Evaluation of Durability Aspect of Concrete Treated with Organosilane Compound

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Abstract-*Experimental study on the effect of organosilane compounds on sorptivity, acid resistance and chloride resistance characteristics of concrete has been carried out. Various concrete grades like M15, M20, M25 and M30 are prepared with variation in organosilane concentration as 0%, 0.25%, 0.50% and 1.00%. Concrete is allowed to cure for 28 days and tested for capillary rise through sorptivity. Acid resistance of concrete is tested by placing specimens 1% sulphuric acid (H_2SO_4) solution for 28 days. And chloride resistance of specimens is done according to NordTest NT Build 443.*

***Key Words*: Concrete, Organosilane Compound, Durability, Sorptivity, Acid Attack, Chloride Attack.**

1. INTRODUCTION

Silanes— They are silicon compounds consisting of one or multiple silicon atoms linked to each other or one or multiple atoms of other chemical elements as the tetrahedral centers of multiple single bonds. Silane compounds will include silicon atoms with four valences.

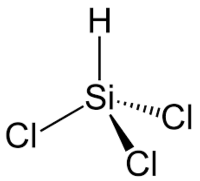

Fig 1: Silane

Any organic derivative of a silane containing at least one carbon to silicon bond is called organosilanes.

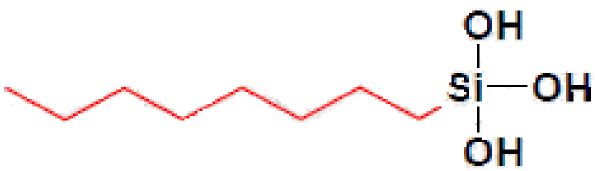

Fig 2: Hydrolyzed Organosilane

$$SiO_2 + 2C \text{ (coke)} \rightarrow Si + 2CO$$

Silicone obtain in the above process is reduced by chlorine in the presence of hydrogen gas.

$$Si + Cl_2 + H_2 \rightarrow HSiCl_3 \text{ (Trichlorosilane)}$$

Trichlorosilane is then reacted with allyl chloride to form 3-chloropropyltrichlorosilane

$$HSiCl_3 + Cl\text{-}CH_2\text{-}CH{=}CH_2 \rightarrow Cl_3\text{-}Si\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}Cl \text{ (3-chloropropyltrichlorosilane)}$$

$$Cl_3\text{-}Si\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}Cl + CH_3\text{-}OH \rightarrow CH_3\text{-}CH_2\text{-}CH_3\text{-}Si\text{-}(OH)_3 + HCl$$

The final product obtained is our required organosilane compound for waterproofing.

2. MATERIALS

The raw materials that were used to prepare the various grout mixes are mentioned below:

A. Cement:

Ordinary Portland cement (OPC) of 53 grade was used to prepare concrete confirming to IS:10262-2009.

B. Sand:

Specific gravity of sand used is 2.65 with Zone II gradation confirming to IS:383-1970.

C. Aggregate:

Specific gravity of aggregate used is 2.70 with nominal maximum size of aggregate as 20 mm confirming to IS:383-1970.

D. Water:

The normal tap water was used for the mixing and curing of the concrete.

E. Organosilane:

Chemical is a clear pale yellow liquid with specific gravity of 1.05. Received from Tawata Technologies. Chemical has a flash point of about 90⁰ C. The chemical is easily soluble in water.

3. PROPORTIONS

The concrete mix is prepared according to concrete mix proportioning guidelines IS:10262-2009. Various concrete grades prepared were M15, M20, M25 and M30 and their proportioning is shown in Table 1.

Table 1 Mix Proportions of Concrete

Concrete Grade	Cement	Sand	Aggregate	Water
M15	1.00	2.12	3.56	0.57
M20	1.00	1.83	3.04	0.50
M25	1.00	1.73	2.82	0.47
M30	1.00	1.57	2.61	0.44

For each mix design 4 variations, one control and 3 different variation of organosilane dose namely 0.25%, 0.50% and 1.00% of weight of cement are used.

After 24 hours of casting specimens are submerged in curing tank and allowed to be cured for a total period of 28 days. After curing specimens are taken out of curing tank and immersed in 5% organosilane solution for surface saturation.

4. EXPERIMENTAL PROGRAM

4.1 Sorptivity Test

The sorptivity of concrete is performed according to ASTM Standard: C 1585 – 04. The sorptivity of concrete is a quantity that measures the unsaturated flow of fluids into the concrete [Hall, 1989]. Sorptivity is a measure of the capillary forces exerted by the pore structure causing fluids to be drawn in to the body of the material.

For one dimensional flow, it can be stated that[Hall, 1989]:

$$i = St^{1/2}$$

Where 'i' is the cumulative water absorption per unit area of inflow surface, 'S' is the sorptivity and 't' is the elapsed time. In a lab situation where the concrete sample can be dried consistently and the flow conditions can be well defined, is it relatively easy to get a good fit line using least squares regression when plotting 'i' vs. the square root of time.

The sides of the concrete sample are sealed, typically with electrician's tape. The initial mass of the sample is taken and at time 0 is immersed to a depth of 5-10 mm in the water.

Fig 3: Sorptivity Test Setup

At selected times (typically 1, 3, 5, 10, 15, 20, 25, 30, 45, 60, 90, 120, 150, 180 minutes) the sample is removed from the water, the stopwatch stopped, excess water blotted off with a damp paper towel and the sample weighed.

The gain in mass per unit area over the density of water is plotted versus the square root of the elapsed time. The slope of the line of best fit of these points (ignoring the origin) is reported as the sorptivity. Results for M15, M20, M25 and M30 are shown in Fig 4, Fig 5, Fig 6 and Fig 7 respectively.

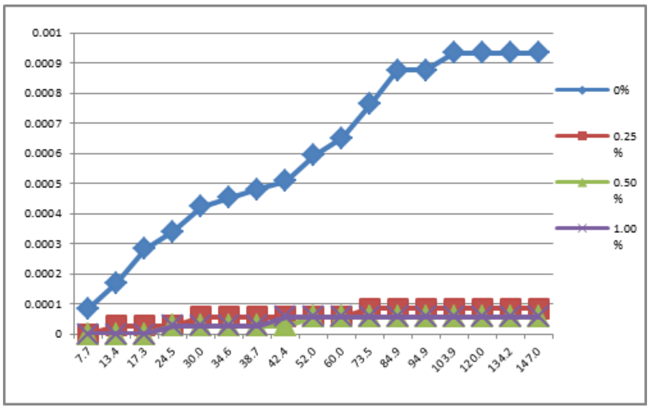

Fig 4: Sorptivity Test: M15

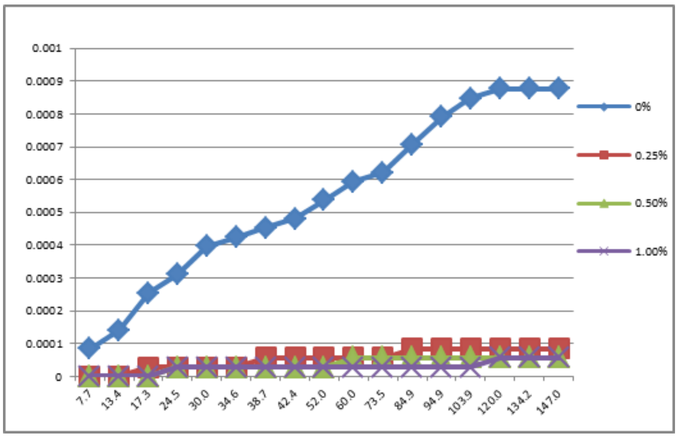

Fig 5: Sorptivity Test: M20

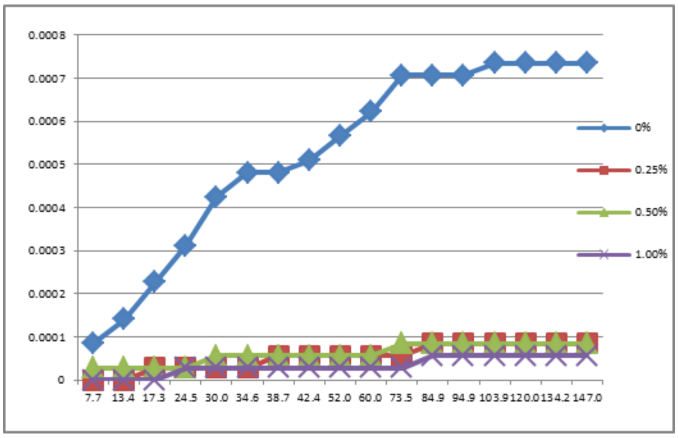

Fig 6: Sorptivity Test: M25

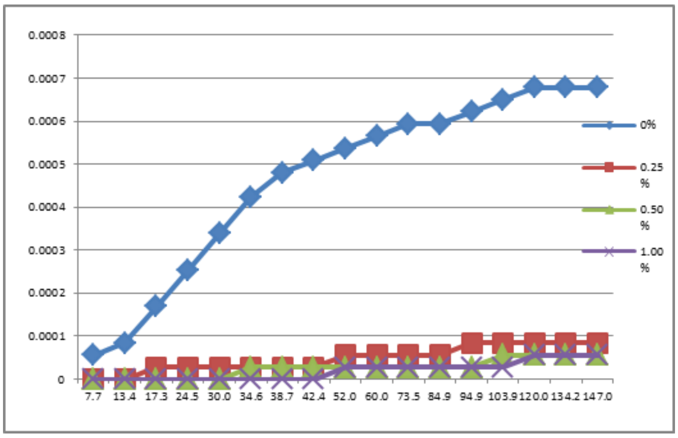

Fig 7: Sorptivity Test: M30

Sorptivity values inferred from the graph for M15, M20, M25 and M30 are 60.9 x10^{-6} mm/$s^{1/2}$, 5.68 x10^{-6} mm/$s^{1/2}$, 4.67 x10^{-6} mm/$s^{1/2}$ and 4.46 x10^{-6} mm/$s^{1/2}$ respectively. Whereas for all the other cases, sorptivity value obtained is almost neglible or nearly zero.

4.2 Sulphuric Acid Attack

In this test 1% concentration of Sulphuric Acid solution should be prepared according to ASTM standards (C 1012 – 04). Each liter of solution shall contain 10.0 g of H_2SO_4. Solution should be first dissolved in 100 mL of water, and shall be diluted with additional distilled or de-ionized water to obtain 1000 mL of total of solution. Samples are placed in sulphate Sulphuric Acid 28 days.

Fig 8: Curing of Specimen in Sulphuric Acid (day 0)

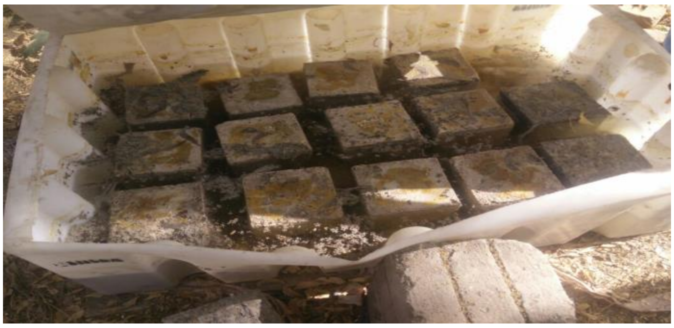

Fig 8: Curing of Specimen in Sulphuric Acid (day 28)

After sulphuric acid curing is completed, samples are taken out and loose material is brushed off from the surface. Then the sample is weighed. Difference in weight is calculated and compared with samples that are not undergone sulphate curing. This process will provide us complete idea of resistance of treated and untreated concrete to Sulphate Attack.

Fig 9: Degradation of Specimen after Acid Curing

Reduction in mass for M15, M20, M25 and M30 is shown in Table 2.

Table 2 Percentage Decrease in Mass

Organosilane Concentration	% Decrease in Mass			
	M15	M20	M25	M30
Control (0%)	2.32	2.45	2.14	2.14
0.25%	2.18	2.07	2.04	1.93
0.50%	2.06	1.92	1.84	1.68
1.00%	1.96	1.69	1.59	1.44

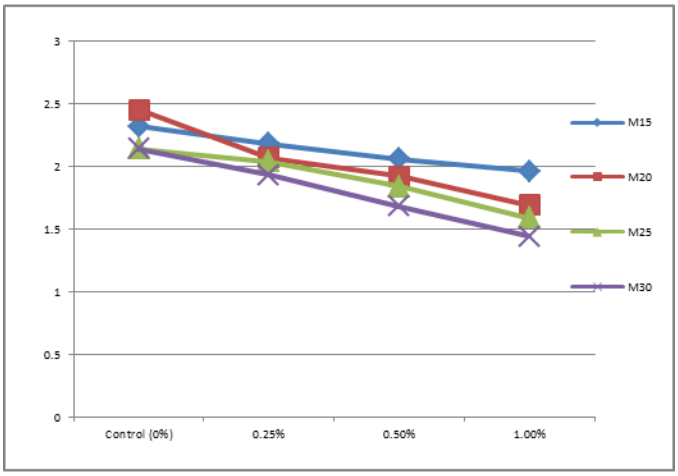

Fig 10: Percentage Decrease in Mass

4.3 Bulk Diffusion Test

Chloride resistance of concrete is checked according to bulk diffusion test (NordTest NTBuild 443). According to this test specimens are placed in 2.8M NaCl solution for 28 days.

Fig 11: Specimens Placed in 2.8M NaCl Solution

After 28 days of curing specimens are taken out and allowed to dry for about 4 hours. Then the specimens are splitted in two halves by placing it vertically in compression testing machine.

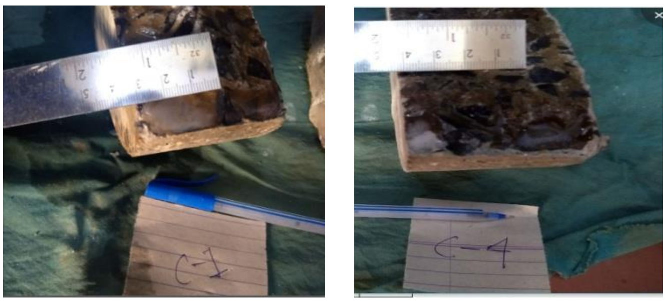

Fig 12: Specimens treated with $AgNO_3$ Solution

After splitting the inside part of specimen is treated with $AgNO_3$. As $AgNO_3$ gives white precipitate in the presence of chloride ions.

$$NaCl(aq) + AgNO_3(aq) = AgCl(\text{white ppt}) \downarrow + NaNO_3(aq)$$

Fig 13: Specimens treated with $AgNO_3$ Solution

Depth of chloride penetration for M15, M20, M25 and M30 is shown in Table 3.

Table 3. Depth of Chloride Penetration

Organosilane Concentration	Depth of Chloride Penetration(in mm)			
	M15	M20	M25	M30
Control (0%)	20	18	15	15
0.25%	5	5	7	3
0.50%	5	3	3	0
1.00%	3	0	0	0

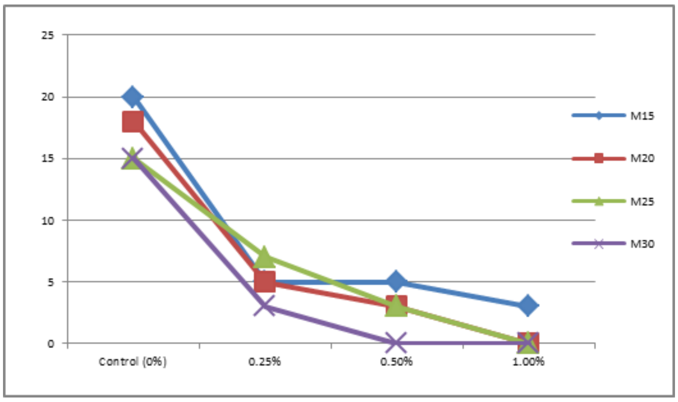

Fig 14: Depth of Chloride Penetration (in mm)

5. CONCLUSIONS

- Organosilane molecule reacts with hydroxyl groups inside the concrete. But concrete will become hydrophobic only in the absence of moisture. So, until the concrete is wet it will not become hydrophobic.
- Because of above property curing of concrete is not affected and concrete gains strength naturally. And once the curing process is complete concrete is allowed to dry and it becomes hydrophobic.
- Organosilane compound stops the capillary rise of water in concrete as inferred from Fig 4, Fig 5, Fig 6 and Fig 7.

- Hence, organosilane compound helps in increasing durability of concrete having one of the surface in contact with water by decreasing capillary rise in concrete.
- Concrete treated with organosilane compound have grater resistance to acid attack as inferred from Table 2.
- This property makes Organosilane concrete more suitable for aggressive industrial environment.
- Resistance of chloride migration of concrete is obtained in Table 3 according to bulk diffusion test. Results show that concrete treated with organosilane compound has more resistance to chloride migration.
- Above property makes concrete suitable for aggressive coastal environment where deterioration of concrete and corrosion of reinforcement due to sodium salts are major problem.

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