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Experimental Study of Bacterial Self-healing Effect in Different types of Advanced Concrete

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Abstract —The Concrete is most efficient and worldwide using material after the water due to easily available and casting on to the site as per requirement. The main key objective of using the concrete is in terms of strength and durability. The durability always play vital role to decide the life span of structure, More or less concrete is a composite material composed of coarse aggregate bonded together with a fluid cement pest which hardens over the time. So there are many chances and reasons to develop a voids and cracks in the concrete while casting and placing and to resolve this problems various admixtures and other construction chemical used before and after the construction work. Here some review of research work on using biological or bacterial poured concrete is been carried out to filled up the pre and post construction cracks. The main aim of this present review work is to study the fulfillment of durability and engineering properties incorporating in various type of advanced concrete like High volume fly ash concrete (HVFAC), Ultra high strength concrete (UHSC) and Light weight concrete (LWC). In addition to the review work, also to study the various effect on self-healing by using sustainable material in advanced concrete.

Keywords- Bacillus Pasteurii, Compressive Strength, Supplementary Cementitious Material (SCM), Self-healing, calcite precipitation, Calcium carbonate.

I. INTRODUCTION

In the construction industry concrete is the major component which is easy available, cheap and convenient to use. The cracks in the concrete are major problem which cause reduced the durability and strength of the concrete structure. Based on the current research carried out the globe, several modifications have been made from time to time to overcome the deficiencies of cement concrete. Durability term of cracks and void is very important aspect in design consideration. There are many reasons to develop cracks in concrete as post construction and pre-construction cracks. The pre-construction cracks developed in structure due to shrinkage and creep, less water availability and curing reason while post construction structural cracks developed within the structure is due to cyclic effect of loading. As all know that concrete is strong in compression and weak in tension so that the steel reinforcement is used in concrete. Some temperature and thermal effect also lead to cracks in concrete structure. To resolve these effects in structure, much physical and chemical solution applied. Biological or bacterial self-healing in concrete is a current advanced concrete in which selective cementation by microbiologically-induced $CaCO_3$ precipitation has been introduced for remediation of micro-cracks. In the concrete technology the current research has led to produce of some special concrete in consideration the speed of the construction work, strength of concrete structure, durability of structure, economical by using the industrial material such as rice husk, fly ash, GGBS, Silica Fume etc. In the literature study, it has been found that the microbial mineral precipitation from metabolic activities of favorable microorganisms in concrete can improve the behavior of concrete. By inserting the suitable types of bacteria in the concrete which should able to transform the soluble organic nutrients in insoluble inorganic ($CaCO_3$) calcium carbonate. This process is called as microbiologically induced calcite precipitation. In the self-healing process bacteria incorporated in to the concrete and calcium lactate food to support those bacteria when they become active. In this paper, the processes that are behind bacterial self-healing concrete and will describe the component that are induced in the process and how they work independently and collectively

II. EXPERIMENTAL PROGRAMME

2.1 Material Used in Experimental Works

2.1.1 Fly Ash: any coal based thermal power station may have the mainly four kind of fly ash such as bottom ash, Pond ash, fly ash and Mound ash. Fly ash is the by-product of the combustion of coal at electrostatic precipitator in thermal power plants. Generally fly ash classified based on chemical property as class F and class C fly ash. We were used class F fly ash.

2.1.2 Cement: Locally Available in market as Ordinary Portland cement was used in the present investigation.

2.1.3 Fine Aggregate: We were used the fine aggregate confirming to is 383-(1970) which easily available in the market.

2.1.4 Coarse Aggregate: The Size of coarse aggregate were used in this investigation between 10mm to 20mm as per confirming to is 383-(1970).

2.2 Classifications of Bacteria

2.2.1 Classification Based on Gram Strain: Bacteria shall be Classified Based on Gram Staining Methods such as Gram Positive and Gram Negative.

2.2.2 Classification Based on Oxygen Requirement: Oxygen required for the survival of bacteria which called as aerobic bacteria and another is anaerobic bacteria.

2.2.3 Classification Based on shape: Generally bacteria shall be classified based on the shape such as Rod-Shaped Bacteria, Sphere-Shaped Bacteria and Spiral-Shaped Bacteria.

2.3 Various Types of Bacteria Applicable in Concrete

(1) Bacillus Subtilis. (2) Bacillus Pasteurii. (3) Bacillus Cohni. (4) Bacillus Cereus. (5) Bacillus Sphaericus.

2.4 Mechanism of Self-healing Process

The principal of self-healing of bacteria is that they should be able to covert the soluble organic nutrients in to insoluble inorganic calcite crystals which are seal the micro cracks. The bacteria and the nutrients which are incorporated in the concrete should not disturb the integrity of the cement sand matrix and also should not negatively affect other important engineering properties in fresh and hardened state of concrete. It was reported that if the bacteria is added directly in to the concrete mixture in suspension, their life time is reduced due to main two reasons first one is continues cement hydration resulting in reduction of cement sand matrix pore-diameter and second is due to insufficient nutrients to precipitate calcite crystals. A novel method of protecting the bacteria spore by immobilization before addition to the concrete mixture appeared to substantially prolong their life time.

2.5 Mix Proportion

Table: 1 Mix Proportion Material

Type of concrete	Material								
	Cement	Fly ash	Fine Agg.	Coarse Agg.	Silica fume	GGBS	Ceramic west	Quarts	Foundry slag
HVFAC	205	205	641	1333	-	-	-	-	-
LWC	240.5	-	339.4	345.7	49.4	191.1	345.7	-	-
UHSC	912	-	-	-	912	-	-	780	780

2.6 Casting

For experimental study, concrete casting and mixing has to be done by the mechanically operated machine which available in the laboratory for fast and easy casting purpose.

Fig: 1 casting of concrete

III. TESTS PERFORMED

3.1 Compressive Strength Test: - The compressive strength of concrete is major test of concrete which will give idea about almost all characteristics of concrete. There is commonly adopted cubes of size 150mmX150mm X150mm are used. The test was performed according to IS 516: (1959).

The compressive strength $\sigma = P/A$

Where,

σ = Compressive strength N/mm2

P = Ultimate failure load of cube in KN

A = Area of cube in mm2

Fig: 2 Compression test machine

3.2 Rapid Chloride Permeability Test: -

Rapid chloride permeability test was carried out for the determination of durability of the concrete. These methods non-destructively measure the chloride permeability of concrete in place.

Fig: 3 RCPT test Device

3.3 High Volume Fly Ash Concrete: -

The High Volume Fly Ash Concrete of M40 Grade was prepared by using the 50% fly ash is replaced by the ordinary Portland cement in conventional concrete.

Table 2 The Compressive Strength of High Volume Fly Ash Concert at 7, 28 and 56 Days.

Type	Bacterial Concentration Cells/ml	Compressive Strength (MPa)		
		7 days	28 days	56 days
HVFAC M 40	100	16.44	32.59	40.44
	103	17.5	35.57	42.44
	105	18.23	36.53	45.03
	107	17.8	36.04	43.3

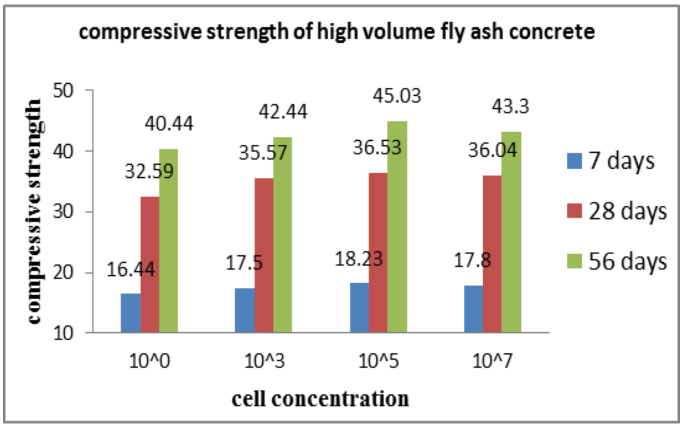

Fig. 4 Compressive Strength of HVFAC with Different cells concentration.

3.4 Light Weight Concrete M25

The Light Weight Concrete was prepared by 40% cement replacing by weight of ground granulated blast furnace slag and 50% coarse aggregate replacing by weight of Ceramic west.

Table 3 compressive strength of LWC at 7, 28 and 56 days

Type	Bacterial Concentration Cells/ml	Compressive Strength (MPa)		
		7 days	28 days	56 days
LWC M 25	10^0	11.37	20.5	25.99
	10^5	13.11	22.78	28.8

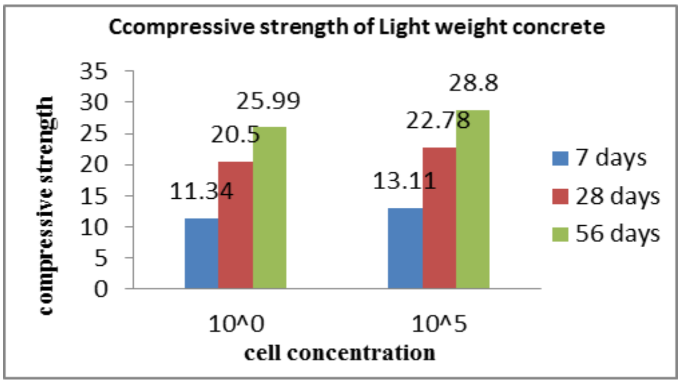

Fig. 5 Compressive strength of LWC with 10^5 cell/ml concentration

3.5 Ultra High Strength concrete M100

Ultra High Strength (M100) grade concrete was prepared by replacing fine aggregate with 50% quarts and 50% foundry slag and also 10% silica fume as an additive along with 1.5% steel fibers by weight of cement

Table 4 compressive strength of UHSC at 7, 28 and 56 days

Type	Bacterial Concentration Cells/ml	Compressive Strength (MPa)		
		7 days	28 days	56 days
UHSC M 100	10^0	64.6	109.3	116.7
	10^5	72.6	120.6	131.0

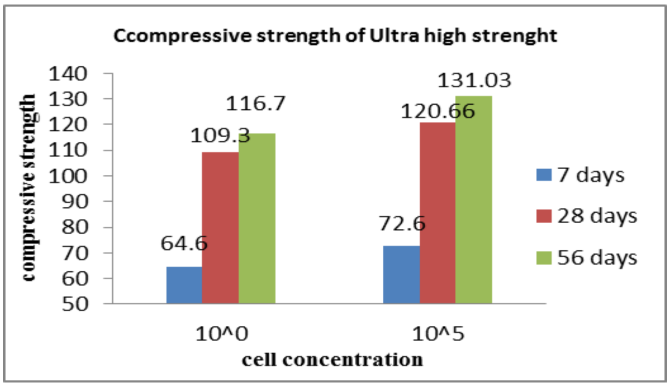

Fig. 6 Compressive strength of UHSC with 10^5 cell/ml concentration

3.6 Rapid Chloride Permeability Test: -

The concrete chloride permeability results and its values remains in whatever categories should represent the chloride resistivity which may understand from the table given below.

Table 5 chloride permeability based on charge passed

Charge Passed	Chloride Permeability
>4000	High
2000 - 4000	Moderate
1000 – 2000	Low
100 – 1000	Very Low
<100	Negligible

Table 6 Rapid Chloride Permeability Test of HVFAC M40 at 28 Days

Sr No	Type	Charge Passed In Coulombs (C)	Average
1	A_1	1566	1584.6
2	A_2	1567.8	
3	A_3	1620	
4	B_1	1272.6	1285.5
5	B_2	1275.3	
6	B_3	1308.6	

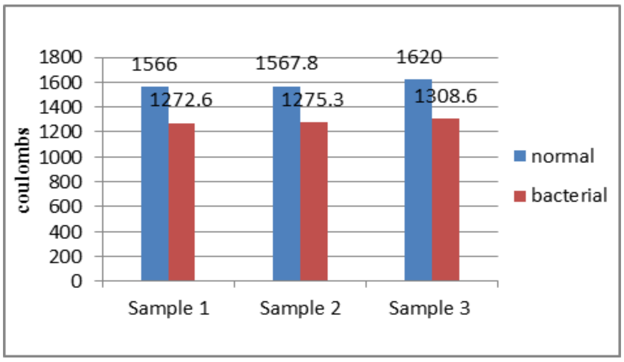

Fig- 7 Comparison of normal (HVFAC) M40 Concrete to bacterial concrete with 10^5 Cells/ml of RCPT

Table 7 Rapid Chloride Permeability Test of LWC M25 at 28 Days

Sr No	Type	Charge Passed In Coulombs (C)	Average
1	A_1	1067.4	1067.46
2	A_2	1068	
3	A_3	1067	
4	B_1	979.8	860
5	B_2	910.8	
6	B_3	689.4	

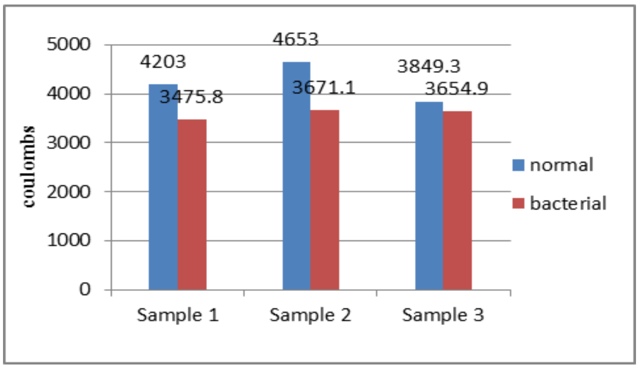

Fig- 8 Comparison of normal (LWC) M25 Concrete to bacterial concrete with 10^5 Cells/ml RCPT.

Table 8 Rapid Chloride Permeability Test of UHSC at 28 Days

Sr No	Type	Charge Passed In Coulombs (C)	Average
1	A1	4203	4235.1
2	A2	4653	
3	A3	3849.3	
4	B1	3475.8	3600
5	B2	3671.1	
6	B3	3654.9	

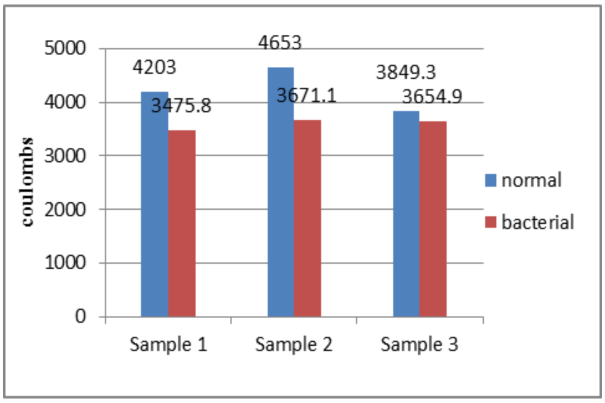

Fig- 8 Comparison of normal (UHSC) M100 Concrete to bacterial concrete with 10^5 Cells/ml RCPT.

IV. CONCLUSION

Inclusions of "bacillus pasteurii" with optimum concentration were produce concrete with good workability ultimately leads to be durable concrete. The compressive strength of HVFAC, LWC and UHSC were increase successively 12.08%, 15.6% and 12.38% with distinct improvement in various properties. Chloride permeability of HVFAC, LWC and UHSC were reduced successively by 18.87%, 19.43% and 14.99%. It has been observed that optimum bacteria cell concentration for concrete is 105 cell/per ml for all three types of concrete. Concrete cracks up to 0.3 to 0.4 mm width can be healed in 56 days' time period which shows effective solution for micro cracks. Oxygen is the agent that can induce corrosion but the bacteria will feed oxygen so the corrosion can be also reduced. Formation of cracks will be healed initial stage itself thereby increasing the service life of the structure then expected life.

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