Performance Of Self Healing Of Bacterial Concrete To Repair For Micro Cracking

Dr. J.Rex[1], Gopi Reddy Abhishek[2], Akella Naga Sai baba[3]

[1]*Associate Professor Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad,500100.*
[2]*PG Student Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad, 500100.*
[3]*Assistant Professor Department of Civil Engineering, Malla Reddy Engineering College, Hyderabad,500100.*

Abstract:- The employment of carbonate-producing bacteria as a new approach to enhance the qualities of concrete has attracted a lot of interest since it is thought to be innocuous to theenvironment, natural, and maybe advantageous. This is a result of the favorable implications attached to these traits. The use of microbially induced carbonate precipitation as a remedy for a number of problems affecting concrete, such as fracture healing, reduction and change of porosity and permeability, and more, has been the subject of much investigation. Concrete crack healing is one of the topics that have been researched. Additionally, it has been shown that the procedure of bacterial carbonate precipitation, also known as bio deposition, contributes to the development of concrete's compressive strength. There has not yet been a thorough investigation of the research relating to the appropriate bacterial solution dose and its effect on concrete durability. This might occur as a result of the project not receiving enough time to complete it. As a result, it has been decided that an investigation will be conducted in order to determine the proper quantities of bacterial solution required for concrete. To do this, severalconcrete cube samples will be made using varying amounts of bacterial solution, such as 15 ml, 30 ml, 45 ml, 60 ml, and 75 ml, respectively. These quantities will be added to the appropriate moulds. This will allow you to determine the proper dosage of the bacterial solution to employ. In order to determine the optimal dosage that should be used, these various samples are also put through a battery of tests using a variety of laboratory techniques, such as the properties of materials, slump cone test, a compressive strength testing machine, an ultrasonic pulse velocity test, plate count cells, and scanning electron microscopes, Rapid Chloride Penetration Test (RCPT), Acid attack test.

Keywords*: Bacterial Concrete, Crack Repair, Bacterial Carbonate, Compressive Strength, Rapid Chloride Penetration Test (RCPT), Ultrasonic Pulse Velocity, Plate Count Cells, Scanning Electron Microscopes.*

1. Introduction

The use of carbonate-producing bacteria has garnered significant attention as a natural, eco-friendly, and potentially effective new method for enhancing the properties of concrete. Numerous studies have been done on the use of microbially induced carbonate precipitation (Dilja Rose Joseph, Life John 2017) [10] to reduce and modify porosity, permeability, and fracture repair in concrete. Additionally, as an alternative surface treatment, bacterial carbonate precipitation, or biodeposition, has demonstrated favorable effects on improving the compressive strength of concrete as well as reducing water absorption and carbonation (Pipat Termkhajornkit et al. 2009) [1].A portion of metabolism involves the production of the urea enzyme by certain bacteria (S. Sunil Pratap Reddy et al. 2010) [2] (C.C. Gavimath et al. 2012) [4]. This enzyme catalyzes the hydrolysis of urea to produce carbonate ions without producing protons in the process, which precipitates CaCO3 in the presence of calcium ions. Because of their negatively charged cell walls, bacteria not only offer a nucleation site for CaCO3 precipitation, but they also produce an alkaline environment that encourages the formation of more CaCO3 crystals. Equation (1) shows how one milliliter of urea is digested intracellularly to produce one milliliter of ammonia and one milliliter of carbonate.Carbonate hydrolyzes to produce ammonia and carbonic acid, per Eq. (2).The previous products, as shown by equations (3) and (4), eventually equilibrate in water to generate bicarbonate, ammonium, and hydroxide ions. The latter raises pH and produces carbonate ions [Eq. (5)], which precipitate as CaCO3 [Eq. (6)] when soluble calcium ions are present.

The entire reaction, represented by Eq. (7), shows that the addition of calcium and urea to the system produces ammonium and calcium carbonate.

$$C\,O\,(N\,H\,)_2 + H\,_2O \rightarrow N\,H_2\,C\,O\,O\,H\, + N\,H \quad \text{.....(1)}$$

$$N\,H\,_2C\,O\,O\,H + H\,_2O \rightarrow N\,H\,_3 + H\,_2C\,O\,_3 \quad \text{..... (2)}$$

$$H\,_2C\,O\,_3 \rightarrow H\,C\,O\,_3 + H^+ \quad \text{..... (3)}$$

$$2N\,H\,_3 + 2H\,_2O \rightarrow 2N\,H\,_{4+} + 2O\,H^- \quad \text{..... (4)}$$

$$H\,C\,O\,_{3-} + H^+ + 2O\,H^- \rightarrow C\,O\,_3{}^{2-} + 2H\,_2O \quad \text{..... (5)}$$

$$C\,O\,_3{}^{2-} + C\,a^{2+} \rightarrow C\,a\,C\,O\,_3 \quad \text{..... (6)}$$

$$C\,O\,(N\,H\,_2)\,_2 + 2H\,_2O\, + C\,a^{2+} \rightarrow 2N\,H\,_{4+} + C\,a\,C\,O\,_3 \quad \text{..... (7)}$$

Aim of the Work

The aim of this project is to

- Bacteria belonging to the bacillus family should be mixed in with the bacteria that are already present in order to produce bacterial concrete (Bacillus subtilis).
- To establish the ideal number of bacteria that should be employed in the manufacturing of bacterial concrete. The goal of this research is to achieve this.
- The method of serial dilution was used in order to determine the total number of viable bacterial cells.
- An ultrasonic pulse velocity test will be used for the purpose of determining whether or not there are openings.
- We use SEM to ascertain whether or not there are voids inside the internal structure of the concrete being examined.
- Investigate bacterial activity from the point of view of chemistry.
- Investigate how the change affects the characteristics of the concrete, such as how its compressive strength and permeability are affected by the transformation.

2. Materials

Cement: For the sake of this specific experiment, Portland cement of the standard 53 grade kind, which can be procured with relative ease, was used. The cement that was utilised was subjected to a battery of tests in accordance with IS: 4031-1988 to assess its different properties. The findings indicated that the cement was compliant with the various criteria of IS: 12269-1987 and had a specific gravity of 3.0. The examinations were carried out in accordance with the recommendations that were included in IS: 4031-1988.

Fine Aggregate: In the course of our investigation, we made use of GODAVARI sand, which provided conclusive evidence that zone III is relevant in light of IS-383's requirements. It was established that the specific gravity of sand is 2.60, giving it a value.

Coarse Aggregate: The component of concrete known as the coarse aggregate is the component that is both the most permeable and the most robust of all of the components that make up concrete. It is possible that drying shrinkage and other dimensional changes brought about by the passage of moisture may be decreased to a level that is more controllable if coarse aggregate is used. During the course of our experiment, we made use of an aggregate that was able to get through a 20mm IS-Sieve but was still able to be captured on a 12.5mm sieve. This allowed us to have the best of both worlds. Because of this, we were able to enjoy the benefits of both settings. After doing more research, it was discovered that the aggregate had a specific gravity of 2.50.

Bacteria: Bacillus Subtilis as shown in figure 1 is selected because it produces Calcium Carbonate which is main component for cement [2].

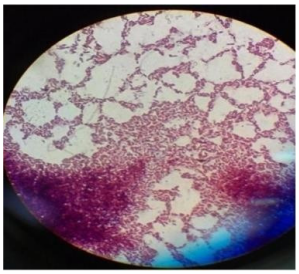

Figure 1: Bacillus Subtilis

3. Methodology

The mix ratio of M30 is 1:1.92:2.89 having the following different mixes confirming with IS:10262-2009 [12]

Conventional Concrete of grade M30
Concrete with 15 ml bacterial solution
Concrete with 30 ml bacterial solution
Concrete with 45 ml bacterial solution
Concrete with 60 ml bacterial solution
Concrete with 75 ml bacterial solution.

Cultivation of Bacteria

A pure culture of Bacillus Subtilis is maintained on nutrient agar slants. It forms uneven, dry white colonies on nutrient agar slants. As seen in figure , two bacterial colonies (Harshali J et al., 2016) are seeded into 350 mL of nutrient in a 500 mL conical flask and incubated at 37 degrees Celsius using an orbital shaker incubator running at 150 rpm. The three primary components of the bacterial culture medium are peptone, sodium chloride, and yeast extract.

Figure 2: Bacterial Solution

Slump Cone test

Three layers of bacterial concrete are added to the container, the workability of which is to be assessed, and the metal plate that acts as the foundation is set on a smooth surface. Tampering each layer 25 times requires the use of a typical 16 mm (5/8 in) diameter steel rod with a rounded end. Once the microbiological concrete is completely filled, the top surface of the mold is knocked off (leveled with the mould top aperture) by screening and rolling the tamping rod. Because concrete was being poured via handles and footrests, the Moulds stayed firmly in place at the base of the molds during the whole process, keeping them from shifting.After the concrete has been leveled and the filling has been completed, the cone should be carefully and gently removed vertically. If the concrete is left unsupported, it will now sink, as seen in figure 3.2. After tamping the area with the tamping rod and placing the cone next to the slumped concrete, the slump is measured. Scale measurements show that the height of concrete decreases to that of molds, with normal concrete measuring 110 mm and bacterial concrete at 50 mm.

Compressive Strength Test

The specimen was taken out of the water for the necessary amount of time to cure, and any excess water was scraped off the surface. The testing machine's bearing surface has to be cleaned. 2014; M. Manjunath et al. [7] The load was applied to the opposing sides of the cube cast as the several sample specimens were inserted into the machine one after the other. The specimen is precisely positioned on the machine's base plate as seen in picture 3.3.
Up until the specimen fails, the force is applied gradually, without shock, and at a rate of 5.2 KN/sec. Both the maximum load and any unexpected failure type features were noted. Pre- and post-crushing concrete cubes in the CTM machine. After a curing interval of 7, 14, and 28 days, the following measurements were made for each bacterial concrete sample: 15 ml, 30 ml, 45 ml, 60 ml, and 75 ml.

Plate count test

To find the total number of viable cells in a bacterial culture, an experiment employing the plate count technique was conducted. The experiment's plate count was counted in order to achieve this. In order to provide a solution to the issue that the research was trying to address, this method is utilized to calculate the number of cells that can reproduce under specific conditions.

Scanning Electron Microscope (SEM)

An examination of the deposited calcium carbonate crystals was done using a scanning electron microscope. The main objectives of this examination (SEM) were the crystals' form and mineralogical composition. A Jeol JSM 5600 LV type Philips XL 30 linked to an EDX unit was used to make the SEM micrographs. The voltage that was used to accelerate was changed to 30 kilovolts. The resolution was changed to W, and the magnification was increased as high as 400,000 times its initial size (3.5 nm). After having a layer of carbon applied to their surface, the samples were subsequently given a covering of gold to cover their exposed areas.

Rapid Chloride Penetration Test (RCPT)

The RCPT is performed by monitoring the amount of electrical current that passes through a sample with dimensions of 50 millimeters for thickness and 100 millimeters for circumference over the course of six hours. The sample's measurements are also 50 millimeters thick and 100 millimeters round. The sample is produced in the majority of laboratories as a slice cut from the center of a cylinder. Throughout the whole test, a steady direct current of sixty volts is maintained between the two ends of the sample. Two leads are submerged in different solutions: one with 3.0 percent sodium chloride (NaCl) and the other with 0.3 M sodium hydroxide (NoaH). As indicated in the Table, a qualitative assessment of the concrete's permeability is provided by the charge that is allowed to pass through the sample. The charge that is permitted to pass through the sample is used for this.

4. Results and Discussions

Compressive Strength Test results

After 7 and 28 days of curing, the compressive strength of the concrete cube was tested and confirmed by IS: 516-1959 [15]. The resulting findings, along with the corresponding graph, are listed below.

Table 4.1 Compressive Strength results for 7 days

Type Of concrete	Compressive strength of concrete after 7 days				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Conventional	20.86	20.70	21.16	21.45	21.55
15 ml	25.89	30.20	29.17	29.22	29.47
30 ml	29.76	33.65	32.48	32.55	32.64
45 ml	33.84	32.74	33.27	33.54	34.16
60 ml	32.58	37.27	34.85	33.37	33.29
75 ml	35.82	37.67	35.70	35.39	34.93

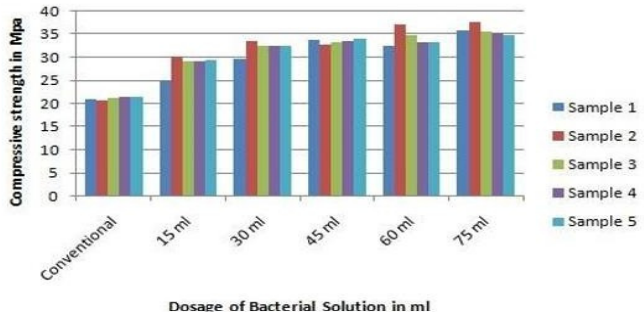

Figure 3: Compressive Strength Graph for 7 Days

Table 4.1 and Graph 4.1 provide information on the specimens' strength after seven days of curing. Every solution's five samples—15, 30, 45, 60, and 75 milliliters—are analyzed over the course of seven and twenty-eight days. Strength rises as bacterial dilution increases. Even after just seven days, the addition of Bacillus subtillis has increased the strength almost to the goal mean strength.

Table 4.2 Compressive Strength for 28 days

Type of concrete	Compressive strength of Concrete after 28 Days		
	Sample 1	Sample 2	Sample 3
Conventional	31.40	33.99	36.81
15 ml	42.61	48.39	46.96
30 ml	54.56	51.89	53.22
45 ml	51.69	55.46	53.74
60 ml	53.80	54.15	53.96
75 ml	49.50	52.95	51.08

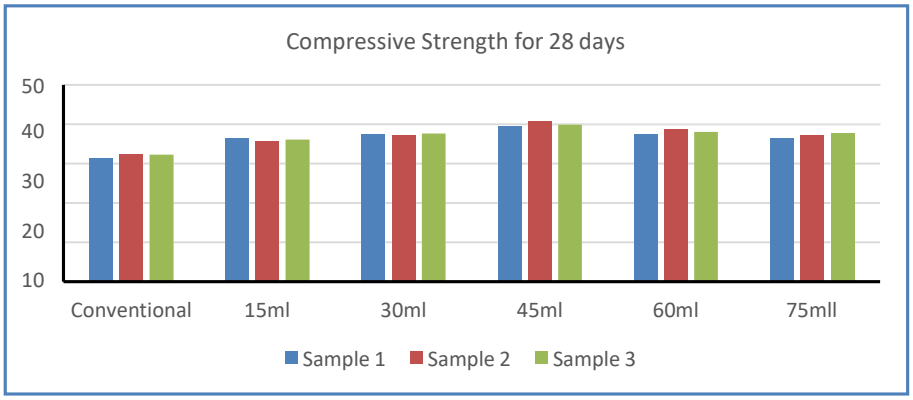

Figure 4: Compressive Strength graph for 28 days

Table 4.2 and graph 4.2 describes about the bacterial concrete specimens compressive strengthafter 28 days of curing at room temperature. The increment of the solution increases the strengthof concrete. But after 45ml solution the strength decreases gradually because of the bacterial content which are effecting the strength characteristics are increased.

Ultrasonic Pulse Velocity

To find out if there were any cavities in the inside structure of the concrete cubes, an ultrasonic pulse velocity test was performed. Following the exercise, the results were analyzed and compiled into table no. 4, which is shown a little bit later in this passage. It was discovered that substantially less time was spent fighting with 30 and 45 milliliters of bacterial concrete, and that the velocity was noticeably higher. These conclusions are supported by the facts. Every single specimen that underwent the testing process was in this condition.

Table No 4.3: Ultrasonic Pulse Velocity Reading

Property of Concrete	RCC Member	Prob. Distance mm	Time Micro sec	Velocity Km/sec	Probing Method
Conventional concrete	Cube	150	29.3	5.120	Direct
Bacterial concrete					
15 ml	Cube	150	29.70	5.13	Direct
30 ml	Cube	150	28.60	5.30	Direct
45 ml	Cube	150	29.30	5.17	Direct
60 ml	Cube	150	30.40	4.98	Direct
75 ml	Cube	150	29.90	5.12	Direct

Plate Count Method

Table No 4.4 : Plate Count Test Result.

bacterial suspension in ml	bacteria Number ofviable
15 ml	68 X 10^3
30 ml	77 X 10^3
45 ml	89 X 10^3
60 ml	48 X 10^3
75 ml	32 X 10^3

Rapid Chloride Penetration Test

Table 4.5: Rapid Chloride Penetration Test M30 grade concrete

Mix	Specimens (Coulombs)		Mean (Coulombs)
Control Concrete	Specimens- 1	1681	1665
	Specimens- 2	1642	
	Specimens- 3	1672	
15 ml	Specimens- 1	1674	1650
	Specimens- 2	1623	
	Specimens- 3	1652	
30 ml	Specimens- 1	1660	1636
	Specimens- 2	1665	
	Specimens- 3	1645	
45 ml	Specimens- 1	1672	1664
	Specimens- 2	1668	
	Specimens- 3	1652	
60 ml	Specimens- 1	1672	1678
	Specimens- 2	1686	
	Specimens- 3	1675	
75 ml	Specimens- 1 Specimens- 2 Specimens- 3	1660 1655 1665	1660

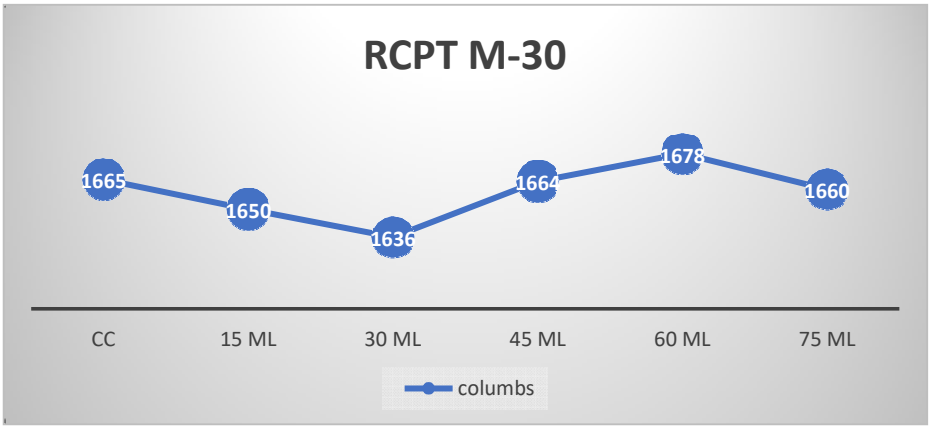

Figure 5: RCPT coulombs

Scanning Electron Microscope (SEM)

This helps to ensure accurate results. In addition to this, it offers an exceptional level of protection to the spores that are contained within the samples by offering resistance against the pressure that is generated inside the samples as a direct consequence of the production of microstructures. The resistance to the pressure that is formed in the samples is what allows this to be achieved. This validates the creation of calcium carbonate with a comparable crystalline structure and shows that the crystal growth recorded in SEM pictures is similarly. The patterns found in the outcomes of the study carried out by Wiktor and Jonkers are compatible with the variations in CaCO3 formation that take place depending on whether or not a carrier chemical is present In addition, this reveals that the crystal formations that were captured by SEM photos.

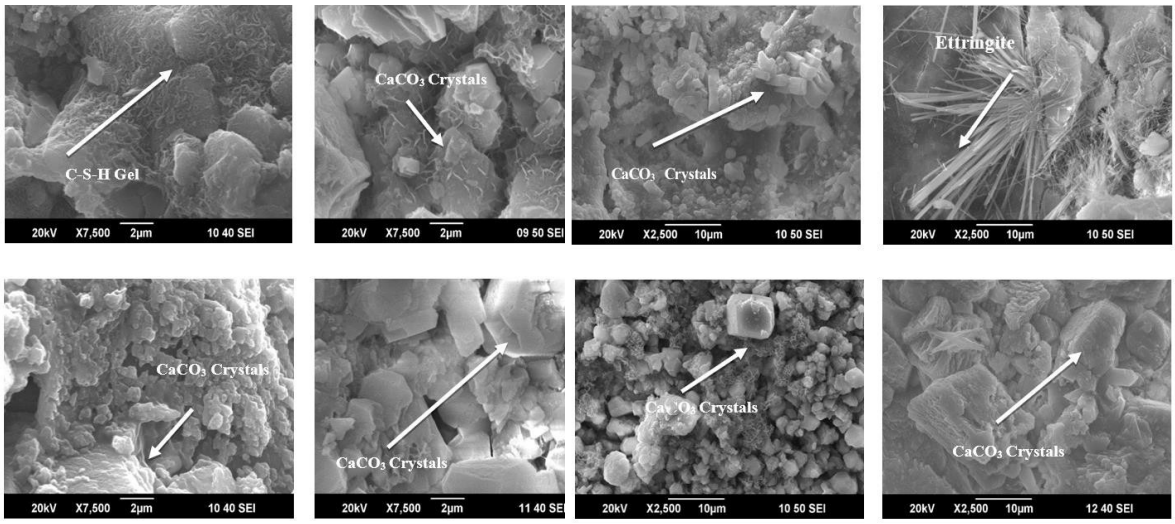

Figure 6: bacterial concrete effects on SEM

5. Conclusion

The production methods that have been studied and the effectiveness that has been assessed on bacterial self-healing concrete are highlighted. In conclusion, autogenous healing concrete may be made using any kind of bacterium that has the capacity to metabolically transform calcium sources into calcium carbonate. To maintain concrete's capacity for self-healing throughout the course of its lifetime, it is critical to shield the microorganisms therein. Comparing bacterial concrete to conventional concrete with an equivalent composition, the former is less strong. On the other hand, compared to ordinary concrete, bacterial concrete may totally mend apparent cracks autogenously.

- Incorporating "Bacillus Subtilis" at the correct concentration results in concrete more strength.
- The increasing of bacterial solution, the strength increases up to 60 ml and then strength decreases.
- As compared with conventional concrete, the concrete specimen containing 45ml solution of bacteria increases 25% strength considering the average of three samples after 28 days of curing.
- The concrete containing the 45ml bacterial solution is good to use for crack repairing purposes.
- Ultrasonic pulse velocity probing in direct method maximum in 30 ml of bacteria used velocity is increased.
- The maximum bacterial plate count in 45 ml
- Maximum Rapid Chloride Penetration values are 60 ml dosage of bacterial concrete.
- Compared to conventional, typical concrete, concrete has a considerably stronger resistance against acid attack. It has been demonstrated that using 60 ml in place of the original bacterial concrete provides noticeably better resistance to acid attack.
- A crack in concrete that is between one and forty-five micrometres wide may be healed in a period of thirty days, demonstrating that there is a viable cure for microcracks.
- Oxygen is the agent that may cause corrosion. However, since bacteria consume oxygen, the rate of corrosion can be lowered while the bacteria continue to thrive.
- The formation of cracks will be healed at an earlier stage than was originally envisaged, which will result in an increase in the service life of the structure beyond its projected life.

References

[1] Pipat Termkhajornkit, Toyoharu Nawa, Yoichi Yamashiro, Toshiki Saito Self-healing ability of fly ash cement systems. (2009).

[2] S. Sunil Pratap Reddy, M.V. Seshagiri Rao, P. Aparna and Ch. Shashikala Performanceof standard grade bacterial concrete, Asian Journal of Civil EngineeringVol.11, No.1 (2010).

[3] Kaustubh Dasgupta, A. S. Sajith Proceedings of SECON'19: Structural Engineering and Construction Management: 46 (Lecture Notes in Civil Engineering)

[4] C.C. Gavimath, B.M. Mali, J.D. Mallpur, A.B.Patil Potential application of bacteria to improve the strength of cement concrete. BioIT Journal Vol 3, Issue 1, 2012.

[5] Navneet Chahal, Rafat Siddique, Anita Rajor Influence of bacteria on the compressive strength, water absorption and rapid chloride permeability of fly ash concrete.

[6] Mayur Shantilal Vekariya, Prof. Jayesh Kumar Pitroda Bacterial Concrete: New Era for Construction Industry. IJETT- Vol 4 Issue 9- Sep 2013

[7] Prof. M. Manjunath, Prof. Santosh A. Kadapure, Ashwin Kumar A. Kalaje An experimental investigation on the strength and durability aspects of bacterialconcretewith fly ash. ISSN 2224-5790 ISSN 2225-0514 Vol. 6, No.6, 2014.

[8] Snajukta Sahoo, B.B. Das, A.K. Rath and B.B. Kar Acid, Alkali and Chloride resistance high volume fly ash concrete. Vol 8 (19) August 2015.

[9] Harshali J., Mitali S., Neha A., Pragati B. Bio concrete and bacteria based self- healing concrete. IJRET eISSN: 2319-1163 pISSN: 2321-7308 Vol.05 Issue: 05 May2016.

[10] Dilja Rose Joseph, Life John Strength assement of fly ash modified microbial concrete. Vol.7 Issue No.4 April 2017.

[11] Etaveni Madhavi, S.B. Sankar Rao, Gaddam Swarna Malika Strength properties ofa bacterial cement mortar when cement partially replaced with GGBS. Vol. 3, Issue-2,2017.

[12] IS 10262: 2009, Concrete mixing Proportioning.

[13] IS: 383-2016 –Coarse and Fine aggregates of concrete specifications‖, Bureau of Indian Standards, New Delhi.
[14] IS: 12269-1987 –Specifications for Ordinary Portland Cement for 53 Grade‖, Bureau of Indian Standards, New Delhi.
[15] IS: 516-1959 –Method of tests for strength of concrete‖, Bureau of Indian Standards,New Delhi.
[16] B. Dharmabiksham, Kallempudi Murali –Experimental investigation on the strength and durability aspect of bacterial self-healing concrete with GGBS and dolomite powder‖ , materials today proceeding, vol 66, no. 3, pp 1156-1161, 2022.
[17] K. Van Tittelboom, N. De Belie, ―Self-healing in cementitious materials are view‖, Materials, vol. 6, no. 6, pp. 2182–2217, 2013.
[18] V. Achal, A. Mukerjee, M. Sudhakara Reddy, –Biogenic treatment improves the durability and remediates the cracks of concrete structures‖, Construction Building Materials, vol. 48, pp.1–5, 2013.
[19] W. Khaliq, M.B. Ehsan, ―Crack healing in concrete using various bio influenced self- healing techniques‖, Construction Building Materials, vol. 102, no. 1, pp.349–357, 2016.
[20] V. Senthilkumar, T. Palanisamy, V.N. Vijayakumar, –Fortification of compressive strength in enterococcus microorganism incorporated microbial commenters‖, International Journal of Chemtech Research , vol. 6, no. 1, pp. 636–644, ISSN: 0974-4290, 2014.