BACTERIAL CONCRETE - SOLUTION FOR MICRO CRACKS

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Abstract-Carbonate-producing bacteria have attracted lots of interest as promising, natural, environmental friendly novel technique to improvement of concrete characteristics. Considerable research has been conducted on utilizing microbial-induced carbonate precipitation to mitigate several concrete problems such as crack repair, reduction and modification of porosity and permeability. Furthermore, bacterial carbonate precipitation (bio deposition) has shown positive influences on compressive strength improvement of concrete. In the meantime, it seems that the study related to the optimum dosage of bacterial solution and its effect on the durability of concrete has not been comprehensively investigated. Therefore, it is decided to carry out an investigation of determining optimum dosages of bacterial solution required for concrete by forming various concrete cube samples having variations of bacterial solution viz. 15 ml, 30 ml, 45 ml, 60 ml and 75 ml. Further these various samples are tested under various laboratory methods viz. slump cone test, compressive strength testing machine, ultrasonic pulse velocity test, plate count cells and scanning electron microscopes thereby an optimum dosage required is computed. Bacterial concrete is found to be superior as compare to that of conventional concrete in all the aspects of durability. Among the different specimen incorporated it shows that bacterial concrete containing 45ml solution is the optimum dosage required, after which the strength found to be stable or decreased.
Keywords - bacteria, carbonate precipitation, microbial, durability

1. INTRODUCTION

1.1 Background

Carbonate-producing bacteria have attracted lots of interest as a promising, natural, environmental friendly novel technique to improvement of concrete characteristics. Considerable research has been conducted on utilizing microbial-induced carbonate precipitation to mitigate several concrete problems such as crack repair(Van Tittelboom et al. 2010;Wiktor and Jonkers 2011), reduction and modification of porosity (Ghosh et al. 2005, 2009), and permeability(De Muynck et al. 2007a; Jonkers and Schlangen 2008;Nemati and Voordouw 2003). Furthermore, bacterial carbonate precipitation (bio deposition) has shown positive influences on compressive strength improvement of concrete (Bang et al. 2001;Ghosh et al. 2005, 2009; Jonkers and Schlangen 2008; Jonkers et al.2010; Reddy et al. 2010) and also, it also reduces water absorption and carbonation of concrete as an alternative surface treatment.

1.2 Aim of the Project work

The aim of this project is to

1. Develop a bacterial concrete by introducing the bacteria's of bacillus family (Bacillus subtitles).
2. To find the optimum dosage of bacteria required for bacterial concrete.
3. To determine the viable bacterial cells by serial dilution method.
4. To know the presence of voids by Ultrasonic pulse velocity test.
5. To know the presence of voids in the internal structure of concrete by SEM.
6. Observe the behavior of bacteria chemically.
7. Observe the change in the properties of concrete such as compressive strength & permeabil178ity.

1.3 Future Scope of Investigation

1. To study the effect of bacteria on High Strength concrete.
2. To study the durability of concrete under various weathering conditions.
3. To determine the maximum width of crack healing using bacterial concrete under various environmental condition.
4. To study the effect of bacteria on the RCC member
5.

2. LITERATURE REVIEW

P.Ghosh et al. (2005), "Use of microorganism to improve the strength of cement mortar" [1]

A method of strength improvement of cement–sand mortar by the microbiologically induced mineral precipitation was described by A thermophile anaerobic microorganism is incorporated at different cell concentrations with the mixing water. The study showed that a 25% increase in 28 day compressive strength of cement mortar was achieved with the addition of about 10^5 cell/ml of mixing water. The strength improvement is due to growth of filler material within the pores of the cement–sand matrix as shown by the scanning electron microscopy. The modification in pore size distribution and total pore volume of cement–sand mortar due to such growth is also noted. E. coli microorganisms were also used in the cement mortar for comparison, but no improvement in strength was observed.

K. Van Tittelboom et al. (2010), **"Use of bacteria to repair cracks in concrete", [2]**
As synthetic polymers, used for concrete repair, may be harmful to the environment, the use of a biological repair technique was investigated by Ureolytic bacteria such as Bacillus sphaericus were able to precipitate $CaCO_3$ in their micro- environment by conversion of urea into ammonium and carbonate. The bacterial degradation of urea locally increases the pH and promotes the microbial deposition of carbonate as calcium carbonate in a calcium rich environment. These precipitated crystals can thus fill the cracks. The crack healing potential of bacteria and traditional repair techniques were compared in this research by means of water permeability tests, ultrasound transmission measurements and visual examination.

V.Achal et al. (2011) "Effect of calcifying bacteria on permeation properties of concrete structures," [3]
Microbially enhanced calcite precipitation on concrete or mortar had become an important area of research regarding construction materials. Study examined by stated the effect of calcite precipitation induced by Sporosarcina pasteurii (Bp M-3) on parameters affecting the durability of concrete or mortar. An inexpensive industrial waste, corn steep liquor (CSL), from starch industry was used as nutrient source for the growth of bacteria and calcite production, and the results obtained with CSL were compared with those of the standard commercial medium.

V.Achal et al. (2011), "Improved strength and durability of fly ash amended concrete by microbial calcite precipitation."[4]
Fly ash acts as a partial replacement material for both Portland cement and fine aggregate. An innovative approach of microbial calcite precipitation in fly ash-amended concrete had been investigated. This is the first report by to discuss the role of microbial calcite precipitation in enhancing the durability of fly ash-amended concrete. The present study investigated the effects of Bacillus megaterium ATCC 14581 on compressive strength, water absorption and water impermeability of fly ash-amended mortar and concrete. Mortar specimens were used for compressive strength and water absorption tests, while concrete specimens were used for water impermeability tests.

H Afifudin et al. (2011), "Microorganism precipitation in enhancing concrete properties."[5]
Microorganism is a unique living element and has the ability to precipitate minerals through the process of bio mineralization. The precipitation process occurred naturally and most of the precipitated products are very important compound composed of such as carbon, nitrogen, oxygen, sulphur, phosphorus and silica. So far, concrete incorporated with microorganism that able to precipitate calcium carbonate (calcite) was reported. However, little information on silica precipitation and its effect on concrete properties had been revealed. The concrete specimens were incorporated with Bacillus subtitles silica adsorbed in their cell wall by -. Concrete specimens with five different concentrations of Bacillus subtitles cell with 104, 105, 106 and 107 cell/ml and control (without Bacillus subtitles) were cast.

J. wang et al. (2012). **"Use of silica gel or polyurethane immobilized bacteria for self-healing concrete."[6]**
Cracks in concrete are the main reason for a decreased service life of concrete structures. It is therefore more advisable and economical to restrict the development of early age small cracks the moment they appear, than to repair them after they have developed to large cracks. A promising way is to pre-add healing agents to the concrete to heal early age cracks when they appear, i.e. the so-called self-healing approach was described by J. wang In addition to the more commonly studied polymeric healing materials, bacterial $CaCO_3$ precipitation also has the potential to be used for self-healing.

A.vahabi et al. (2013) ,"Calcium carbonate precipitation by strain Bacillus licheniformis AK01, newly isolated from loamy soil: a promising alternative for sealing cement-based materials".[7]
The relevant experiments were designed by available to determine the ability of indigenous bacterial strains isolated from limestone caves, mineral springs, and loamy soils to induce calcium carbonate precipitation. Among all isolates examined an efficient carbonate-precipitating soil bacterium was selected from among the isolates and identified by 16S r RNA gene sequences as Bacillus licheniformis AK01.

R.Pei et al. (2013), "Use of bacterial cell walls to improve the mechanical performance of concrete". [8]
The role of bacterial cell walls of Bacillus subtitles as a concrete admixture to improve the mechanical performance of concrete. The bacterial cell walls are known to mediate microbial induced carbonate precipitation, a process in which $CaCO_3$ is formed from Ca^{2+} ions and dissolved CO_2.
M.V.S.Rao et al. (2013), "A sustainable self-healing construction material."[9]
The well-known fact that concrete structures are very susceptible to cracking which allows chemicals and water to enter and degrade the concrete, reducing the performance of the structure and also requires expensive maintenance in the form of repairs. Cracking in the surface layer of concrete mainly reduces its durability, since cracks were responsible for the transport of liquids and gasses that could potentially contain deleterious substances. When micro cracks growth reaches the reinforcement, not only the concrete itself may be damaged, but also corrosion occurred in the reinforcement due to exposure to water and oxygen, and possibly CO_2 and chlorides too.

J.M Irwan et al. (2013), "Concrete Repair, Rehabilitation & Retrofitting II". [10]
World widely, concrete is one of the most popular construction materials because of its strong, durable and inexpensive material. It has specialty of being cast in any desirable shape but plain concrete however is porous, possesses very low tensile strength, limited ductility and little resistance to cracking. These problems become more complicated in various environmental conditions to which

concrete is exposed. Conventionally, a variety of sealing agent namely, latex emulsions suffer from serious limitations of incompatible interfaces, susceptible to ultraviolet radiations, unstable molecular structure and high cost.

3. RESEARCH METHODOLOGY

3.1 Selection of Bacteria

There are various types of Bacteria's that can be used in the concrete such as B. Subtilis, B. Pasteurii, B. Cohnii, B. Licheniformis etc. selected was Bacillus Subtilis since this bacteria produces Calcium Carbonate and due to ease of availability from local chemtech lab used it for future investigation. It is also formally known as Hay bacillus or grass bacillus, is a Gram-positive, catalane-positive bacterium, found in soil and the gastrointestinal tract of ruminants and humans. A member of the genus Bacillus, B. subtilis is rod-shaped, and can form tough, protective endo-spores, allowing it to tolerate extreme environmental conditions. B. subtilis has historically been classified as an obligate aerobe, though evidence exists that it is a facultative aerobe. B. subtilis is considered the best studied Gram-positive bacterium and a model organism to study bacterial chromosome replication and cell differentiation. It is one of the bacterial champions in secreted enzyme production and used on an industrial scale by biotechnology companies.

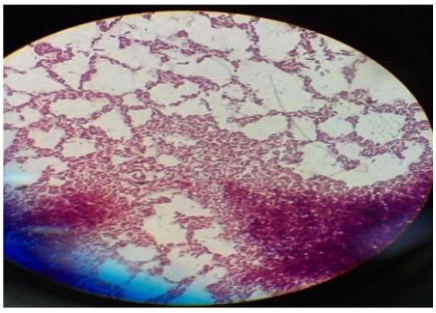


Fig 1: Microphotograph of strains of Bacillus Subtilis

3.2 Cultivation of Bacteria:

The pure culture of bacteria i.e. Bacillus Subtilis is preserved on nutrient agar slants. It forms irregular dry white colonies on nutrient agar slants. Two colonies of the bacteria are inoculated into nutrient both of 350 ml in 500ml conical flask and incubated at the temperature of 37 degree Celsius and 150 rpm orbital shaker incubator.

The medium composition used for growth of bacterial culture consists of Peptone, NaCl, yeast extract.

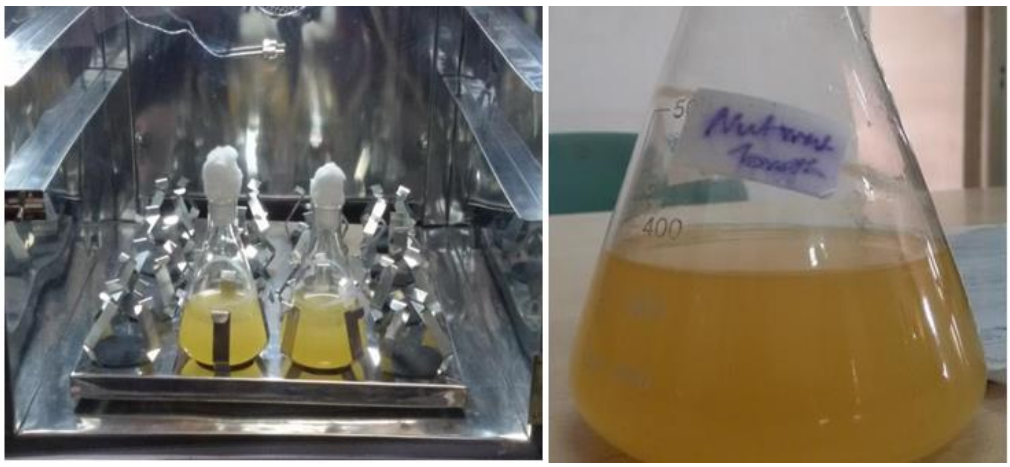


Fig 2: Bacterial solution in incubator

3.2.1 Experimental Procedure for Cultural Growth of Bacteria:-

S. pasteurii PTCC 1645 (DSM 33, ATCC 11859; CCM 2056; NCIB 8841; NCTC 4822) and B. subtilis PTCC 1715 (BGSC 1A747) prepared from the Persian type culture collection were used throughout the study. S. pasteurii formerly known as B. pasteurii is a bacterium with the ability to precipitate calcite and solidify sand given a calcium source and urea, through the process of biological cementation. B. subtilis is a common soil bacterium, which can produce calcite precipitates on suitable media supplemented with a calcium source (Reddy et al. 2010). The bacteria were cultured in liquid medium according to the

suppliers' recommendations. The medium used to grow bacteria consisted of 5.0 g peptone, 3.0 g meat extract, per liter of distilled water; to which 1.5% agar was added to obtain a solid medium for the stock culture. This medium was supplemented with 0.01 g MnSO4 · H2O to enhance sporulation and pH was adjusted to 7.0 using 1 N HCl. The mixture was first sterilized by autoclaving for 20 min at 121°C, allowed to cool to room temperature (25°C). According to supplier's recommendation for culturing of S. pasteurii strain, 10 mL filter-sterilized20% urea solution through a sterile 0.22 μm filter (Jet Biofil) was added aseptically post autoclaving to 100 ml cooled molten peptone/meat extract medium. For the first experiments, B. subtilis and S. pasteurii cultures were obtained through activation of lyophilized bacteria whereas for all later experiments cultures were obtained through sub culturing. Then, cultures were incubated at 30°C on a shaker incubator at 130 rpm for 72 h. Afterward, bacterial cells were harvested by centrifuging (5,000 r=min, 10 min) the 72 h-old grown culture and the cells were washed twice in saline solution (NaCl, 8.5 g=L).

3.2.1Safety Measures for Bacterial Solution

Bacteria are harmful for the health and it may lead to diseases, therefore precautions must be taken. It is compulsory to use gloves while dealing with the bacterial solution. The flask must be heated before pouring the bacterial solution. The whole procedure must be done between the two candles so that the bacterium doesn't get contaminated by the interference of the other bacteria's present in the environment.

3.3 Material

3.3.1 Cement:

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 3.0.

Fig 3: Cement.

3.2.2 Sand:

In this investigation the Sarangkheda sand confirming the zone III according to IS- 383.Specific gravity of sand was found out to be 2.60.

Fig 4: Sand.

3.3.3 Coarse Aggregate:

The coarse aggregate is strongest and porous component of concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring on account of movement of moisture. In investigation the aggregate used was passing through 20mm IS-Sieve and retaining on 12.5mm sieve. The specific gravity of aggregate was found out to be 2.50.

Fig 5: Coarse Aggregate.

3.3.4 Cube Moulds

The cube Moulds (150x150 mm) was placed in position on an even surface. All the interior faces and sides were coated with mud oil to prevent the sticking of concrete to the Moulds.

Fig 6: Cube Moulds

Fig 7: Curing of cubes

Fig 8: Bacterial Beads

4. EXPERIMENTAL METHODS & TEST

4.1 Preparation of concrete Mix, Cubes and samples labeling

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. In investigation M 30 grade of concrete was used. The mix ratio obtained after the mix design as per IS 10262 was M30 (1:2.21:3.09).Further, the concrete in the cube Moulds and six different samples were made which are as follows

a. Conventional Concrete of grade M 30.
b. Concrete with 15 ml bacterial solution.
c. Concrete with 30 ml bacterial solution.
d. Concrete with 45 ml bacterial solution.
e. Concrete with 60 ml bacterial solution.
f. Concrete with 75 ml bacterial solution.

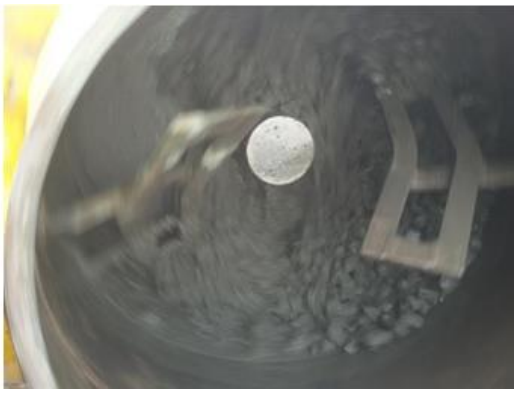


Fig 9: Mixing of Concrete

Fig 10: Labeling of Cube samples

4.2PH of concrete

The term pH refers to the measure of hydrogen ion concentration in solution and defined as the negative log of H+ ions concentration materials. The values of PH 0 to a little less than 7 are termed as acidic and the values of PH a little above 7 to 14 are termed as basic. When the concentration of H+ and OH- ions is equal then its termed as neutral PH.
In investigation it was found that the PH value of concrete by using the litmus paper. Once the concrete was completely mixed the litmus paper was touched to the concrete, the color of the litmus paper changed to darkish green with reading between 7-8.Therefore it gives the basis that bacterial solution will survive and further concreting work proceeded.

Fig 11: Litmus paper indicating the pH value of Concrete

4.3 Methods of mixing bacterial solution into concrete

There are different methods of mixing the bacterial solution in the concrete which are viz.

(a) Direct Mixing
(b) Indirect Mixing
(c) Injection method

In this the direct method adopted in which, firstly the measuring jars were sterilized in oven for a temperature of about 100^0C for 5 min. After 5 min once it gets slightly cooled, the bacterial solution is poured form the flask in the measuring jar. The flask is firstly heated under the candle before pouring it into the jar, so that the bacterium doesn't get contaminated by the other bacteria's present in the environment.

Fig 12: mixing of bacteria

Once the bacterial solution is mixed in the water, the water is properly stirred and then it is used for immersion in the concrete.

4.3.1 Casting of cubes and curing of different specimens of bacterial concrete

Once the concrete is completely mixed the concrete is poured in the cube, compaction is been done by the vibration machine. Concrete cubes were removed from the Moulds after 24 hrs. And they were put into the curing tank. Curing was done for 7, 14 and 28 days for all samples viz. Conventional, 15 ml, 30 ml, 45 ml, 60 ml and 75 ml.

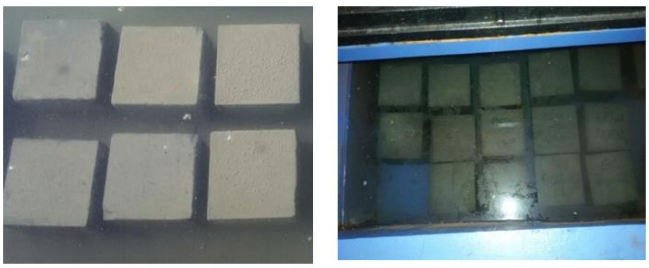


Fig 13: Curing Tank of concrete cube.

4.4 Experimental test on bacterial concrete-

Various tests are performed on bacterial concrete in order to get the results in various forms. These experimental methods are summarized below

4.5 Slump cone test-

The concrete slump test is an empirical test that measures workability of fresh concrete. The slump cone test indicates the behavior of a compacted concrete cone under the action of gravitational forces. The test is carried out with a Moulds called as slump cone. The slump cone is placed on a horizontal and a non-absorbent surface and filled in three layers of fresh concrete, each layer being tamped 25 times with a standard tamping rod. The test is suitable only for concretes of medium to high workability's (i.e. having slump values of 25mm to 125mm).

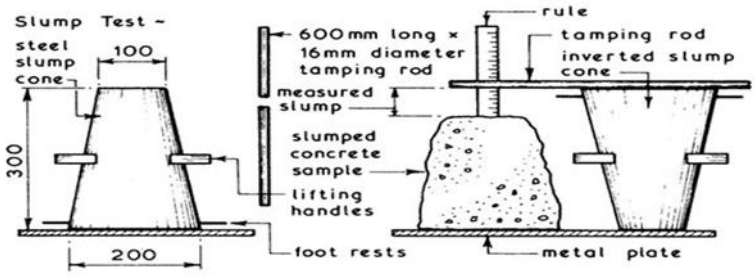


Fig 14: Showing the Slump Height.

The slump cone test results are used to observe the behavior of the concrete as shown in the below fig.11

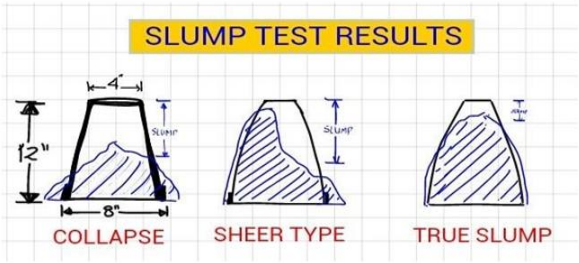


Fig 15: Slump Test Result.

The metal plate i.e. base is placed on a smooth surface and the container is filled with bacterial concrete in three layers, whose workability is to be tested. Each layer is temped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end. When the mound is completely filled with bacterial concrete, the top surface is struck off (leveled with Moulds top opening) by means of screening and rolling motion of the temping rod. The Moulds firmly held against its base during the entire operation so that it could not move due to the pouring of concrete by means of handles or foot rests. Immediately after filling is completed and the concrete is leveled, the cone is slowly and carefully lifted vertically, an unsupported bacterial concrete will now slump. The slump is measured by placing the cone just besides the slump concrete and the temping rod is placed over the cone so that it should also come over the area of slumped concrete. The decrease in height of concrete to that of Moulds is noted with scale which is found to be 110mm for conventional concrete and 50mm for bacterial concrete. Figure shows the performance of slump cone test.

Fig 16: Slump Cone Test

4.5.1 Compressive strength test

The concrete cubes were removed from the tank after their respective days of curing. The cubes were allowed to dry under the Laboratory condition. Once the cube were completely dried, placed under the compressive testing machine with an intention to get the compressive strength of concrete. The entire sample specimen tested under compressive testing machine.

Fig 17: CTM Machine

After removing the specimen from water over specified curing time and wiped out excess water from the surface. Cleaning out the bearing surface of the testing machine. The various sample specimens were placed one after another in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast. The specimen centrally aligned on the base plate of the machine. The load gradually applied without shock and continuously at the rate of 5.2 KN/sec till the specimen fails. The maximum load recorded and any unusual features in the type of failure noted down. Concrete cubes placed in the CTM machine before crushing and after crushing shown in fig. 16 below. Readings of each bacterial concrete sample viz. conventional, 15ml, 30ml, 45ml, 60ml and 75ml were taken each time after curing interval of 7days, 14 days and 28 days

Fig 18: After Crushing of Cubes.

4.5.2 Ultra sonic pulse velocity

This method consists of producing an ultrasonic longitudinal pulse by an electro acoustical transducer which is held in contact with one surface of the freshly placed concrete member under test. After traversing a known distance in the concrete, the pulse to be measured from which the pulse velocity timing circuit enables the transit time of the pulse to be measured from which the pulse velocity is calculated. This procedure is called the "**Ultrasonic method**." Ultrasonic pulse velocity test is generally carried out to determine the presence of voids in the internal structure of concrete by means of passing the ultrasonic rays through the body on concrete and also to know the denseness of the concrete structure. All the respective bacterial concrete samples viz. conventional, 15ml, 30ml, 45ml, 60ml and 75ml were tested and the corresponding readings were obtained in the form of trouble time and velocity.

Fig 19: **Test of bacterial concrete samples using Ultrasonic Pulse Velocity Machine.**

4.5.3 Plate count test-

The plate count test was conducted to determine total viable cells in a bacterial culture by plate count method. This method is used for determination of the number of cells that multiply under define conditions. It requires culture viz. Liquid culture of bacillus subtitles, water, and milk. Further the media taken is 20 ml nutrient agar deep tubes (3 in nos.), also the apparatus used were test tubes, pipettes, Petri plates, glass marking pencil and spreader. The plate count method is most commonly used for enumeration of viable cells in water, milk, food, and many other pharmaceutical substances. All organisms grow, reproducing a visible mass of microorganism called colony. After testing the bacterial concrete cubes in CTM machine, small part of all the samples were tested result shows the formation of visible mass as shown in fig.

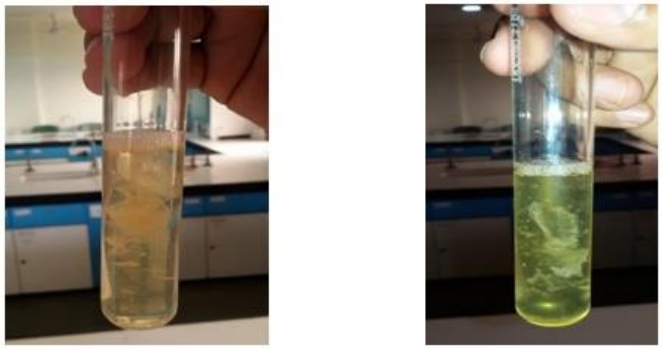


Fig.20: Formation of visible mass

The development of one colony from one microorganism can occur when the bacterial suspension is homogenous. If microorganism have a tendency to aggregate (e.g- Staphylococci, streptococci, diplococcic) that resulting counts will be lower than the actual no. of individual cells. Hence, counts of microorganism are often reported as colony forming units/ml rather than no. of bacteria/ml. the original sample is usually diluted so that the no of colonies developing on the plate will be in the range of 30-300.The total count of microbial suspension is obtained by multiplying the no. of cells per plate by the dilution factor. 1 g of concrete material from concrete block which was kept for curing for 14 days from different concrete block (containing 15, 30, 45, 60 and 75 ml of bacterial suspension) collected to study number of viable bacteria by serial dilution method.

4.5.4 Experimental procedure to obtain plate count test of bacterial solution

First mixing of 24hr. Incubated 1 g concrete material from each block was done by rolling the test tube between the palms to ensure even dispersion of cell in the culture. By using sterile pipette, aseptically transfer of 0.1ml bacterial suspension to the test tube containing 10 ml waterfall injection was done. The test tubes were labeled as tube a, tube B and tube C.

4.5.5 Scanning Electron Microscope (SEM)

The Morphology and mineralogical composition of the deposited calcium carbonate crystals were investigated using scanning electron microscope (SEM). SEM micrographs were obtained using a jeol JSM 5600 LV model Philips XL 30 attached with EDX unit, with accelerating voltage 30K.V., magnification 10x upto 400000x and resolution for W.(3.5 nm). Samples surface were first coated with carbon then with gold.

Fig 21: Scanning Electron Microscope Machine

5. EXPERIMENTAL RESULTS AND DISCUSSION

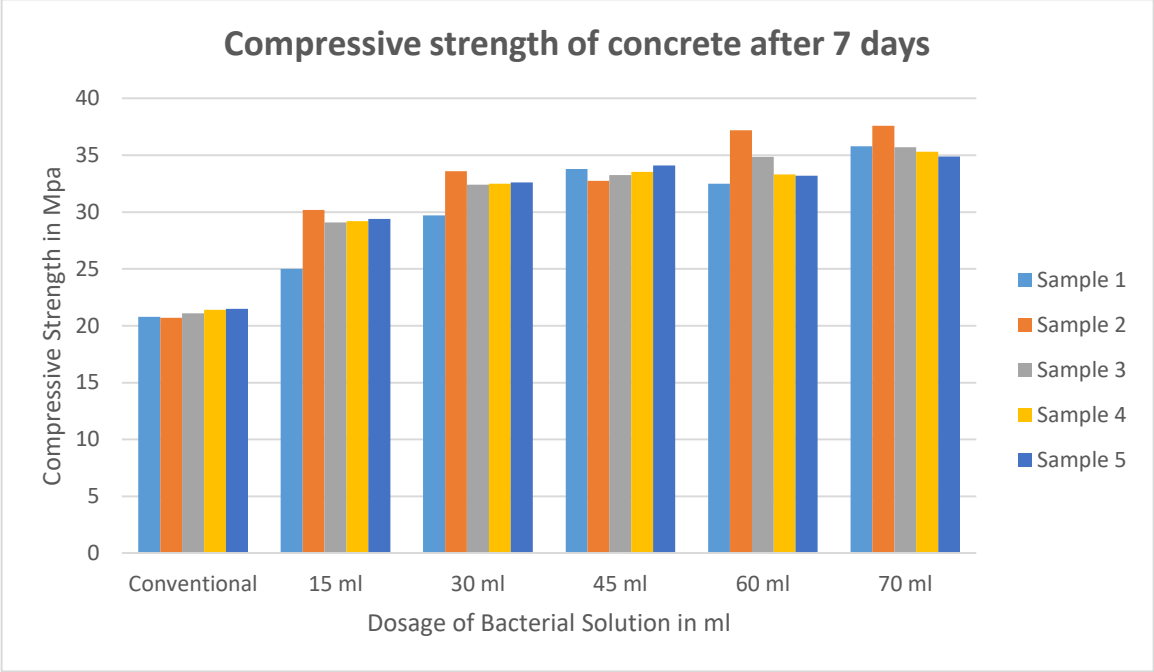
Various tests were conducted to know the characteristics of the concrete cube. The test was conducted to investigate the optimum dosage of the bacterial solution under which the cube attains its maximum strength.

5.1 Compressive Strength

Compressive strength of concrete cube was carried out after curing period of 7, 14 and 28 days. The results so obtained are tabulated below with their respective graph.

Table No 1: Compressive strength for 7 days

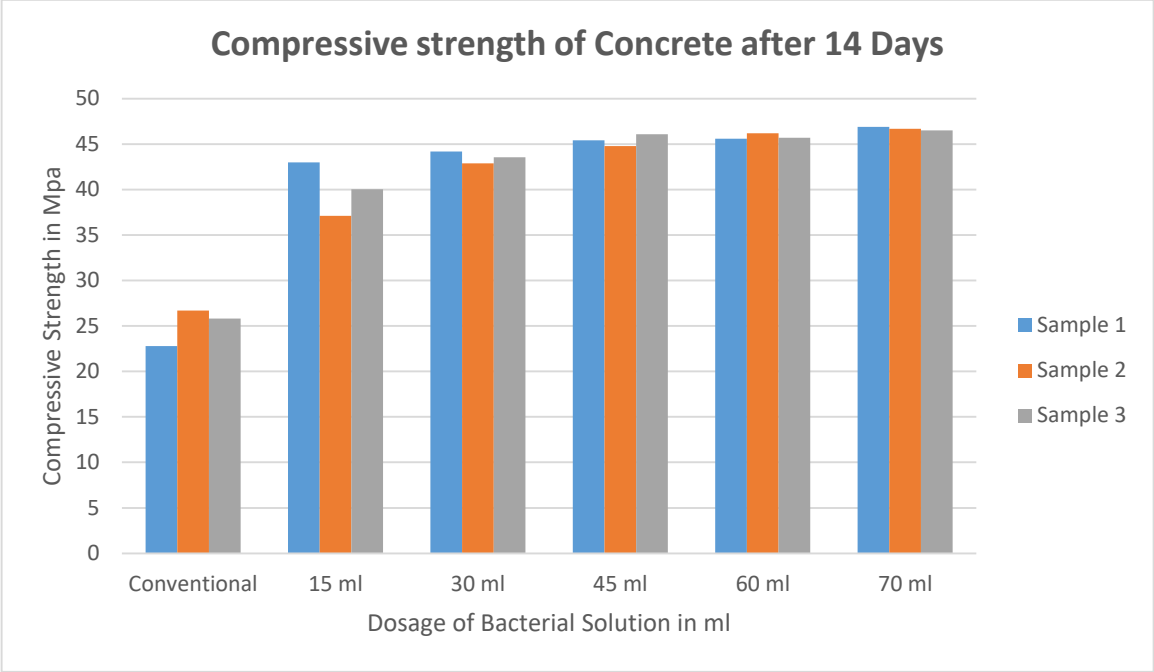
Type Of concrete	Compressive strength of concrete after 7 days				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Conventional	20.8	20.7	21.1	21.4	21.5
15 ml	25	30.2	29.1	29.2	29.4
30 ml	29.7	33.6	32.4	32.5	32.6
45 ml	33.8	32.74	33.27	33.54	34.1
60 ml	32.5	37.2	34.85	33.3	33.2
75 ml	35.8	37.6	35.7	35.3	34.9



Graph No 01: Compressive strength of concrete after 7 days

Table No 2: Compressive strength for 14 days

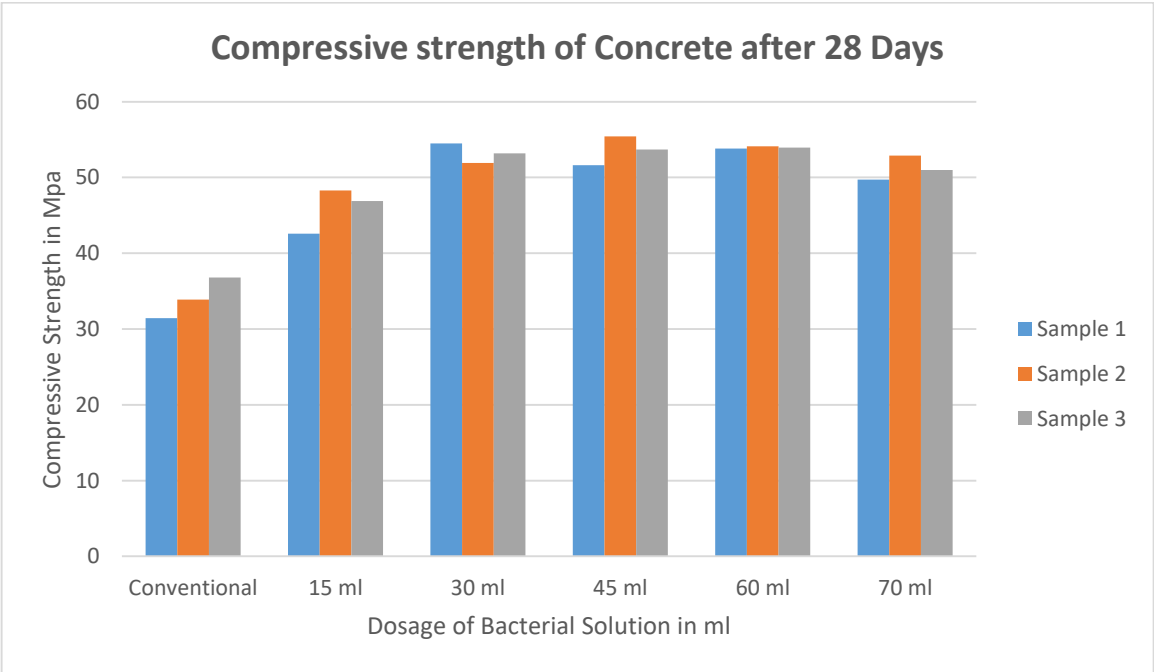
Type of concrete	Compressive strength of Concrete after 14 Days		
	Sample 1	Sample 2	Sample 3
Conventional	22.8	26.7	25.83
15 ml	43.0	37.1	40.05
30 ml	44.2	42.9	43.55
45 ml	45.4	44.8	46.1
60 ml	45.6	46.2	45.7
75 ml	46.9	46.7	46.5



Graph No 02: Compressive strength of concrete after 14 days

Table No 3: Compressive strength for 28 Days

Type of concrete	Compressive strength of Concrete after 28 Days		
	Sample 1	Sample 2	Sample 3
Conventional	31.45	33.9	36.81
15 ml	42.6	48.3	46.9
30 ml	54.5	51.9	53.2
45 ml	51.6	55.4	53.7
60 ml	53.8	54.1	53.95
75 ml	49.7	52.9	51.0



Graph No 03: Compressive strength of concrete after 28 days

5.2 Ultrasonic Pulse Velocity:-

Ultra sonic pulse velocity test was carried out to know the presence of voids in the internal structure of the concrete cubes. The results so obtained after conducting the test are tabulated below in table no.4. This results shows that of all the samples tested the trouble time of 30ml and 45ml bacterial concrete found to be much lesser, again velocity is also higher.

Table No 4: Ultrasonic Pulse Velocity Reading

SR No.	Property of Concrete	RCC Member	Prob. Distance mm	Time Micro sec	Velocity Km/sec	Probing Method
1	**Conventional concrete**	Cube	150	29.3	5.12	Direct
2	**Bacterial concrete**					
	15 ml	Cube	150	29.8	5.03	Direct
	30 ml	Cube	150	28.3	5.30	Direct
	45 ml	Cube	150	29	5.17	Direct
	60 ml	Cube	150	30.2	4.97	Direct
	75 ml	Cube	150	29.2	5.14	Direct

5.3Plate Count Method:-

Table No 5: Plate Count Test Result.

Sr. No.	mlofbacterialsuspension	Number of viable bacteria
1.	15	68×10^3
2.	30	77×10^3
3.	45	89×10^3
4.	60	48×10^3
5.	75	32×10^3

CONCLUSION

This study gives the idea that introducing the bacteria into the concrete makes it very serviceable and it also improves the properties of the concrete as compared to the conventional concrete

Bacteria repair the crack by the process of carbonate precipitation (bio deposition) the microbial concrete block the cracks and repair it. The other aspect of the bacterial concrete is that it is eco-friendly rehabilitation material.

The development of carbonate precipitation decreases the water permeability by decreasing the width of the crack. In the study it was found that the optimum dose required for bacterial concrete is 45 ml amongst the all other dosage i.e. 15ml, 30ml, 60ml, 75 ml. Bacterial concrete is very useful in the region like Nasik because the variation of temperature of day and night in Nasik is greater than 20 degree Celsius. Such a large amount of temperature variation may lead in formation of cracks. Therefore use of bacterial concrete reduces the cracks. In near future there is scope for use of such a material.

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