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EXPRIMAENTAL STUDY OF MICROBIAL CONCRETE

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Abstract— ***Concrete is an absolutely essential component of construction materials used in infrastructure and most***
Buildings. Despite its versatility in construction, it is known to have several limitations. It is weak in tension, has limited ductility and little resistance to cracking. Based on the continuous research carried out around the globe, various modifications have been made from time to time to overcome the deficiencies of cement concrete. The corrosion of the concrete is caused by the interaction between biological and chemical processes. Microbial concrete has emerged as a novel technique in recent years. It can be used for various purposes, amongst which remediation of cracks in concrete is the primary one. Due to microbial activities of the bacteria, microbiologically induced calcite precipitation (MICP), a highly impermeable calcite layer is formed which contributes to increase the performance of concrete structure and also has excellent resistance to corrosion. Hence this technique being environmental friendly can be used as their substitute. It was also observed in the study that the metabolic activities in the microorganisms taking place inside the concrete results into increasing the overall performance of concrete including its compressive Strength and Durability.

Keywords— ***Microbial concrete, Bacteria****,* ***Bacillus Subtilis****,* ***Compressive strength****,* ***Flexural strength****,*

1 Introduction

Concrete is one of the most important and widely used building materials being used in many types of engineering structures. The economy, the efficiency, the strength and its ability to be moulded to any shape make it an attractive material for a wide range of structural applications. At present, concrete is the largest consumed manmade material. But despite of its wonderful properties it has few drawbacks amongst which the main one is its vulnerability to cracking. Environmental sustainability as well as enhanced mechanical and durability concrete properties. Durability is a major concern for concrete structures during their service life, particularly when they are exposed to an aggressive environment. It is well known that concrete is a porous material that various corrosive species can penetrate through interconnected capillary pores and micro-cracks. Many of the physical and chemical deterioration mechanisms of concrete are related to these aggressive substances since the degradation of concrete originates mainly from an ingress process. Without immediate and proper treatments, cracks in concrete structures tend to expand further and eventually require costly repair. Even though it is possible to reduce the extent of cracking by available modern technology, remediation of cracks in concrete has been the subject of research for many years. Keeping all these points in consideration, we need such techniques which have the potential to contribute both better environmental sustainability as well as enhanced mechanical and durability concrete properties. Microbial concrete has emerged as a new technique in recent years which can be used for various purposes, amongst which remediation of cracks in concrete is the primary one.

2 Microbial concrete

The microbial concrete makes use of calcite precipitation by favourable bacteria. In this technique bacteria (microorganism) are used hence the concrete is called Bacterial or Microbial concrete. The “Microbial concrete” can be prepared by adding spore forming bacteria in the concrete that are able to continuously precipitate calcite, this process of production of calcite precipitation is called Microbiologically Induced Calcite Precipitation (MICP). Recently, it is found that microbial calcite precipitation resulting from metabolic activities of favourable microorganisms in concrete improved the overall properties of concrete. Bacterial Cultures improves the strength of cement sand mortar and crack repair on surfaces of concrete structures. The basic principle for this process is that the microbial urease hydrolyzes urea to produce ammonia and carbon dioxide and the ammonia released in surrounding subsequently increases pH, leading to accumulation of insoluble calcium carbonate. Calcium carbonate precipitation, a metabolic process which occurs in some bacteria. Calcite formation by Bacillus species is used in making microbial concrete, which can produce calcite precipitates on suitable media supplemented with a calcium source. Bacterial spores are specialized cells which can endure extreme mechanical and chemical stresses and spores of this specific genus are known to remain viable for up to

200 years. Spores are dormant but viable bacterial spores immobilized in the concrete matrix will become metabolically active when revived by water entering freshly into the concrete. Calcite precipitation is selective and its efficiency is affected by the porosity of the medium, the number of cells present and the total volume of nutrient added. The bacteria precipitate calcite in the presence of nutrients. The alkaline environment of concrete with pH around 12 is the major hindering factor for the growth of bacteria. The technique is used to improve the compressive strength and reduce the permeability of concrete. There are various types of Bactria which are used for making microbial concrete and help to improve the concrete strength and durability.

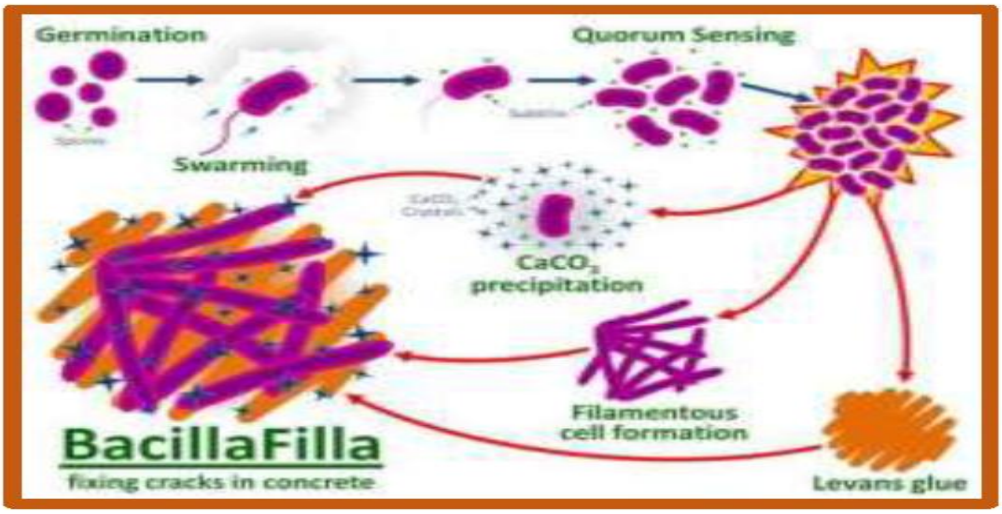

Fig 1. Microbial Concrete

Advantages of Microbial Concrete

1) More Resistible to the Crack as Compare to the Ordinary Concrete.
As a sand material contains bacteria which are not present in the ordinary concrete, the cracks are resisted and the concrete becomes stiffer.
2) Increase in the Compressive Strength of concrete
The tests have shown that the compressive strength of bacterial concrete is 10 % more than the ordinary concrete.
3) Resistance against the Atmospheric Effects
The bacterial concrete helps in resistance to the freeze - thaw cycle, because of the decrease in the permeability of concrete.
4) Act as an Impervious Material.
It was studied in different research work about the permeability of concrete. Carbonation test is an effective tool in testing the permeability because, the decreasing gases permeability due to the surface treatment, increases resistance towards the injection of carbonation and chloride.
5) Act as an Anti – Corrosive Concrete.
The bacterial concrete helps in sealing the path of water or other harmful gases which results in increase in the life of steel, and makes the reinforced concrete more durable. Moreover, it also resists the attack of acid on the reinforced concrete.

Dis-Advantages of Microbial Concrete
1) High Cost
The cost of the bacterial concrete is almost double than the conventional concrete but it can be reduced by the growth of these techniques.
2) Unfavourable Atmospheric Condition.
Atmospheric conditions are very important for the survival of bacteria and various chemical growth processes; hence it is very important to develop the favourable atmospheric conditions. For proper bio – chemical process to takes place.
3) Non– Availability of I.S. Codes
As it is a newly developed research material and not widely used in the construction area and so, there is no I.S codes available to calculate the dose of bacteria to be used for the optimum performance.
4) Study and Investigation of Bacterial Concrete is Costly
As different bacteria have different tendency to produce different amount of calcite precipitates. It is very important to identify the bacteria. The bacteria investigation can be done by “Scanning electron microscopy” method. But it is very costly and requires expertise.

3 MATERIALS AND METHODS

3.1Ordinary Portland cement (OPC)

Ordinary Portland cement of 53 grade available in local market is used in the investigation. The cement used has been tested for various properties as per IS: 4031- 1988 and found to be confirming to various specifications of IS: 12269-1987 having specific gravity of 3.

Table - 1: Physical properties of ordinary Portland cement

Fineness of Cement	1.89%
Standard Consistency	33%
Initial Setting Time (min)	112min
Final Setting Time (min)	229 min

3.2 Fine and Coarse aggregate

Locally available clean, well-graded, natural river sand having fineness modulus of 2.89 conforming to IS 383-1970 was used as fine aggregate, sand is conformed as Zone II. Crushed granite angular aggregate of size 20 mm nominal size from local source with specific gravity of 2.79 was used as coarse aggregate. Their physical properties are shown in Table 2.

Table - 2: Physical properties of fine and coarse aggregate

Specific gravity of Fine aggregate	2.75
Specific gravity of Coarse aggregate	2.79

3.3 Bacteria Selection

Bacillus subtilis obtained and used in this study.
Primarily 2.6 g of Nutrient broth (media) is added to a 200ml conical flask containing distilled water. It is then covered with a thick cotton plug and is made air tight with paper and rubber band. It is then sterilized using a cooker for about 10-20 minutes. Now the solution is free from any contaminants and the solution is clear orange in colour before the addition of the bacteria. Later the flasks are opened up and an exactly 1ml of the bacterium is added to the sterilized flask and is kept in a shaker at a speed of 150-200 rpm overnight. After 24 hours the bacterial solution was found to be whitish yellow turbid solution.


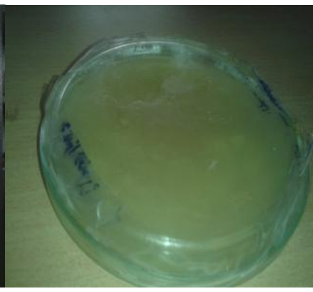

Fig 2.Nutrient Broth & Agar   Fig 3. Bacillus subtilis   Fig 4.Cultured Bacterial Sample   Fig 5. Incubator

3.4 Preparation of Test Specimens

The size of concrete cube 150mm x 150mm x 150mm and beam size 100mm x 100mm x 500mm respectively. The concrete mix design was carried out as per IS 10262-2009 for M40 grade of concrete. Ratio of mix is 1:1.4:2.with w/c ratio 0.47 was found out. Bacterial solution added by 0ml,5ml,10ml,15 ml . The concrete cubes, beam with and without bacteria were casted and cured for 28 days.

4. RESULTS

COMPRESSION TEST RESULTS

In this compressive strength of cubes for M25 grade concrete made with and without bacteria for 7,14 and 28days was tested, tabulated and compared in the table 3 and Fig 6,7 . The cubical Moulds of size 150mm x 150mm x 150mm were cleaned and checked against the joint movement. A coat of oil was applied on the inner surface of the Moulds and kept ready for the concreting operation. Meanwhile the required quantities if cement, fine aggregate and coarse aggregate (passing through IS sieve of 20 mm size and retained on 4.75 mm) for the particular mix are weighed accurately for concreting. Fine aggregate and cement were mixed thoroughly in a hand mixer such that the colour of the mixture is uniform. Then, weighed quantity of coarse aggregate is added to the mixer and then it rotated till uniform dry mixture is obtained. Then, calculated quantity of bacterial solution and water was added and mixing was continued for about 3 to 5 minutes to get a uniform mix. The wet concrete is now poured into the Moulds and for every 2 to 3 layers and compacted manually. After concreting operations, the upper surface is levelled and finished with a mason"s trowel. The corresponding identification marks were labelled over the finished surface and they were tested for 7,14 and 28 day strengths in a compressive strength testing machine.

Fig 6 .Casting of cubes &crushing in Compression testing machine

TABLE – 3: Compressive strength of cubes for M25 grade concrete made with and without bacteria for 7,14 and 28days.

Days of curing	Normal concrete		Bacterial concrete(5ml)		Bacterial concrete (10 ml)		Bacterial concrete (15 ml)	
	Load (KN)	Compressive strength(Mpa)	Load (KN)	Compressive strength(Mpa)	Load (KN)	Compressive strength(Mpa)	Load (KN)	Compressive strength(Mpa)
7 days	470	20.90	481	21.35	489	21.79	496	22.05
14 days	588	26.15	626	27.85	656	29.23	685	30.45
28 days	715	31.65	712	32.65	744	33.08	776	34.53

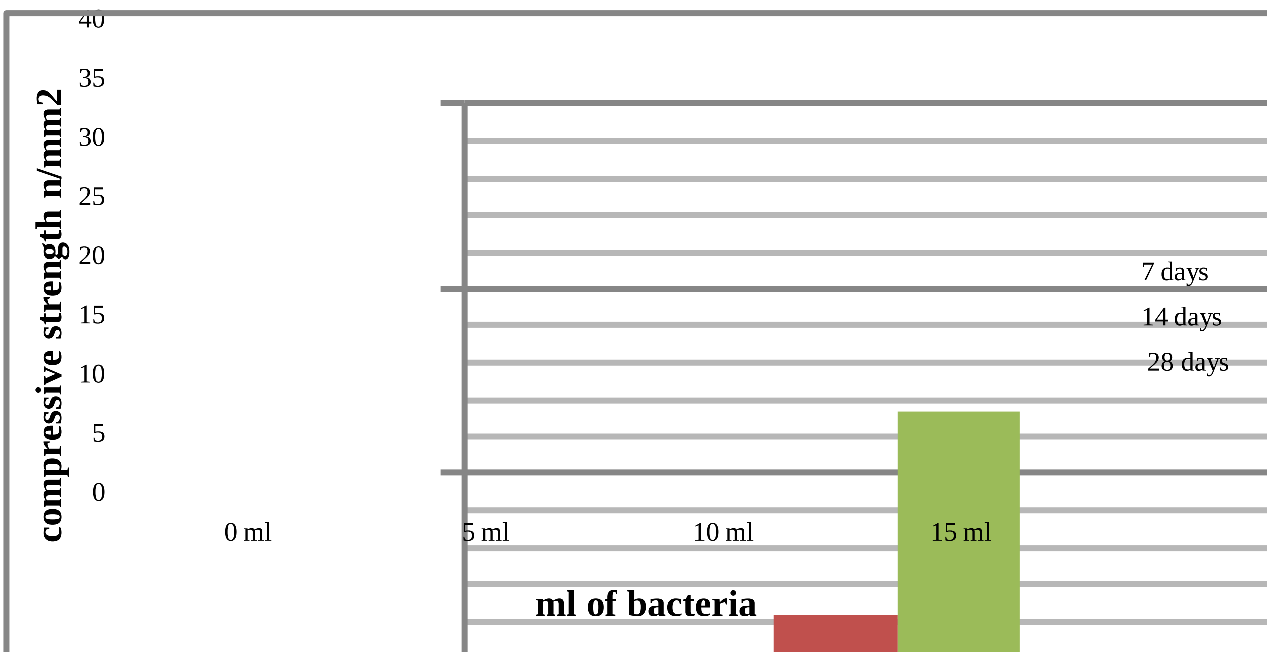

Fig 7. Comparison of compressive strength results of cubes made with and without bacteria

Flexural Strength Test Result

In this Flexural Strength of Beam for M25 grade concrete made with and without bacteria for 7,14 and 28days was tested, tabulated and compared in the table-4 and Fig.8, 9. Moulds of 10cm x 10cm x 50cm is used and the Moulds are cleaned and the joints between the sections of Moulds shall be thinly coated with Moulds oil and a similar coating of Moulds oil shall be applied between the contact surfaces of the bottom of the Moulds and the base plate in order to ensure that no water escapes during the filling. The interior faces of the assembled Moulds shall be thinly coated with Moulds oil to prevent adhesion of the concrete. Meanwhile the required quantities of cement, fine aggregate and corresponding coarse aggregate for the particular mix are weighed accurately for concreting. Fine aggregate and cement were mixed thoroughly in a hand mixer such that the colour of the mixture is uniform. Then, weighed quantity of coarse aggregate is added to the mixer and then it rotated till uniform dry mixture is obtained. Then, calculated quantity of water and bacterial solution was added and mixing was continued for about 3 to 5 minutes to get a uniform mix. The wet concrete is now poured into the Moulds in 2 to 3 layers and compacted manually. After concreting operations, the upper surface is leveled and finished with a mason"s trowel. The corresponding identification marks were labeled over the finished surface and the beams were tested for 7 and 28 days strengths.

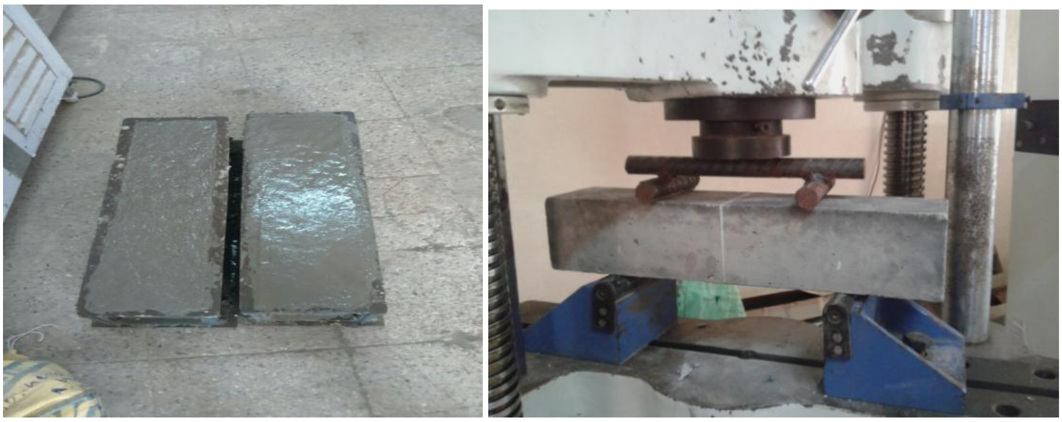

Fig 8.Casting of beams &test in Flexural Strength testing machine

TABLE – 4: Flexural strength of cylinders for M25 grade concrete made with and without bacteria for 7,14 and 28days.

Sr no	Days	Normal Concrete (N/mm2)	Bacterial Concrete (N/mm2)
1	7	3.80	4.60
2	14	5.23	6.30
3	28	6.90	7.50

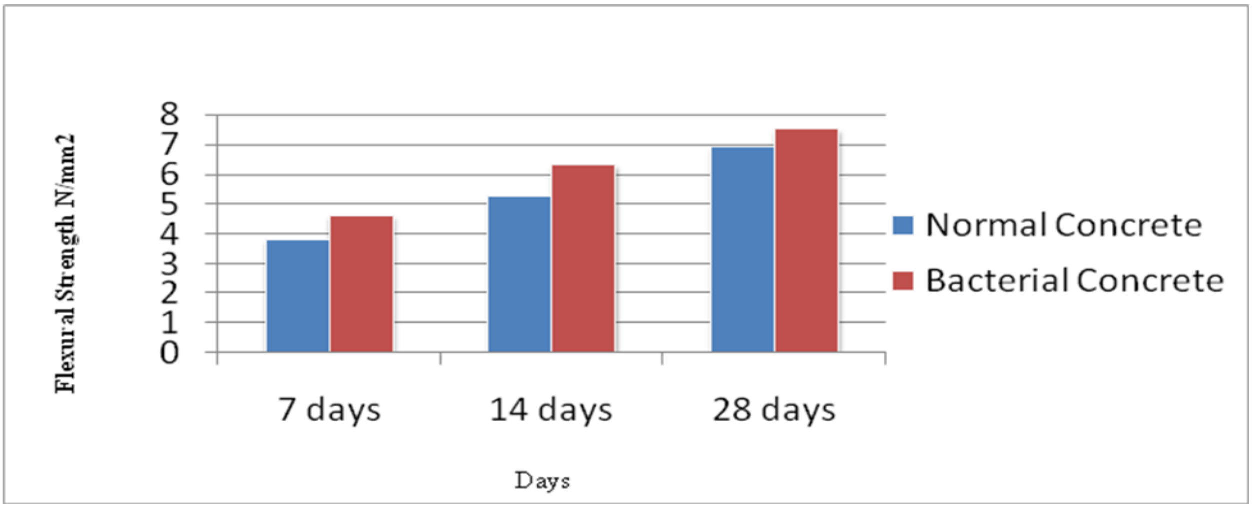

Fig 9. Comparison of Flexural strength results of beam made with and without bacteria

5. CONCLUSIONS

1. Maximum Compressive strength obtained 34.53 Mpa for 15 ml bacterial mix considerably increases 2.8% when compared with control mix.
2. In the flexural strength testing of beams maximum strength obtained 7.50 Mpa for 15 ml with bacteria solution has less deflection when compared with controlled beam .
3. The microbe proved to be efficient in enhancing the properties of the concrete by achieving a very high initial strength increase and thus we can conclude that the produced calcium carbonate has filled some percentage of void volume thereby making the texture more compact and resistive to seepage. When bacterial concrete is fully developed, it may become yet another alternative method to replace OPC and its hazardous effect on environmental pollution. Hence can be used for construction as it is resistant to corrosion as well.

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