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EXPERIMENTAL STUDY OF SELF HEALING CONCRETE BY CEMENTATIOUS MATERIAL

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Abstract: The aim of this study is to develop smart concrete capable of self-healing as a method for crack control and enhanced service life of the concrete structure. This concept is one of the maintenance-free methods which, apart from saving direct costs for maintenance and repair reduce the indirect costs a saving generally welcomed by contractors. The application of sodium silicate solution as self -healing agent was investigated in this paper. This system involves a sodium silicate solution stored in glass tube present in the concrete matrix. Point loading was carried out to form a crack on the specimen at the age of 28 days. As tip of the tube got fractured due to the load, result in releasing the sodium silicate. Non-destructive test was conducted to quantify the healing process inside the cube and surface crack width was measured. It was observed that the concrete have shown positive result in regarding the healing of cracks formed in the cube.
Keywords: Self-healing, Sodium Silicate, Un-hydrated cement, autogeneous healing, autonomous healing, NDT test, surface crack.

INTRODUCTION

Cracks, especially micro cracks, are very common and could appear during any stage of the service life of concrete structure. Cracks can be caused by different factors including structural/excessive loading, plastic/drying shrinkage, harsh environmental exposure, poor construction procedures and thermal effects. Due to provide an easy path for the transportation of liquids and gasses which potentially contain harmful substances, cracks may lead to deterioration of concrete and corrosion of reinforcement. Hence, mechanical performance and durability of concrete structures are reduced. In addition, cracking is aesthetically poor. Consequently, large costs are involved in inspection, monitoring, maintenance and repair the cracks of concrete structures every year. Therefore the best way to heal cracks is by triggering a healing mechanism without human intervention upon appearance of the crack, inspection and monitoring are consequently needed no longer or at a reduced frequency. Compared to other engineering materials, concrete is unique because it intrinsically contains micro-reservoirs of un-hydrated cement particles which are widely dispersed and available for self-healing. Self –healing can be achieved by two strategies. One is autogenous healing technique, other is autonomous healing technique. The autogenous healing means that cracks/damages can be naturally sealed by the self of concrete, like a bone to heal. Such healing of micro-cracks is attributed to rehydration of un-hydrated cement particles in concrete matrix. For autonomous healing in self-healing capabilities are achieved by the release of healing material from the agent as a result of cracking from the onset of damage. When cracks happen, the agent containing self-healing compounds within the concrete material break and the healing agent is released to heal the cracks. In this study attempt have been made to experiment with autonomous healing method to verify whether sodium silicate can be used as a healing agent and autonomous method can be achieved.

Materials:

Cement

Cement acts as a binder to join the aggregate into a solid mass. It is one of the most important constituent of concrete. Ordinary Portland cement 53 grade with normal consistency was used in concrete.

River sand

River sand is one of the important constituents in concrete. It gives body to concrete and reduces shrinkage and effects economy.

Coarse aggregates

The maximum size of coarse aggregate should be 20 mm and minimum size should be 10 mm. The coarse aggregate with angular in shape and the rough surface texture is used.

Sodium Silicate

Also known as water-glass or liquid glass, these materials are available in aqueous solution and in solid form. The sodium silicate reacts with calcium hydroxide, a product of cement hydration, and produces a calcium-silica-hydrate (C-S-H) gel – a binding material natural to concrete.

Epoxy Resin

In epoxy resin system, a low viscosity epoxy resin in an organic film pipe that melts at 93°C. Upon formation of a crack, sensed via a strain gauge, there is a reduction in electrical conductivity and hence increased resistance and temperature. This increased temperature melts the organic supply tube and cures the epoxy resin after it has flowed into the crack.

Cyanoacrylates

Commonly known as super glues, cyanoacrylates are a one part system that, in the presence of moisture, react and cure very rapidly forming a bond often stronger than the material it is bonding, i.e. concrete. Hence the healed crack is actually stronger than the surrounding material itself. This system showed that if a system is damaged and healed and then damaged again, a new crack will form around the healed crack. The use of cyanoacrylates in concrete is further enhanced by them being an acidic solution, which due to the concrete's alkaline environment causes yet quicker healing.

Glass tube

The tubes used were made of glass tubes of 16 mm dia. and 125 mm long.

Microcapsule

Microcapsules which are used are known as Polyurethane capsules. Mostly they are in spherical shape with average diameter of 39-72 micro meter and shell thickness of 3.8-5.5 micro meter.

Water

Water is an important ingredient of concrete and it initiates chemical reaction with cement. Ordinary potable water is used. Water also required to trigger polymerization action when sodium silicate comes in contact with water so that crack can be bond together.

METHODOLOGY

Glass tube are embedded in the concrete mix with sodium silicate filled in those tube. When mechanical stress is applied, on the cube after 28 days of casting the tube rupture and release sodium silicate into adequate crack. The sodium silicate reacts with calcium hydroxide, a product of cement hydration, and produces a calcium-silica-hydrate (C-S-H) gel – a binding material natural to concrete. The C-S-H gel (x. (CaO.SiO2).H2O) fills the crack, and allows some recovery of strength. The relevant chemical reactions are shown below:

$$Na2O \bullet SiO2 + Ca(OH)2 \Rightarrow x(CaO \bullet SiO2) \bullet H20 + Na2O$$

$$x(CaO \bullet SiO2) \bullet H20 + Na2O + CO2 \Rightarrow CaCO3 + SiO2 + 2NaOH$$

C-S-H is a complex product that often has varying C/S ratios present and may differ slightly in nanostructure. It has been observed in hydrated cement and is described as a network of nanoparticles. For this application, only the first reaction is considered because the product forms rapidly. It is the newly formed C-S-H gel that will act as a binder and healer in cracks and pores, bridging the gaps in the material and ultimately improving its strength.

The second reaction is based on a much longer time scale (years). Sodium-silica-hydrate (N-S-H) is observed in concrete as a result of the reaction between sodium hydroxide and silica. N-S-H is thought to be analogous to C-S-H but has not been well characterized. Thus, the long-term products initiated by the presence of sodium silicate will still be helpful to the integrity of the concrete.

Concrete Sample:

Samples were prepared with M35 grade of concrete cube with 150*150*150 mm dimension.

Crack Formation:

The crack formation on cube was carried out after 28 days of casting the cube by the help of compressive machine with point loading. The loading was carried out until the tube was break in the cube and the flow of sodium silicate coming out of those crack.

Test on materials:

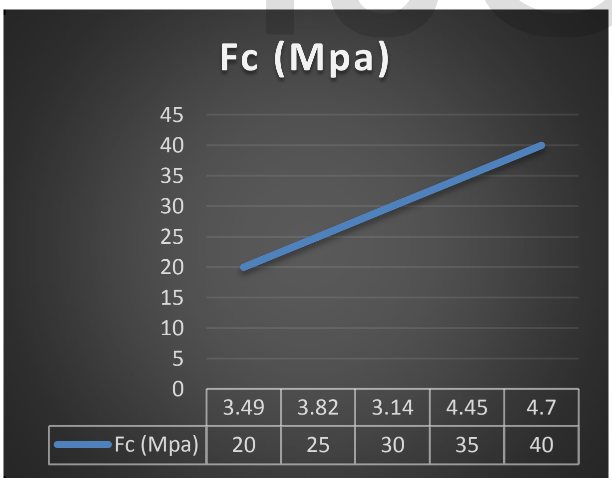
Ultra Sonic Pulse Velocity test:

Ultrasonic pulse velocity method consists of measuring the time travel of an ultrasonic pulse, passing through the concrete to be tested. The pulse generator circuit consists of electronic circuit for generating pulses and a transducer for transforming these electronic pulse. The time of travel between initial onset and the reception of the pulse is measured electronically. The path length between transducer divided by the time of travel gives the average velocity of wave propagation.

The basic principle of crack detection is that, if the depth of crack is small, compared to distances between the transducers the pulse will pass around the end of crack and the signal is received at the line path upon which pulse velocity computations are made.

Co-relation between USPV and Compressive Strength:

Applying the regression analysis method in IS code 1331(part 1) the relation between compressive strength and Ultra sonic pulse velocity test has been developed. From the relevant correlation curves, most likely cube compressive strength of concrete has been obtained.



RESULT

Ultra Sonic Pulse Velocity test:

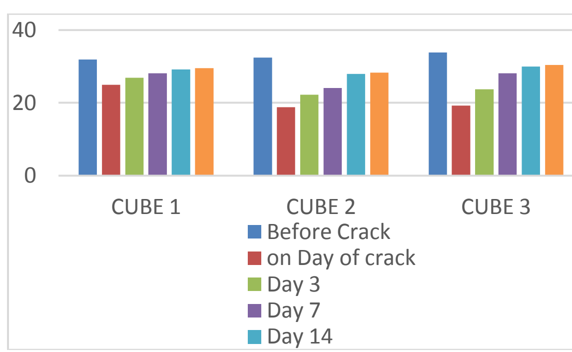
Cube No	grade	Date of casting	Age of concrete	Travel time (micro sec)	Velocity (km/s)
1	M35	3/10/2015	Before crack	35.10	4.27
1	M35	3/10/2015	On day of crack	39.30	3.82
1	M35	3/10/2015	3	38.10	3.94
1	M35	3/10/2015	7	37.30	4.02
1	M35	3/10/2015	14	36.70	4.09
1	M35	3/10/2015	28	36.50	4.11

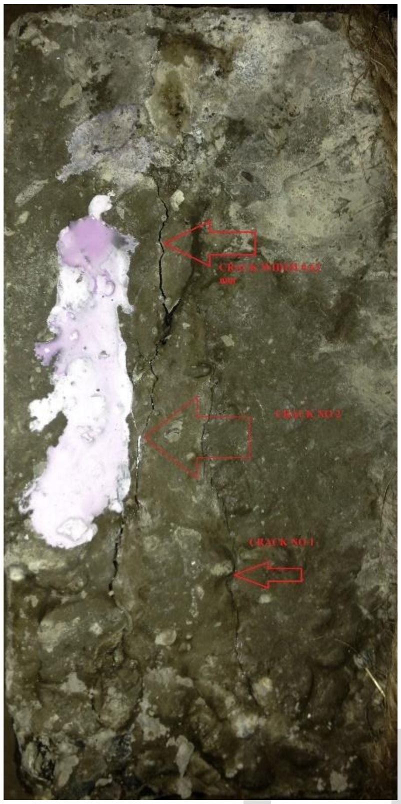
Cube No	grade	Date of casting	Age of concrete	Travel time (micro sec)	Velocity (km/s)
2	M35	3/10/2015	Before crack	34.9	4.3
2	M35	3/10/2015	On day of crack	43.9	3.42
2	M35	3/10/2015	3	41.2	3.64
2	M35	3/10/2015	7	39.9	3.76
2	M35	3/10/2015	14	37.4	4.01
2	M35	3/10/2015	28	37.1	4.04

Cube No	grade	Date of casting	Age of concrete	Travel time (micro sec)	Velocity (km/s)
3	M35	3/10/2015	Before crack	34.20	4.39
3	M35	3/10/2015	On day of crack	43.50	3.45
3	M35	3/10/2015	3	40.10	3.74
3	M35	3/10/2015	7	37.30	4.02
3	M35	3/10/2015	14	36.20	4.14
3	M35	3/10/2015	28	35.10	4.17

Cross probing method was conducted for the test.

USPV and Compressive Strength:





After 7 days

On Day of crack

After 3 days

After 7 days

After 14 days

CONCLUSION

From above result it can be concluded that the use of sodium silicate as healing agent improves the healing properties of concrete.

1. It helps to improve the autonomous property of a concrete.
2. Sodium silicate reacts with calcium hydroxide, a product of cement hydration and produces a calcium-silica-hydrate which is a binding material natural to concrete. C-S-H fill the crack and allow some recovery of strength.
3. The healing of a concrete while using sodium silicate gets slow after 14 days.

Future Scope:

There are different approach for self-healing. However it is Quit difficult to select the most efficient approach as each research group uses its own test method.
In our opinion, development of standard test method would be very useful to compare the efficiency of one approach against another.

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