ISSN No. 0976-5697

VOLUME 13 SPECIAL ISSUE 1, JUNE 2022

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

"Self-Healing Concrete Using Sodium Silicate"

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Abstract: Crack formation is a very common phenomenon in concrete structure which allows the water and different types of chemical into the concrete through the cracks and decreases their durability, strength and which also affect the reinforcement when it comes in contact with water, CO2 and other chemicals. Micro-cracks are formed due to shrinkage and thermal expansion at early age, and due to structural loading or environmental actions while in service. Cracks provide entry points for gas, liquid and deleterious chemicals which pose a significant risk to the safety and serviceability of reinforced concrete structures. To mitigate this hazard, self-healing materials have emerged as a viable solution. For repairing the cracks developed in the concrete, it requires regular maintenance and special type of treatment which will be very expensive.
The aim of this study is to compare the Normal concrete and Special concrete based on sodium silicate in terms of their influence on the original properties of fresh and hardened concrete and functionality. So, to overcome this problem an autonomous self-healing mechanism is introduced in the concrete which helps to repair the cracks by producing Sodium silicate micro encapsulation which blocks the micro cracks and pores in the concrete. Sodium silicate improves the structural properties such as water permeability, durability and compressive strength of the normal concrete which was found by performing different types of experiment.

Keywords: Self-healing,Concrete……..

I. INTRODUCTION

Concrete is second largest material consumed in world. Concrete structures built around the world are subject to a wide range of differing conditions of use and exposure to environmental conditions including, but not limited to, erosion, impact loads, weather, and pollution. These factors, coupled with the quality of construction built into the structure, mean that the time to initial deterioration may vary widely. Protection systems are intended to provide a barrier between the concrete and its environment as well as the operational demands imposed on the structure. The barrier will extend the time to initial deterioration.
They are subject to long-term loading due to their own weight, dynamic loading scenarios including earthquakes, as well as environmental degradation. Concrete structures should undergo inspection and evaluation of their health condition, and proper maintenance actions should be proposed.

Due to cracks providing 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. Consequently, large costs are involved in inspection, monitoring, maintenance and repair of 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. Concrete structures are subjected to various loads during construction and service, and various internal forces and deformations will inevitably occur within the structure. If the strength or stiffness of the structure is insufficient, various damage deterioration phenomena, including cracks, may occur on the surface or inside the structure. Therefore, after a detailed analysis of the structure environment and the establishment of the structure of the overall or local mechanical model, we can do the mechanics analysis of the

structure in various working conditions, and judge, interpret or predict structural cracks, furthermore we can put forward a scientific treatment program. The analysis results can play an important role in eliminating the various structural and mechanical causes leading to cracks. Self–healing can be achieved by two strategies. One is an autogenous healing technique, the other is an autonomous healing technique. 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 unhydrated cement particles in concrete matrix. 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 breaks and the healing agent is released to heal the cracks. In this paper we have focused on Autonomous self-healing. Specifically we have focused on sodium silicate agent based healing. Autonomous type of crack healing in concrete is the type that includes closed capsules (either spherical or cylindrical) that contain a healing agent. When a crack happens, the capsule breaks and the inside agent (like sodium Silicate) fills the crack due to gravitation forces. Generally, this type is called autonomous self-healing. To facilitate the production of self-healing concrete, encapsulated healing agents are preferably added to the concrete mix during preparation.

II. LITERATURE REVIEW

Luciana Restuccia, Anna Reggio (2017) In this paper the author discussed the mechanisms of self-healing concrete. The study shows that new self-healing technology for cement-based materials is proposed. This technology is based on the encapsulation method of repairing agents inserted in randomly distributed shells inside the material during its preparation. Two different kinds of shells were used: glass spheres and pharmaceutical capsules. The material the shells are made of has to be endowed with a series of fundamental characteristics. That material has to be inert with respect to the repair agent so that it doesn't react with it, resisting the severe stress condition that the shells undergo during the mixing.

Asad Shaikh, D.M. Joshi (2015) 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 a self -healing agent was investigated in this paper. This system involves a sodium silicate solution stored in a 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. The tip of the tube got fractured due to the load, resulting in releasing the sodium silicate. Non- 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 has shown positive results regarding the healing of cracks formed in the cube.

P Giannaros, A Kanellopoulos and A Al-Tabbaa (2016) In this work, microencapsulated sodium silicate in both liquid and solid form was added to cement specimens. Sodium silicate reacts with the calcium hydroxide in hydrated cement paste to form calcium-silicate-hydrate gel that fills cracks. The effect of microcapsule addition on rheological and mechanical properties of cement is reported. It is observed that the microcapsule addition inhibits compressive strength development in cement and this is observed through a plateau in strength between 28 and 56 days. The improvement in crack-sealing for microcapsule-containing specimens is quantified through measurements over a 28 day healing period.

Meera C M et al (2016) This paper discussed the different types of self-healing mechanisms. The mechanisms are autogenous, autonomous self-healing mechanism, hollow glass fiber system, microencapsulation system, shape memory alloy system and bacteria based system. The bacteria used for the experiment is Bacillus subtilis along with its nutrients. The use of this bacteria showed improvement in various properties of the concrete like compressive strength, split tensile test, porosity, acid resistance and chloride resistance. It is also shown that the bacteria is safe and very cost effective.

Shannon Guo, Samir Chidiac (2019) This paper presents a comprehensive literature review on the state-of-the-art of autonomous self-healing concrete using microcapsules. Common capsule shell, core materials, and corresponding manufacturing techniques are summarized. The criteria for a successful self-healing system is identified and approaches to enhance the efficiency and effectiveness of self-healing are discussed. The advantages and limitations of autonomous selfhealing are identified along with recommendations for future development.

III. METHODOLOGY

Procedure: First of all, we decided which method of self-healing we have to take for experiments. We had so many methods of self-healing. That's why we studied the methods of self-healing and we adopted the most convenient method out of them, which is the "Concrete Based on Sodium Silicate and Sodium silicate is used as self-healing agent."

We also had to figure out how much sodium silicate is required in the special concrete. After studying various research papers and data, we analyzed that the limit of sodium

silicate required in the special concrete is 0.6% to 1% of the total weight of concrete. Then we took 0.6% of sodium silicates. We decided to make two types of concrete. The first one is Normal Concrete and the other one is Special concrete. Here 'Special Concrete' refers to the mixture of Sodium silicate in the Normal concrete. Both concretes casted with M20 Mix Proportion (1:1.5:3) and will be designed with a w/c ratio of 0.50. We took cubes of standard size (150mm X 150mm X 150mm). We decided to prepare samples of cubes for 3, 7 and 28 days. Then these samples are studied for a compressive strength test, Ultrasonic Pulse Velocity Meter Test. Ultrasonic Pulse Velocity Meter Test is an indirect method to check the self-healing properties of special concrete. We were doing these tests in this study so that we can analyze the properties like density, formation of inner structure, permeability etc. of Normal concrete and special concrete. Consequently, the focus of this study was on the autonomous or sodium silicate based self-healing of concrete. As it was found to be a more convenient self-healing approach with respect to both; the material properties and full-scale applications.

This study consisted of the experimental investigation of the effects of various parameters or properties like density, formation of inner structure, permeability etc. on the efficiency of the self healing process which are related to both the mix composition of concrete as well as the self healing exposure conditions.

IV. EXPERIMENTAL INVESTIGATION

Materials used :

A. Cement

The ordinary Portland cement (OPC) of grade 33 used in the concrete work. The cement was available in the college campus. While storing the cement, all possible contact with the moisture is avoided.

B. Sand

The General river sand was used in the Cement Concrete. It was also available on the college campus.

C. Aggregate

In this project, Aggregates of size 20mm and 10mm are used. Aggregate consists of naturally occurring materials such as gravel or resulting from crushing of parent rock, natural rock, slag, expanded clays, shale (lightweight aggregates) and other approved inert materials with similar characteristics.

D. Sodium Silicate

The locally available sodium silicate collected from the RIICO Industrial Area, Kaladwas, Udaipur (Raj.). Sodium silicate is used as a healing agent and an autonomous method can be achieved. The sodium silicate reacts with calcium hydroxide, a product of cement hydration, and produces a calcium-silicate-hydrate (C-S-H) gel, a binding material natural to concrete. The C-S-H gel (x. (CaO.SiO2).H2O) fills the crack.

E. Water

Clean potable water is used for the concrete work.

Preparation of Normal Concrete:

Steps involved in preparation of normal concrete are taken as general.Mix proportion of Concrete we used was M 20 with a ratio of 1:1.5:3. We did hand mixing and After mixing we poured prepared concrete in cubes of 150*150*150 mm cubes.

Preparation of Special Concrete:

In special concrete, all preparation methods are the same as Normal concrete. But in special concrete, glass tubes are filled with Sodium Silicate Agent and Put into the concrete during Casting.

Sodium Silicate as Healing Agent:

After careful analysis, it was concluded to use the sodium silicate (Na2SiO3). Commonly known as liquid glass, this compound is widely used in the building sector

Glass Tubes as Filler:

The choice of the sodium silicate container was oriented towards a new experimentation that is to say the use of pre-formed Glass tubes, which had to have a series of fundamental characteristics: To contain the remedial agent without reacting prematurely, · To maintain their structure without breaking during the mixing step and,· To resist to considerable mechanical stress,· To be capable of breaking down in the

presence of cracks,· To have a good compatibility with the cement mixture.

Reaction of Sodium Silicate with Concrete:

Glass tubes are embedded in the concrete mix with sodium silicate filled in those tubes. 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-silicate-hydrate (C-S-H) gel – a binding material natural to concrete. The C-S-H gel fills the crack within 48 hrs of cracking, and allows some recovery of strength.

Testing of Concrete Specimen

De-moulded concrete specimens will be kept for 24 hours away from direct sun and wind in a shelter. The concrete specimen will be cured in a water tank to permit a complete hydration process. After curing the desired test will be performed on the prepared specimens as per recommended guidelines for the test.

Compressive Strength Test:

The Purpose of this test is to determine the crushing strength of hardened concrete as per guidelines of IS 516(1959). It serves as a good guide for quality control. Size of cubes (150 x 150 x 150) mm will be used for this test. Compressive strength formula for any material is the load applied at the point of failure to the cross-section area of the face on which load was applied.

Compressive Strength = Load / Cross-sectional Area

Ultrasonic Pulse Velocity Test:

Portable ultrasonic pulse velocity tester is used for this study. An ultrasonic pulse velocity (UPV) test is an in-situ, nondestructive test to check the quality of concrete and natural rocks. UPV will be conducted on specimen of size (150mm x 150mm x 150mm). Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids. A transducer for transforming electronic pulse into mechanical pulse having an oscillation frequency in range of 40 kHz to 50 kHz. The quality of cement concrete was accessed using the guidelines given in IS1331 (Part 1): 1992. The high UPV Test and lower time of travel indicate good quality of concrete in terms of density, uniformity, homogeneity, etc. Pulse velocity is measured by a simple formula:

PULSE VELOCITY = LENGTH OF STRUCTURE / TIME TAKEN

V. RESULT AND CONCLUSION

This Chapter describes the results of the tests carried out to investigate the properties of special concrete with or without sodium silicate. Various tests have carried out for hardened concrete to evaluate mechanical and durability properties. For mechanical properties compressive strength tests have been carried out and for durability properties Non-destructive test (UPV) has been carried out. This test has been performed as per procedure discussed in the previous chapter. In the succeeding parts, the result for compressive strength and Static modulus of elasticity, Ultrasonic Pulse Velocity Meter test (UPV) are presented. Analysis and discussions on the above discussed test have also been reported.

ULTRASONIC PULSE VELOCITY TEST (UPV):
Portable ultrasonic pulse velocity tester is used for this study. UPV will be conducted on specimen of size (150mm x 150mm x 150mm). The ultrasonic pulse velocity of concrete is mainly related to its density and modulus of elasticity. Transducers with frequency 54 KHz will be used to transmit and receive the pulse through specimen. . The quality of cement concrete was accessed using the guidelines given in IS 1331(Part 1): 1992. The high UPV Test and lower time of travel indicate good quality of concrete in terms of density, uniformity, homogeneity, etc.

Table: 1 UPV Test Value Before Breaking

S.NO.	CUBE NAME	UPV VALUE
1	A4	**4.658**
2	S1	**4.385**
3	S2	**4.657**
4	S6	**4.322**

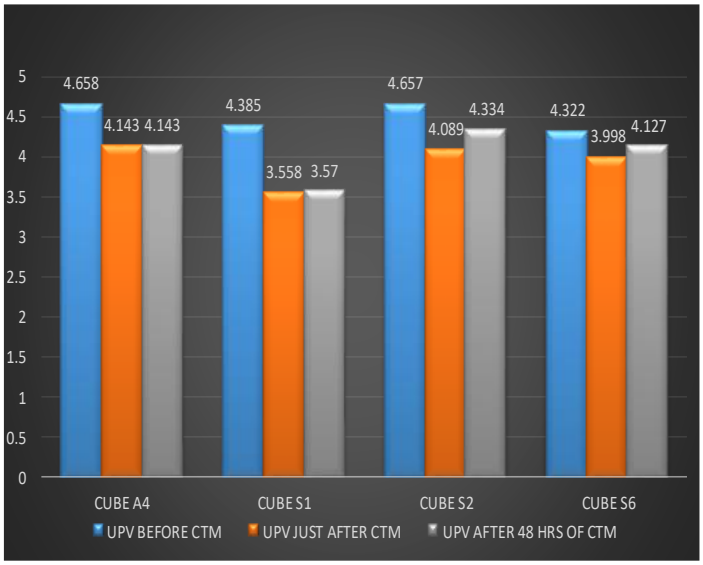
Table: 2 UPV Test Value Just After Breaking

S.NO.	CUBE NAME	UPV VALUE
1	A4	**4.143**
2	S1	**3.558**

3	S2	**4.089**
4	S6	**3.998**

Table: 3 UPV Test Value after 48 hrs. of Breaking

S.NO.	CUBE NAME	UPV VALUE
1	A4	**4.143**



2	S1	**3.558**
3	S2	**4.089**
4	S6	**3.998**

Following observations and conclusions are found from the present study:

1. According to the IS 1331(Part 1): 1992 Code if there are any Internal Cracks or flaws in the concrete, the Pulse Velocity will be lower.
2. Cube A4 is the cube in which No Sodium Silicate tubes were placed. The Value of UPV of cube A4 after loading decreases by 0.515 and remains same after 48 hrs. of Compressive Strength testing machine.
3. While Cube S1, S2 & S6 are the Cube in which Sodium Silicate tubes were placed. Value of UPV of Cube S1, S2 & S6 Just after Breaking on compressive strength testing machine decreased by 0.827, 0.323 & 0.324 respectively.
4. Now the Values of UPV of Cubes S1, S2 & S6 after 48 hrs. of cracking increased by 0.012, 0.245 & 0.129 respectively as compared to previous readings.
5. This shows that the tubes of Sodium Silicate break on a compressive strength test and immediately solution comes out of the tube. Within 48 hrs. the solution reacts with the concrete material and forms a Silica Gel. This Gel filled not all but few cracks and quality of concrete improved within 48 hrs. of cracking.

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