Experimental Study on Bacterial Concrete

[1]Kushal Sable, [2]Kshitij Mahadik, [3]Viraj Bhadale, [4]Prasad Mandhare, [5]Azaruddin Shaikh, [6]Shrikant Kate
[1,2,3,4,5] Undergraduate Student, [6]Assistant Professor
Department of Civil Engineering
KJEI's Trinity Academy of Engineering, Savitribai Phule Pune University, Pune, India

Abstract: Due to low tensile strength, cracks are common phenomena of concrete, through which transport of harmful substances causes early deterioration of the concrete structure. Crack formation in concrete structures is inevitable due to deterioration throughout its service life due to various load and non-load factors. Bacterial concrete is a prominent solution for the cracks. Subtilis bacteria increases the compressive strength of standard grade concrete up to about 15% at 28 days, and also shows a significant improvement in split tensile strength compared to conventional concrete. Thus the project emphasis on the concept of preparing a bacterial based concrete that can help to resolve the problem of cracking economically without the use of the destructive method to enhance the durability of concrete structures.

Index Terms - Concrete, Bacteria, Crack Formation, Bacillus Subtilis, Bacterial Concrete

I. INTRODUCTION

Concrete is a composite material composed of coarse aggregate and fine aggregate bonded together with fluid cement that hardens over time. When aggregates are mixed together with dry Portland cement and water, the mixture forms fluid slurry that is easily poured and molded into shape. (Samudre et al. 2007) The cement reacts chemically with the water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. Concrete has high compressive strength but very low tensile strength due to which it fails in tension. So to overcome the tensile failure various techniques are being used such as providing steel reinforcement, various fibers as reinforcement or pre-stressing of concrete. Using these techniques overall strength of concrete is increased but due to the various factors like weathering, aging, asymmetric load, etc. degradation of structure takes place which leads to the formation of cracks. Cracks are very harmful to structure because of various chemicals can insert through these cracks damaging the concrete and reinforcement from inside which results in loss of strength and failure of the structures. Failure of the structure may cause a lot of economical as well as life loss. (A. Gandhimathi, N. Vigneswari, S.M. Janani, D. Ramya 2005) Finding and repair of these cracks is essential but very difficult and time-consuming job. So to overcome these problem bacterial concrete is one of the best solutions.(Kate and Jamale 2018) As self-healing property of bacterial concrete can repair cracks automatically without any human intervention. The bacteria present in these concrete secrets lime when it gets activated which repair the crack automatically. This reduces the time and cost of finding and repairing the cracks manually.

Due to low tensile strength, cracks are common phenomena of concrete, through which transport of harmful substances causes early deterioration of the concrete structure. So, for sustainable development, it is needed to increase the durability of concrete. Self-healing approaches may be regarded as a promising solution to reduce the excessive maintenance cost of concrete structures. This paper presents the crack-healing phenomenon in concrete by the microbial activity of bacteria namely Bacillus Subtilis. The bacteria were directly incorporated in different concentrations in concrete. The results showed that by using the bacteria not only the cracks were healed; the compressive strength of concrete was also improved. The results show(Amirreza Talaiekhozan et al. 2014)ed a different healing behavior depending on the exposure, demonstrating that the presence of water is essential for the healing reactions. The cracks were healed mainly due to the calcite precipitation by the bacterium

Recent studies reveal that using bacteria to mix into concrete material promote generating a specific precipitated product. Such product allows improving physio-mechanical properties of concrete materials at both early and later age. Given in the result of material analysis, there is an increasing crystalline of precipitated calcite by bacteria. At a smaller scale in bacteria modified mortar(prismatic samples 40x40x160 mm), both compressive and flexural strengths increase in comparison with those of normal sample, 57 61 MPa (in compression) and 9 11 MPa (inflection). At greater scale in bacterial concrete (cube samples150x150x150 mm), compressive strengths are higher (about 18 than obtained results of the normal concrete sample at age of 2months.(Vekariya and Pitroda 2013) For the (Borah and Chetia 2016)reason off better control of the process of precipitation, Bacillus subtilis HU58 and nutrient were first immobilized in diatomite Lam Dong, before introducing in a cement matrix. We examined the self-healing capacity of crack opening that was artificially prepared Cl-1.8 mm by width) after the early setting of cement mortar. Results of the water permeability test, developed in the laboratory presented the evidence of remediating crack and fissure due to bacteria.

Carbonate-producing bacteria have attracted lots of interest as a promising, natural, environmental friendly novel technique to the improvement of concrete characteristics. Considerable research has been conducted on utilizing microbial-induced carbonate(Kumar et al. 2015)e precipitation to mitigate several concrete(Dinesh et al. 2017) 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 the bacterial solution and its effect on the durability of concrete has not been comprehensively investigated. Therefore, it is decided to carry out (Getnet Meharie 2018)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.(Kate and Jamale 2018)

This research was done because due to low tensile strength, cracks are common phenomena of concrete, through which transport of harmful substances causes early deterioration of the concrete structure.(Kate and Kumbhar 2017) It can cause a structural failure which causes greater economical as well as life damage. The locating and maintenance of these cracks is an expensive and time-consuming process. So, for sustainable development, it is needed to increase the durability of concrete

Bacterial concrete is a prominent solution for the cracks. As the self- healing property of the bacterial concrete reduces locating as well maintaining cost up to a certain extent. It reduces the chances of structure failure. In addition to the self-healing property, it increases strength at a certain amount. So the objective of our project is

1. Study and analysis formations of cracks in concrete
2. Determine suitable bacteria for crack healing in concrete
3. To determine optimum bacterial dosage and observe the change in the properties of concrete.
4. To compare the cost of bacterial to the conventional concrete

II. LITERATURE REVIEW

Meera C. M., Dr. Subha V (2017): It was observed that with the addition of bacteria there is a significant increase in the tensile strength by63% for a bacteria concentration of 105 cells/ml at 28 days. It was observed that the compressive strength of concrete showed a significant increase by 42% for cell concentration of 105 of mixing water.

"Salmabanu Luhar1, Suthar Gourav2" (2014): Bacteria repair the cracks in concrete by producing the calcium carbonate crystal which blocks the cracks and repairs it. The stress-strain test was performed on the cylindrical specimen prepared in the universal testing machine of 3000KN capacity which shows higher toughness of bacterial concrete over conventional concrete. "Dinesh R. Shanmugapriyan & S.T.Namitha Sheen"(2017): This paper is an attempt to define bacterial concrete, its classification and types, mechanism adopted, advantages, disadvantages and its application in the field of construction by literature view are discussed Mohini P. Samudre, M. N. Mangulkar, S. D. Saptarshi"(2014): This paper outlines the basic mechanism involved in microbial concrete on which studies were carried out to investigate the causes involved in enhancing the strength and durability of concrete. Microbial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and very convenient for usage.

III. RESEARCH METHODOLOGY

For this project M25 grade of concrete has been used. The cement used is 53 grade ordinary Portland cement. Well-graded sand with a bulk density of 1.75 kg/cum was used. 10 mm and 20 mm aggregates with bulk density 1.56 and 1.57 were used. 200 gm of fly ash with fineness 18% was used. The mix proportion adopted was 1:3.12:3.25. Admixtures i.e. superplasticizer 13gm was used. 8 cubes of 150x150x150mm and 2 beams of 700x150x150mm are used for comparison purpose. Bacteria used are Bacillus subtilis and method of insertion is direct and indirect.

Collection Of Material: Selection of bacteria - Bacillus Subtilis is considered the best gram-positive bacterium and a model organism to study bacterial chromosome replication and cell differentiation there are various types of bacterias that can be used in the concrete such as Bacillus Subtilis, Bacillus 0Pasteurii, Bacillus Cohnii, Bacillus Licheniformis, etc. They had selected Bacillus Subtilis since this bacteria(Meera and Subha 2016) produce calcium carbonate and due to ease of availability from National Chemical Laboratory (NCL). They had used for their future investigation. It is also formally known as Hay bacillus or grass bacillus is a Gram-positive, catalase-positive bacterium found in soil and the gastro-intestinal trap of remints 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. Bacillus Subtilis (Table 3.1) has historically been classified as an obligate aerobe, through evidence exist that is a facultative aerobe

Table 1- Bacterial details

NCMR accession no.	MCC 2183
Taxonomic designation	Bacillus subtilis
Strain Designation	LS-1
Synonym(s)	----
History	----
Source of isolation	Lonar lake soil sample
Location	Town: Lonar, Dist.: Buldhana, State: Maharashtra, India
Medium Name & No.	72a (Horikoshi and Akiba Agar (HAA)/Broth (HAB) Medium (pH 12.0))
Growth conditions (pH / Temp. °C)	12.0 / 30°C
Incubation (days/ h)	24 h
Subculturing period (days)	3-6 months
Risk group	----
GenBank accession no	----
Other culture collection no.	----
Additional Information	----
Reference	(1) Int. J. Syst. Bacteriol.,1980, 30:225., (2) J. Biosci.Discov., 2012, 3:34.

Cultivation of Bacteria- The pure culture of bacteria that is Bacillus subtilis is preserved on nutrient agar slants. It forms irregular dry white colonies on nutrient agar slants. Two colonies of bacteria are inoculated into the nutrient broth of 250 ml in 750 ml conical flask and incubated at a temp of 37 degrees C and 150 rpm orbital shaker incubator. (fig 1) The medium composition used for growth of the bacterial culture of peptone, NaCl, beef extract. (fig 2)

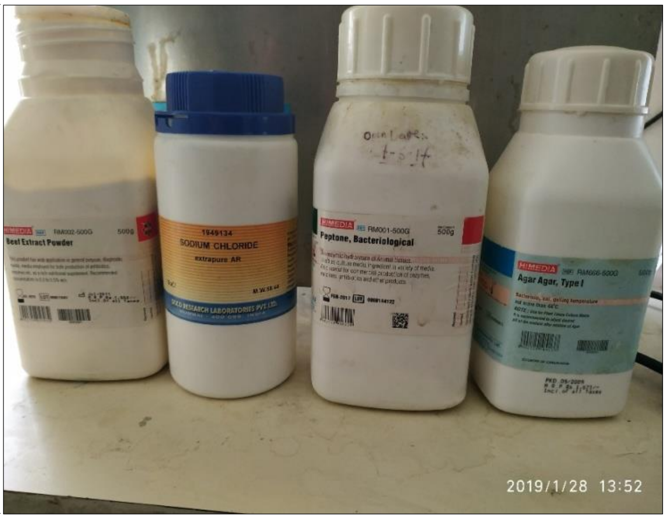

Fig. 1 Bacterial cultural Fig. 2 Chemicals used as nutrients for bacteria

Experimental procedure for cultural growth of bacteria - Bacillus Subtilis MCC 2183.B subtilis is a common soil bacterium, which can produce calcite precipitates on suitable media supplemented with a calcium source. (Palanisamy 2017) The bacteria were cultured in a liquid medium according to the supplier's recommendations. The medium used to grow bacteria consisted of 10gm peptone, 10gm beef extract, 5gm NaCl per lit of distilled water. For solid medium, 2% of agar was added to the same. The mixture was first sterilized by autoclaving for 20 mins at 121 degrees C, allowed to cool down to room temperature (25 degree C). The whole culturing process was performed under sterile condition. Then the cultures were incubated at 37 degree C on a shaker incubator at 130 rpm for 72 hrs.

Safety measures for a bacterial solution - Bacteria are harmful to health and it may lead to disease, therefore precautions must be taken. The flask must be sterilized before use. The whole process must be done between two burners so that bacterium does not get contaminated by the interference of the other bacteria present in the environment

Analysis of mix design

Table 2 Mix design contents

Total cementitious, content	21.00 kg
Cement	15.8 kg
Fly ash	5.2 kg
coarse aggregate 20 mm	40 kg
coarse aggregate 10 mm	26.1kg
Fine aggregate	50 kg
Admixtures	0.21kg
Total water	10.8 lits

Analysis of bacterial count

Table 3 Bacterial count

The concentration of 1-liter solution	Flask 1	Flask 2	Flask 3
600 nm	0.27	0.22	0.17
540 nm	0.59	0.52	0.46

Therefore cell concentration in Flask 1= 1.08*108 cells/ml, Flask 2= 8.0*107 cells/ml, Flask 3= 6.8*107 cells/ml

Casting of Cubes by Direct Method - From study direct method is adopted in which, firstly the measuring jars were sterilized in the oven for a temperature of about 1000□for 5 min. After 5 min once it gets slightly cooled, the bacterial solution is poured form the flask in the measuring jar.(Pasnur and Jain 2018) 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. 45ml of bacterial solution for each concrete block is to be adopted. Once the bacterial solution is mixed with water, the water is properly stirred and then used for immersion in the concrete.(figure 3)

Fig. 3 Casted Cube

IV. Results and Discussion:

General - The tests performed for this project are a compression strength test for 7, 14, and 28 days (figure 4) and flexural strength test for 28 days(figure 5). Compressive strength test is carried out in the compressive testing machine. In this test, the compressive strength of the cubes is determined. Flexural strength test is conducted on a universal testing machine for 28 days. In this test, the flexural strength of the beam is determined. Cost Analysis is also carried out for comparison between the cost of using conventional concrete and cost of bacterial concrete.

Compression Test:

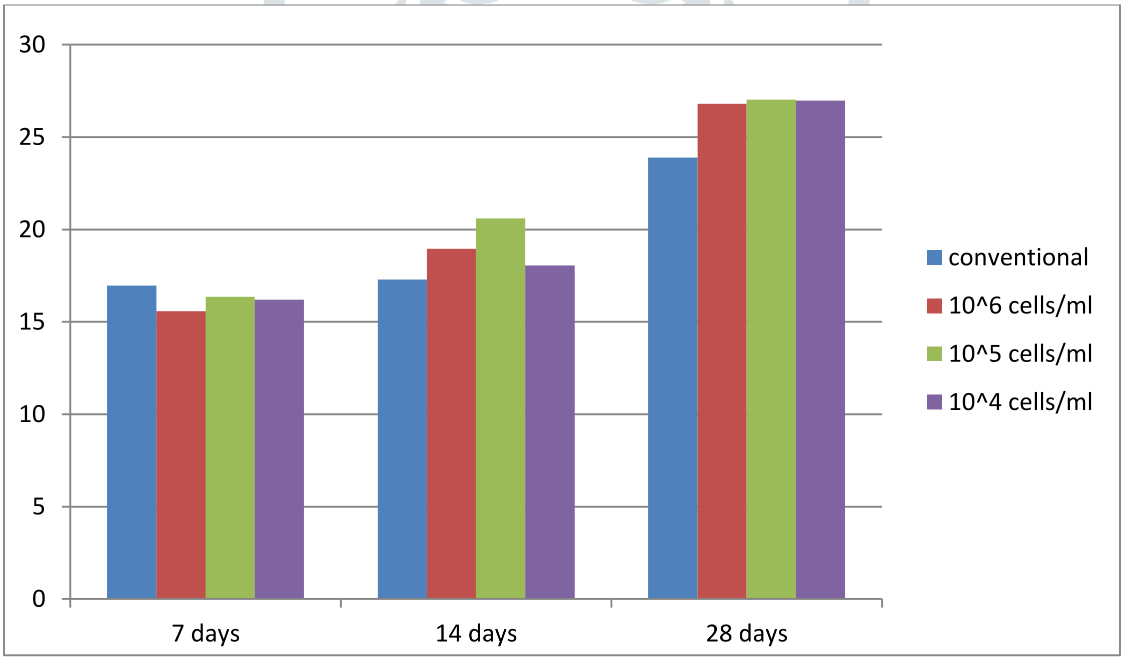

Fig. 4 Comparison between conventional and bacterial concrete for flexural strength

The test results show that the strength of bacterial concrete exceeds the strength of conventional concrete in 14 and 28-day compression test(figure 4). The conventional concrete shows more compressive strength on the 7th day than bacterial concrete. The concrete with a concentration of 10^5 cells/ml shows higher growth in compressive strength compared to other concentration as well as conventional concrete and is, therefore, an optimum dosage for preparation of bacterial concrete.

Flexural Test:

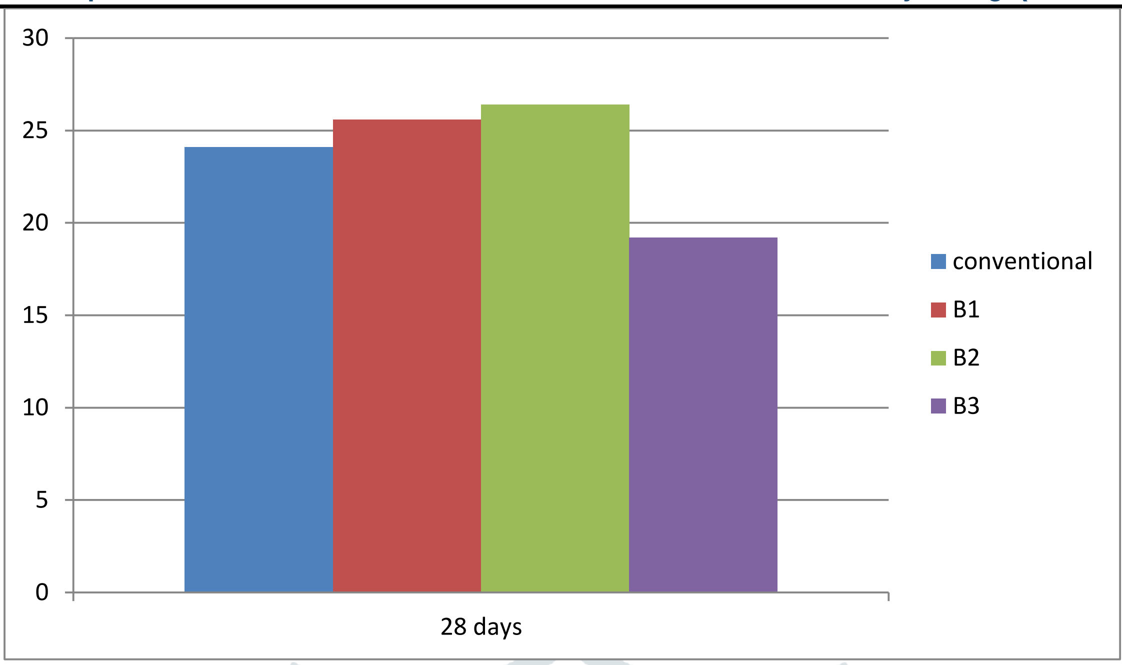

Fig. 5 Comparison between conventional and bacterial concrete flexural strength

The test results show that the flexural strength of bacterial concrete exceeds the strength of conventional concrete in flexural strength as tested in a Universal testing machine (UTM) (figure5). The concrete with a concentration of 10^5 cells/ml shows higher growth in flexural strength compared to other concentration as well as conventional concrete and is, therefore, an optimum dosage for preparation of bacterial concrete.

Cost Analysis

Approximate cost of bacterial concrete for 1m^3

1. Bacteria cost Rs.1200/- for approx.. 36Liter of the bacterial solution
2. (Considering 3 months life span and 2.5 days incubation period)
3. Nutrient Broth cost (100gm) Rs.412/-
4. For 0.06 m^3 concrete – 100ml of bacterial solution of 10^5 cells/ml
5. For 100ml bacterial solution – 1.3gm of Nutrient Broth
6. For 1 m^3 concrete
7. 1 m^3 concrete – 1.7 L of a bacterial solution of 10^5 cells/ml
8. 1.7 L of the bacterial solution – 22.1 gm of Nutrient Broth
9. Cost of 22.1 gm of Nutrient Broth – approx. Rs.91/-
10. Cost of bacteria for 1.7 L solution – approx. Rs.57/-
11. The total cost of Bacteria + Nutrient Broth for 1m3 of concrete = approx. Rs.148/-

Repair and maintenance cost of a project

12. Different structures have different percentage of repair and maintenance cost.
13. On an average5% of the project cost is given for the repair and maintenance.
14. In that 1-2% is given for crack repair.

Closure

Therefore a maximum amount of repair and maintenance can be saved by using bacterial concrete and proves to be economical in the long term.

V. CONCLUSION

The strength of the bacterial concrete is more than conventional concrete as compared.All concentrations of bacterial concrete show relative hike in strength than conventional concrete. Amongst all, 105cell/ml shows the maximum strength gain. The bacteria in the concrete heal the crack without human interference. In bacterial concrete, cracks are not only healed but strength is also regained.As the repair and maintenance cost of the project minimizes, the bacterial concrete is economical. The direct method of insertion of bacteria is more economical than the indirect method. As the chemical required in the indirect method is costly, the overall cost of a project increases. a maximum amount of repair and maintenance can be saved by using bacterial concrete and proves to be economical in the long term. The cracks were healed mainly due to the calcite precipitation by the bacterium. Different concentrations of bacteria also show a difference in the efficiency of healing.

ACKNOWLEDGMENT

We must mention several individuals and organizations that were of enormous help in the development of this work. Professor Shrikant Kate our supervisor, philosopher and personality with a Midas touch encouraged me to carry this work. His continuous invaluable knowledgeable guidance throughout the course of this study helped me to complete the work up to this stage and hope will continue in further research. We are also very thankful to Prof. Mughda Dicholkar of Bio-Technical Department of Sinhgad College of engineering my examiner for their valuable suggestions and guidance in working of bacteria.

REFERENCES

A. Gandhimathi, N. Vigneswari, S.M. Janani, D. Ramya, D. S. and T. M. (2005). "Experimental Study on Self - healing Performance of Concrete." *Emerging Trends in Engineering Research*, 17, 17–28.

Amirreza Talaiekhozan, Ali Keyvanfar, Arezo Shafaghat, Ramin Andalib, M.Z Abd Majid, Mohamad Ali Fulazzak, Rosli Mohamad Zin, Chew Tin Lee, Mohd Warid Hussin, Norhaliza Hamzah, Nur Fatimah Marwar, and H.I. Haidar. (2014). "A Review of Self-healing Concrete Research Development." *Journal of Environmental Treatment Techniques*, 2(1), 1–11.

Borah, M. M., and Chetia, N. (2016). "A Review on Self Healing Concrete." *International Conference on Advanced Material Techniques (ICAMT) - 2016*, 5(3), 53–58.

Dinesh, S., Shanmugapriyan, R., and Sheen, S. T. N. (2017). "A Review on Bacteria - Based Self-Healing Concrete." (1), 1023–1026.

Getnet Meharie, M. (2018). "Factors Affecting the Self-Healing Efficiency of Cracked Concrete Structures." *American Journal of Applied Scientific Research*, 3(6), 80.

Kate, S. R., and Jamale, P. B. (2018). "To Investigate the Effect of Permeability Properties on Hsc Using Different Mineral Admixture." *Journal of Advances and Scholarly Researches in Allied Education*, 15(2), 314–318.

Kate, S. R., and Kumbhar, S. S. (2017). "Water Quality Analysis a case Study of Urun-Islampur City." *Journal of Water Resource Engineering and Pollution Studies*, 2(3), 1–14.

Kate, Shrikant & Cahvan, Vikramsing & Karanawat Yash Lalwani, Shubham & Mahamuni, Mahesh & Patil, Nilesh. (2018). Planning of Multi-Storey Building Using Advance Tools and Techniques. 10.13140/RG.2.2.21386.77769.

Kate, Shrikant & B. Jamale, Prajkta. (2018). To Investigate the Effect of Permeability Properties on Hsc Using Different Mineral Admixture. Journal of Advances and Scholarly Researches in Allied Education. 15. 314-318. 10.29070/15/56838.

Kumar, A. P., Devi, A. R. A., Anestraj, S., Arun, S., and Santhoshkumar, A. (2015). "An experimental work on concrete by adding bacillus subtilis." *Indian Journal of Environmental Protection*, 35(11), 911–915.

Meera, C. M., and Subha, V. (2016). "Strength And Durabilityassessment Of Bacteria Based Self- Healing Concrete." 1–7.

Palanisamy, M. (2017). "Bacterial Concrete : a Review." *International Journal of Civil Engineering and Technology*, 8(2), 588–594.

Pasnur, P. K., and Jain, V. (2018). "A Review Paper on Basic Characteristics of Bacterial Concrete." *Journal of Advances and Scholarly Researches in Allied Education*, 15(2), 657–660.

Samudre, M. P., Mangulkar, M. N., Saptarshi, S. D., and Student, P. G. (2007). "A Review of Emerging Way to Enhance the Durability and Strength of Concrete Structures: Microbial Concrete." *International Journal of Innovative Research in Science, Engineering and Technology (An ISO*, 3297(2), 2319–8753.

Vekariya, M. S., and Pitroda, J. (2013). "Bacterial Concrete: New Era for Construction Industry." *International Journal of Engineering Trends and Technology*, 4(9), 4128–4137.