Novel Technique of Sodium Silicate in Healing of Concrete

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Abstract— Self-healing of concrete is done by using many things such as bacteria, polymers etc. In this project we have tried the self-healing of concrete by using chemicals. The chemicals are sodium silicate, and polyethylene glycol. Here the sodium silicate will acts as healing agent which is replaced directly to the water. Polyethylene glycol is used to increase the compressive strength and mainly for self-curing of concrete. It is added to the water of about 2% on both combinations. The sodium silicate that are added will reacts calcium hydroxide and forms sodium silica hydrate which is a gel, that has the capacity to heal the cracks and increase its strength up to 30%. In this experimental study we have analysed that the sodium silicate heals the crack completely and also increases strength in both self and water curing. Here the water curing is done in addition to polyethylene glycol. The obtained sodium silica hydrate is used to heal the cracks and the formed calcium silica hydrate heals the crack and also acts as corrosive inhibitor.

Key words: Sodium Silicate, Polyethylene Glycol, Calcium Silica Hydrate, Sodium Silica Hydrate, And Cracks Up To 2mm

I. Introduction

Concrete plays a major role in the construction industry. For a durable structure, good quality concrete must be used. In the life cycle of a structure, concrete and stone gets affected by physical, chemical and environmental factors. Concrete structures are affected by cracking, spalling, etc. The cracks are formed by thermal expansions, external loads, temperature variations and other environmental factors.

Fig. 1: Cracks formed in structure

A. *Types of Cracks in Buildings*

Structural cracks occurs during incorrect design, faulty construction or overloading (this is common where property owners carry out modification to buildings or even load building with additional floors without consulting with professionals) and this may endanger the safety of a building. Example. Extensive cracking in RCC beam.

Non-structural cracks are mostly due to internally induced stresses in building materials and might not at a first endanger safety of a building but may look unsightly or may create an impression of faulty work or may give a feeling of instability. Vertical crack in a long compound wall due to shrinkage or thermal movement.

B. *Causes of Cracks*

Permeability is defined as the property that governs the rate of flow of a fluid into a porous solid. Thermal movement includes thermal expansion andcontraction of the concrete. In thermal movement temperature is a monotonic function of the average molecular kinetic energy of a substance. When a substance is heated, the kinetic energy of its molecules increases. Concrete Creep is defined as the deformation of structure under sustained load. It includes poor quality of materials and poor workmanship during the construction of a concrete structure. It’s always important to take good care of your building, by doing maintenance works after a lapse of certain periods. The soil is the most important material in the highest varying property in a building construction, same type of soil can change from solid to almost a liquid because of change in moisture content. Lack of or poor structural design and specifications is another cause of cracks in the building. It’s important that the designers consider all the environmental aspects that include soil investigations that will enable the designer to come up with a proper design of foundation.

Roots of tree generally spread horizontally on all sides to the extent of height of the trees are located in the vicinity of a wall, they can cause cracks in the building due to expansion action of roots growing under the foundation. Sometimes plants can begin to grow in fissures of walls, because of seeds contained in bird drooping or carried by wind or other means. If these plants are not removed well in time, these may in course of time develop and cause severe cracking of wall.

II. Experimental Study

The reaction that we are trying to attain here is as follows

$NaSio_2$ + $Ca(OH)_2$ → $(CaO \cdot SiO_2) \cdot H_20$ + Na
Sodium Silicate   calcium hydroxide   Calcium Silica hydrate C-S-H Gel

$Na_2O \cdot SiO_2$ + $Ca(OH)_2$ → $(Na_2O \cdot SiO_2) \cdot H_20$
anhydrous Sodium Silicate   calcium hydroxide   Sodium Silica hydrate N-S-H Gel

A. *Materials Used*

Grade of Concrete – M30
Cement – Ordinary Portland cement of 53 grade
Fine Aggregate – Zone I sand as used for general construction
Coarse Aggregate – Size greater than 4.75mm

B. *Results from Test Undergone For Materials*

Fineness modulus of cement = 10 %
Specific gravity of cement = 3.15
Specific gravity of fine aggregate = 2.55
Specific gravity of coarse aggregate =2.65

C. *Chemicals Used*

Sodium silicate
Polyethylene Glycol (PEG)

Chemicals	Cube (mi)	Cylinder (ml)	Prism (ml)
Sodium Silicate	22.8	37.8	33.75
Poly Ethylene Glycol	22.8	37.8	33.75

Table 2 Quantity of Chemicals

Here sodium silicate is used for its healing property and also to increase the strength of the concrete, whereas PEG is used for self-curing and to make the concrete stable which has the range of 400.

Fig. 2: Sodium Silicate

Fig. 3: Polyethylene Glycol

C. Properties of Sodium Silicate

- Sodium silicate in a liquid state is preferred in this type of experiment. Here the liquid sodium silicate is colorless and dissolves in water.
- It is one of a number of related compounds like, sodium ortho silicate, sodium pyro silicate, etc. All are glassy, colorless and dissolve in water.
- Sodium silicate is stable in neutral and alkaline. In acidic solutions, the silicate ion reacts with hydrogen ions to form silicic acid, which when heated and roasted forms silica gel, a hard, glassy substance.

D. Properties of Polyethylene Glycol

Chemical formula - $C_2nH_4n+2On+1$, n = 8.2 to 9.1
Molar mass - 380-420 g/mol
Density - 1.128 g/cm3
Melting point - 4 to 8 °C (39 to 46 °F)
Viscosity - 90.0 cSt at 25 °C, 7.3 cSt at 99 °C

E. Quantity of Chemicals Added

For every specimen Sodium silicate is replaced with water by 2%, and Polyethylene Glycol is added by 2% with water.

III. Mix Design

As per IS 10262: 1982 the result obtained in the calculation of mix ratio is as follows,

Cement	Fine Aggregate	Coarse Aggregate	Water
425 Kg/m^3	508.40 Kg/m^3	1203.53 Kg/m^3	191.6 Kg/m^3
1	1.19	2.03	0.45

Table 3: Mix Ratio of Concrete

A. Casting of Specimens

Specimen	No of Casting		Sizes
	Self Curing	Water Curing	
Cube	12	12	15cm x 15cm x 15cm
Cylinder	12	12	15cm dia x 30cm height
Beam	12	12	10cm x 10cm x 50cm

Table 4: Specifications of Specimens

Fig. 4: Dry mix

Fig. 5: Addition of chemicals

IV. Formation of Cracks

Since the formation of crack is visible externally by naked eye only after couple of years. But here we have made the artificial cracks by applying initial crack load on the specimen by using compression testing machine. And hence the cracks are measured by using demec gauge. Since the chemical sodium silicate has the tendency to heal the crack up to 2mm.

Description	Self Curing		
	Before Mechanism Load (KN)	After Mechanism Load (KN)	% of Increase in Load
Sodium Silicate	557.3 638.2	651.2 763.6	16.8 19.6
Description	Water Curing		
	Before Mechanism Load (KN)	After Mechanism Load (KN)	% of Increase in Load
Sodium Silicate	589.2 518.3	668.3 589.4	13.4 13.7

Table 5: Initial Crack Loads at 7 Days for Cube

Description	Self Curing		
	Before Mechanism Load (KN)	After Mechanism Load (KN)	% of Increase in Load
SS	712.4 696.1	856.5 862.4	20.2 23.8
Description	Water Curing		
	Before Mechanism Load (KN)	After Mechanism Load (KN)	% of Increase in Load
SS	743.6 784.3	868.8 897.2	**16.8** **14.3**

Table 6: Initial Crack Loads at 28 Days for Cube

A. Compressive Strength Test

Compression strength test was undergone by using the cube and cylinder specimens. Compressive strength can be measured by plotting applied force against deformation in a testing machine, such as a universal testing machine.

Description	Self-Curing		Water Curing	
	Ultimat e	Compres sive	Ultimat e	Compres sive

	Load (KN)	Strength (N/mm²)	Load (KN)	Strength (N/mm²)
Sodium silicate	904.2 912.6 905.1	40.18 40.56 40.22	912.4 956.2 961.6	40.55 42.49 42.73

Table 7: Compressive Strength at 28 Days

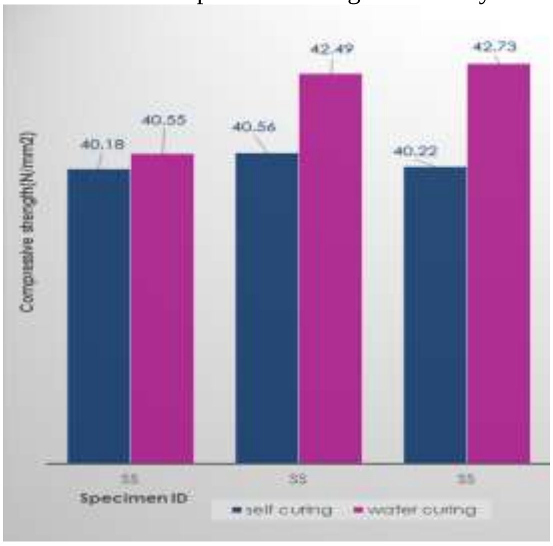

Fig. 6: Results of Compressive Strength Test

B. Splitting Tensile Strength Test

The tensile strength of concrete is one of the basic and important proper-ties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces.

Fig. 7: Splitting Tensile Strength Test

Description	Self Curing		Water Curing	
	Ultimate Load (KN)	Splitting Tensile Strength (N/Mm²)	Ultimate Load (KN)	Splitting Tensile Strength (N/Mm²)
SC	300 328	42.44 46.40	320 340	45.27 48.10

Table 8: Splitting Tensile Strength at 28 Days

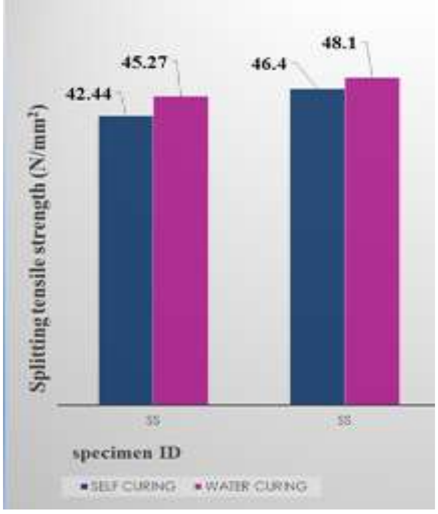

Fig. 8: Results of Splitting Tensile Strength

C. Flexural Strength Test

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, is a material property, defined as the stress in a material just before it yields in a flexure test.

Fig. 9: Flexural Strength Test

Description	Self Curing		Water Curing	
	Ultimate Load (T)	Flexural Strength (N/Mm²)	Ultimate Load (T)	Flexural Strength (N/Mm²)
SS	8.24 7.92	33.95 32.63	8.52 8.37	35.10 34.48

Table 9: Flexural Strength at 28 Days

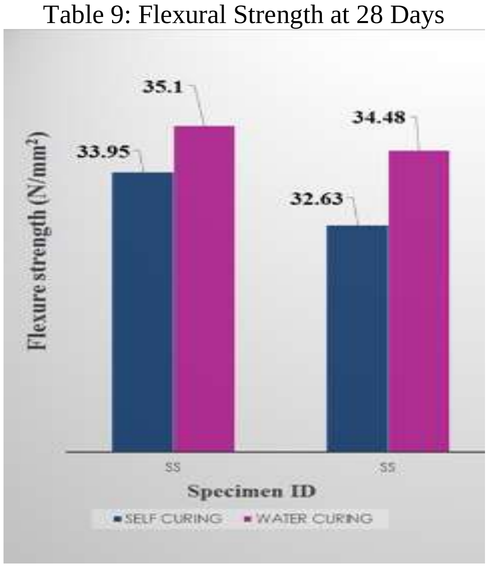

Fig. 10: Results of Flexural Strengths

D. Results of Healing

The below comparison figure shows that the crack made in specimens heals completely and also increases the strength.

Fig. 11: Healing Mechanism of Cube and Cylinders

V. CONCLUSION

- The artificial crack made on specimens heals completely and the intensity of first crack load increases.
- On comparing self-curing and water curing, the self-cured specimens show better performance in 28 days when compared to 7 days.
- On sodium silicate added specimens, it heals the crack by white powdered coating.
- On comparing the compressive strength of specimens the water cured with the addition of PEG possess more when compared to the self-curing specimens.
- The water curing specimens has more splitting tensile strength when compared to self-curing specimens.
- By the comparison of both self and water cured specimens, water curing attains more flexural strength.

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