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Concept Validation of Bacterial Fly Ash Mortar with Experimental Study for Self Healing Concrete

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Abstract- It's a renowned fact that concrete used around the globe is second only to water. A typical durability-related phenomenon in many concrete constructions is crack formation. While larger cracks hamper structural integrity, also smaller sub-millimeter sized cracks may result in durability problems as particularly connected cracks increase matrix permeability. Use of cement in repair causes more requirement production of cement, hence CO2 emission increase and cost affecting repairing expenditure. Porosity of building materials allows the moisture and water due to precipitation seep into the concrete members in time which causes cracks. There by corrosion of steel reinforcement thus reducing the structural integrity and durability of structure. This paper describes an experimental work conducted for studying the various properties of Self-healing concrete and hardened concrete are to design a concrete mix for particular strength. For the testing purposes different type of concrete specimen was prepared and then the artificial cracks of 0.5 mm grooved in specimen and the fly ash based slurry with bacterial solution injected in the specimens. After curing for 14 & 28 days tested under the microscope. The tests gives the significance results in compression, flexure, Mass density, Weight density, Split tensile as well as in bio-precipitation process for conventional concrete. This is mainly due to production of calcite precipitations in concrete when it is cured properly. These self-healing concrete which heals crack for effective duration of initially after 14 days and as long as possible and the bacterial cell life 60years.

Keywords— ***Self-healing concrete, Bacteria, Durability, Fly ash, Compressive strength, Microscope.***

I. INTRODUCTION

The demand of concrete is increasing day by day for the need of development of infrastructure facilities. Concrete is one of the most essential materials used in construction field. Concrete which forms major component in the construction industry as it is cheap, easily available and convenient to cast. But drawback of these materials it is weak in tension so, it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of structure which are built using these materials. These process of damage occurs in the early life of building structure and also during its life time. Synthetic materials like epoxies are use for remediation. But they are not compatible, costly, reduce esthetic appearance and need constant maintenance. Therefore bacterial induced Calcium Carbonate precipitation has been proposed as an alternative and environmental friendly crack remediation and hence improvement of strength of building materials.

On the other hand, we need Ordinary Portland Cement (OPC) as the primary binder to produce the concrete as well as for its repairs and maintenance. However, it is well known that the production of cement (OPC) not only consume huge amount of natural resources but also releases substantial quantity of carbon dioxide to the atmosphere.

Also there is already huge volume of fly ash is generated around the world; most of the fly ash is not effectively used, and a large part of it is disposed in landfills. Research leading to microbial Calcium Carbonate precipitation and its ability to heel cracks of construction materials has led to many application like crack remediation of concrete, sand consolidation, restoration of historical monuments and others such application so it can be define as the process occurs inside or outside microbial cell or even some distance away within the concrete. Often bacterial activity supply trigger a change in solution chemistry that leads to over the saturation and mineral precipitation. Use of these Bio mineralogy concepts in concrete leads potential invention of new materials called- Bacterial Concrete.

Utilization of concepts of bio mineralogy in concrete lead to invention of a new material termed as bacterial concrete. Self – healing concrete refers to a new generation concrete in which selective cementation by microbiologically induced CaCO3 precipitation has been introduced for remediation of micro cracks. Self healing bacterial concrete can be prepared in two ways; one is by direct application and other is by encapsulation in concrete. In present study among these two methods the encapsulation method is adopted which is also called as "Active process", even though it's costlier than direct application. Hence to reduce its cost comparatively by using fly ash to make bacillus sphericus bacterial paste for encapsulation. Bacillus bacteria are harmless to human life and hence it can be used effectively. They precipitate inorganic crystals hence the healing of the cracks takes place in the concrete and withstand any temperature conditions.

II. METHODOLOGY

Research consist preparation of conventional concrete specimens with mix design grooving cracks of 0.5 mm in concrete. The slurry of fly ash for encapsulation consists of B. sphericus bacteria. All the ingredients are used pertaining to their required standards in terms of mechanical properties, physical properties, chemical properties, shape & size, texture & source, etc. The ingredients of conventional concrete viz. Cement, coarse aggregate, fine aggregate, and water are used of identical specification in cement concrete.. Only the new material i.e. Fly ash is selected on the basis of specification further the concrete mix was designed for proportions by 'Indian Standard method for 'Concrete Mix Design'. The fly ash used in this study was Low-Calcium Class F processed fly ash from Pozzocrete, near Eklahare Power Plant, Nashik (Product Code: POZZOCRETE60). The chemical composition of fly ash used along with the specifications are given inTable-I.

TABLE I

Composition of Class F Fly Ash (POZZOCRETE60)

Sio_3	Al_2O_3	Fe_2O_3	MgO	SO_3	NgO	CaO	LOI
57.30%	27.13%	8.06%	2.13%	1.06%	0.73%	0.03%	1.60%

The bacterial solution is made up from the microbiological lab with considering its properties to sustain the dormant and active condition with the chemical reaction $Ca(C_3H_5O_2)_2 + 7O_2 = CaCO_3+5CO_2+5H_2O$. Locally available river artificial sand is used as fine aggregate and in the concrete mix. For encapsulation the fly ash and bacterial solution is to be taken as in 1:1 proportion required to fill 0.5 mm surface crack grooved in specimens. The detailed proportions of different ingredients of concrete mix are shown in Table IIbelow.

Ingredients	Unit	Conventional concrete	Bacterial Concrete
Cement	Kg	87.5	87.5
Coarse Aggregate	Kg	135	135
Fine Aggregate	Kg	80.50	80.50
Mixing Water	Kg	35	35
Curing Period	Days	14	14
	Days	28	28
No. of Cube	14 days	3	3
	28 days	3	3
No. of Cylinder	14 days	3	3
	28 days	3	3
No. of Beam	14 days	3	3
	28 days	3	3

III. RESULTS AND DISCUSSIONS

A. Results

The concrete specimens cube, cylinder & beam were tested for compressive, Split. tensile, Flexural strength respectively at the age of 14 days and 28 days curing results mentioned in Table III. Likewise after curing the all tested sample taken for the microscopic test to observe the percentage of calcite precipitation. Hereby the results of all the variations are mentioned in TableIII.

TABLE III

Results of average strength and weight at 14 & 28 days of curing

Sr. No	Concrete Specimen	Average strength of 14 Days (kN)		Average strength of 28 Days (kN)		Average Weight (Kg)			
		Cracked	Un-cracked	Cracked	Un-cracked	Cracked		Un-cracked	
						14 Days	28 Days	14 Days	28 Days
1.	Cube	14.65	15.12	30.48	29.89	8.31	8.15	8.23	8.27
2.	Beam	2.79	3.31	4.50	4.74	38.96	37.62	38.39	38.92
3.	Cylinder	1.34	1.39	2.79	2.87	12.8	12.86	13.23	13.07

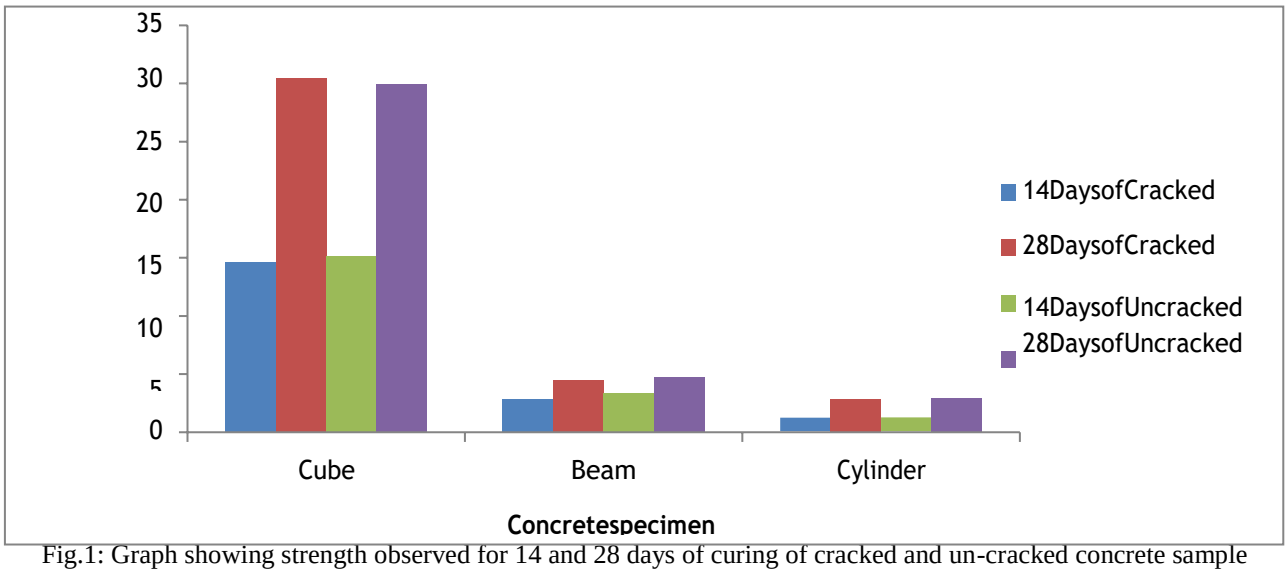

Fig.1: Graph showing strength observed for 14 and 28 days of curing of cracked and un-cracked concrete sample

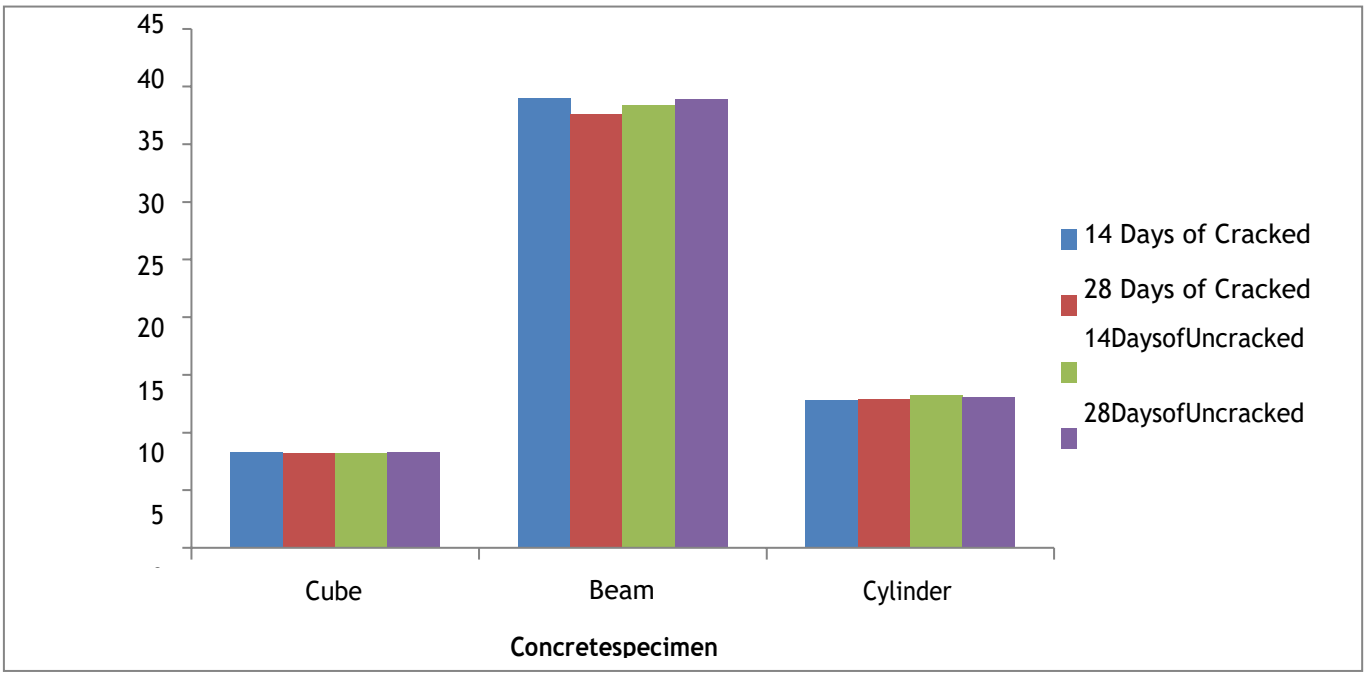

Fig2: Graph Showing Weight strength for 14 and 28 days of curing of cracked and un-cracked concrete sample

TABLE IV

Results of microscopic observation of $CaCO_3$ %

Age of concrete specimen	Type of specimen	% of $CaCO_3$
14	Cube	13.1
	Beam	12.4
	Cylinder	12.9
28	Cube	21.3
	Beam	20.4
	Cylinder	20.6

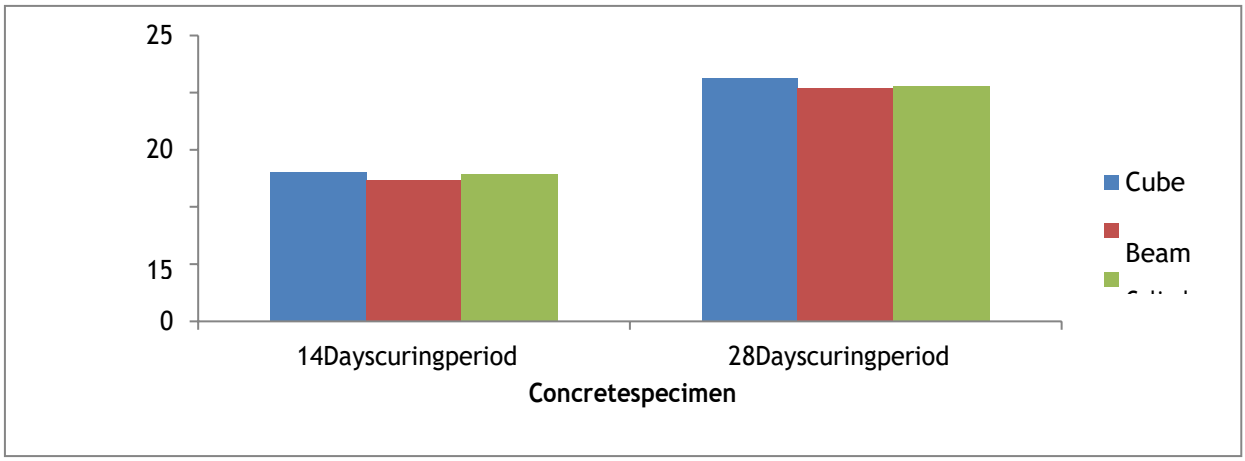

Fig.3 Graph showing of %CaCO3 in cracked concrete specimen

B. Discussion-:With reference to the results above the following discussions can made

1. It is possible to heal or seal by filler material formation freshly formed cracks to inhibit ingress ofwater.

2. In microscopic test of cracked concrete for 28 days curing period the increased in precipitation of CaCO3 is observed than for 14 days curing period.

3. Bacterial concrete is able to heal or seal by filler material as fly ash slurry with the bacterial solution with formation of freshly formed cracks to inhibit ingress of water and other chemical which could cause preliminary degradation of the material matrix or embedded.

4. The average physical strength for cracked & un-cracked concrete specimen is observed as increasing by 1-5 % at 14 & 28 days of curing period respectively.

5. The economy factor regarding repair & maintenance work for small concrete works can be achieved by using this solution.

CONCLUSION

Research proposes the effective utilization of fly ash & bacterial solution as mortar to self heal the concrete, thus eminently expressing the mode of reducing the cost of repair and maintenance work in concrete structure. Currently increasing scale of construction in industry requires high durability for structure expose to harsh environment. Hence it has become need for today to discover and implement such notions that would lead to reducing cost of repair & maintenance and sustainability in construction industry. The concept of biological cement concrete proves to be working and effective, however the self healing concrete is able to heal or seal by filler materials as fly ash slurry with the bacterial solution with formation of freshly formed cracks inhibit ingress of water and other chemical which could cause preliminary degradation of material matrix or embedded.

FUTURISTIC SCOPE

The present study of self healing concrete shows the significant potential to be a material for the future, because it is not only environment friendly but also possesses the required strength and durability. However, on the present study further research can be carried out to know the chemical reactions between bacteria and replacement of cement with fly ash in concrete. Also the changes in properties due to variations in curing temperature and comparison between active and dormant process needs to be explored. Further it is also necessary to find certain steps to reduce the cost of production of self healing concrete or mortar.

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