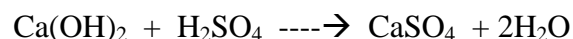
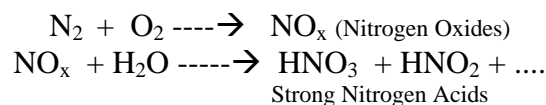
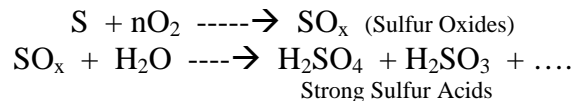
Carbonation is considered natural decaying process of the cementitious material. Air contains carbon dioxide. When water dissolves carbon dioxide, it becomes acidic because of the formation of Carbonic acid (H_2CO_3). Carbonic acid can react with $\text{Ca}(\text{OH})_2$ of the cementitious material and generates CaCO_3 . This reaction decreases pH of the material. When pH reaches close to 8, then almost all $\text{Ca}(\text{OH})_2$ is replaced with CaCO_3 . $\text{Ca}(\text{OH})_2$ is crystalline strong material and it is replaced by amorphorous CaCO_3 . The life expectancy of any concrete structure is determined by the carbonation reaction rates.

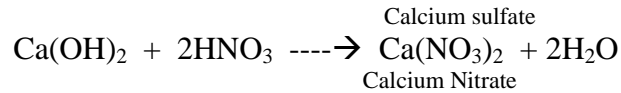


Concrete Aging (Carbonation)

Acid Rain

Most acid rain is caused by environmental factors. Burning of fossil (natural oil based) fuel (automobile and power plants) can generate sulfur oxides and nitrogen oxides. These oxides combining with water (during rain) form sulfuric and nitric acid. These are two very strong acids. These acids can react with any basic material that include, all cementitious material, sand stone, brick etc. For concrete material, the reaction with $\text{Ca}(\text{OH})_2$ can form $\text{Ca}(\text{NO}_3)_2$ and CaSO_4 . These are salts and much weaker material then crystalline $\text{Ca}(\text{OH})_2$. Acid rain has special effect in India. In India monsoon season appears once a year (last for 3-4 months). Rest of the year is completely dry. These pollutants accumulate in the atmosphere. Therefore the first rain shower water is most acidic and most damaging to the building material.

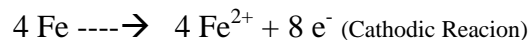




Acid Rain Corrosion Building Materials

Corrosion of Steel in Reinforce Concrete

Corrosion steel in reinforced concrete creates serious structural problems. Corrosion of steel is an electrochemical process. In this reaction, Fe (steel) loses electrons and Oxygen (O₂) gains these electrons. Fe is oxidized and Oxygen is reduced. These reactions require electron transport medium. If concrete is wet, water provides required electron transport medium. Therefore water is essential for corrosion to start. The other important factor is the presence of Chloride. Chloride is always present in concrete. Additional chloride is induced by rain water particularly in the coastal area. Steel bar in the concrete has iron oxide layer which is known as passivation layer. This layer protects steel from further corrosion. However if this layer gets wet, the oxide becomes hydrated iron oxide which is chemically more reactive. Water intrusion in concrete also provides migration of chloride to steel bar. These Chlorides react with hydrated iron oxide and exposes the steel for further corrosion. The overall reaction does not involve Chloride. Therefore chloride acts as a catalyst. Free chlorides continue promoting corrosion until steel structure is converted to rust.



Corrosion Electro-Chemical Process



Corrosion Epoxy Coated Steel

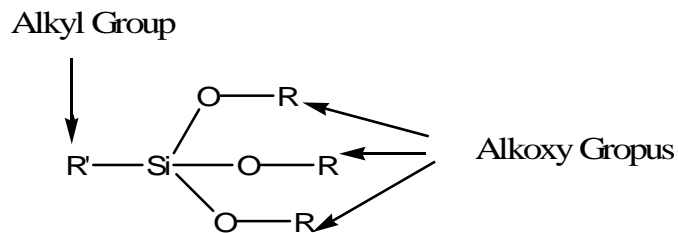
Corrosion Reinforced Concrete

Conclusion

The durability of Concrete structures depends on extent of destructive reactions occurs during the life cycle of the structure. All these reactions require water as reactant or as reaction medium. If intrusion of water is reduced then these reactions can be minimize and durability of the structure can be increased. Therefore it is important to protect cementitious material from water.

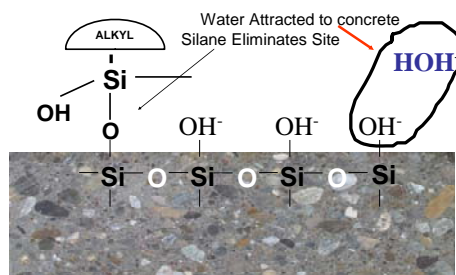
Solution

The technology that provides long lasting protection from water and salt, is based on Organosilane chemistry. Organosilane compounds are only reactive and penetrative material that provides logitivity to the structure. The Silane molecule reacts with surface –OH groups and alters surface property from hydrophilic (water loving) to hydrophobic (water repellent). This technology is known for over 40 years. However, because it is a solvent based technology and relatively expensive, wide spread use did not materialized.



Organosilicon Waterproofing Products
Alkylalkoxysilane

Reactive Silanes Cap Off Silanol Sites



Zycosil developed by Zydex Industries, Vadodara, Gujarat, is an organosilane water soluble product. This product is reactive to cementitious surface similar to solvent based organosilane products. Additionally because of its nano size particles (3-6 nM), penetrates inside the pores of the substrates. The longitivity of the product performance is due to reactivity with the substrate and the depth of penetration.

Zycosil Product

Zycosil is a new generation of nano technology, which has been developed for waterproofing having UV resistance, thermal resistance and has an ability to withstand the wind erosion due to its nano-size and penetrative power. Zycosil development has kept the eco issues in mind. This is the first water based nano technology, which means it meets all the toughest VOC standards. Zycosil is diluted in water and forms a water clear solution which can be applied to both new and existing concrete and masonry structure by simple spray, brush or roll application. Zycosil chemically binds to the concrete and masonry surface and once dried orient itself to give perfect barrier properties for the incoming water. The conventional coating based film forming chemistry tend to trap moisture inside the substrate which leads to the failure of paint film inside the building. Zycosil chemical bonding to allow the structure to breathe and would not expect the paint to peel off maintaining the strength of the building for a long time. Zycosil being chemically reactive to mineral based building material would not leach out due to repeated rains. It has a unique composition, which is resistant to UV degradation and penetrates deep enough at low concentration to give economical & effective protection.

Test Results

(1) ACCELERATED WEATHERING

The samples were treated with Zycosil (1part Zycosil with 10 part water).
The weathering test was carried out using a UV chamber.

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

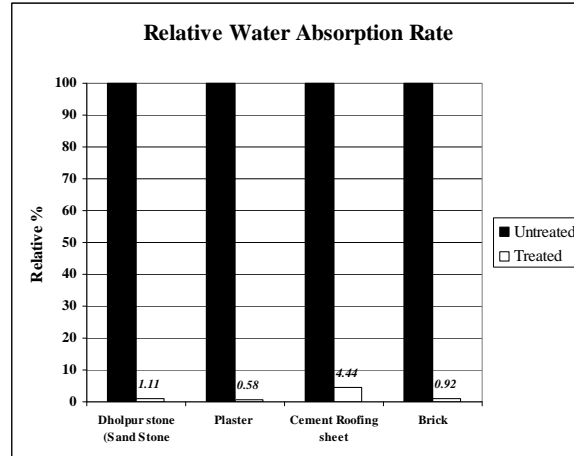
The samples, Concrete blocks, Bricks, Plaster, Sand stone, and Cement Sheet have undergone over 90 cycles.

All the Samples retained over 98 % of water repellency, after 90 cycles. This is equivalent to over 20+ years performance.

(2) Water absorption rate

The samples were treated with Zycosil (1part Zycosil with 10 part water).

These tests were carried out using RILEM Test Method II.4. The RILEM tube was affixed on the substrate surface. Then water is filled to 5-ml mark. The rate of water absorption is measured. The hydraulic pressure generated on the substrate surface is equivalent to 140 KM/Hr. wind driven rain.



(3) Water immersion Test

The 24 and 48 hours immersion test (ASTM D6489) for concrete (M-35) showed over 90 % reduction on absorption of water.

These test results are also confirm by Independent Laboratory (SETSCO) in Singapore.

APPLICATIONS

- New Buildings
- Existing / Old Buildings
- Coastal Areas
- Cement Roofing Sheets
- Concrete Paved Area
- Clay Articles / Tiles / Pots
- Stones
- Exposed Bricks

COMMERCIAL APPLICATION AREA

- Cooling Tower
- Waste Water Treatment Facility
- Cement Concrete Pipes
- Bridges
- Rail Road Sleepers
- Flyovers
- Tunnels
- Marine Piers
- Docks
- Ship Yards

