SELF HEALING BACTERIAL CONCRETE

Ms. Sanchali Pandurang Pawar, Ms.Pallavi Ramdas Marge, Mr. Pratik Bhagwan Kshirsagar
Ms. Chitralekha Veneshwar Dudhabale, Prof. Prashant L Jogdand

Department of Civil Engineering, G H Raisoni College of Engineering & Management,pune.

Abstract: A major The cement industry is major global contributor to world CO_2 emission (8% in 2008). A major cause of this high percentage in this durability issues associated with concrete in recent years a new base on concrete that has the ability to heal cracks which are major cause of this durability issue has been developed called self healing bacterial concrete.

In this we will introduced the form of concrete in various forms which is particular attention paid to the form which incorporates use of microbes as the healing agent.

Whenever cracks occur the water present in bacteria become active and covert the incorporated organic compound in to the mineral calcium carbonate, known as lime stone.

Lime stone precipitate and it's able to seal and block cracks, allowing autonomous healing. This helps in the development of bacteria based self healing, introducing the proposed healing system.

Key words :- Cracks, Durability issue, Self healing concrete, Calcium carbonate, Bcteria.

INTRODUCTION: Backgrownd: In past, quite a few investigation on self healing of concrete have been conducted. Neville (2002) gives a useful overview of his literature search in field. He puts the practical significance of autogenous healing in reduction of water transport through cracrk, for example water concrete pipes.

History of microbiology, Bacteria were first observed by Antoine Van Leeuwenhoek 1676, using a single-lens microscope of his own design. He called them "animalcules" and published his observation in series of letters to the royal society. The name bacterium was introduced much later, by Christian Gottfried Ehrenberg in 1838. Louis Pasteur demonstrated in 1859 that the fermentation process is caused by the growth of microorganisms. Along with his contemporary, Koch, Pasteur was an early advocate of the scientific theory of disease. There are generally two differing types of cell membrane in bacteria called gram positive and gram negative. The first phase of growth is that the lag phase, a period of slow growth when the cells are adapting to the high nutrients environment and preparing for rapid growth. second phase of growth is that the logarithmic phase (log phase), also called the exponential phase. The final phase of growth is that stationary phase and is caused by depleted nutrients. The cells reduce their metabolic activity and consume non-essential cellular proteins.

Bacterial Concrete : The Process can occur inside or outside the microbial cell or perhaps a long way away within the concrete. Often bacterial activities simply trigger a change in solution chemistry that ends up in over saturation and mineral precipitation. Use of those Bio mineralogy concepts in concrete ends up in potential invention of latest material called Bacterial Concrete.

Bacteria based system involves the employment of ureolytic bacteria of genus Bacillus for the assembly of carbonate minerals. The metabolism of this genus of bacteria involves the enzymatic hydrolysis of urea to ammonia and greenhouse gas. The reaction also causes a rise of pH from neutral to alkaline conditions forming bicarbonate and carbonate ions, which precipitate with the Calcium ions within the concrete to make carbonate minerals. The further crystallisation of the carbonate minerals heals the pores and cracks within the concrete. Various Bacteria used in the concrete are - Bacillus Pasteurii, Bacillus phaericus, Escherichia coli, Bacillus Subtilis (used in the present study).

LITERATURE SERVAY: in order to carry out the project work various literature were studied and finding obtained by them were used to identify the research area, summarization of literature are as follow.

H M Jonkers, the main objective of this study was establish whether bacteria incorporated in the cement stone matrix could act as self healing agent to catalyze the process of autonomous repair of freshly formed cracks. One major problem associated with crack formation is that the process results in a drastic increase in material permeability increasing the risk of matrix and embedded reinforcement degradation by ingress water and other aggressive chemical. Active bacterially mediated mineral precipitation could result in cracks plugging and concomitant decrease in material permeability.

As bacteria function as catalyst, a suitable mineral precursor compound needs additionally to be incorporated in the material matrix to provide a truly autonomous repair mechanism. However, the maximal allowable amount of mineral precursor compound introduced to the concrete mixture is likely limited as larger quantities may negatively affect other concrete properties such as setting time and (final) strength. Therefore, the addition of smaller quantities of mineral precursor compounds will probably result in autonomous repair of micro- (<1mm diameter) but not in heal.

Conclusion : Although concrete with a high self-healing (crack healing) potential is wanted, the addition of healing agents such as bacteria and/or (organic) chemical compounds to the paste may result in unwanted decrease of strength properties. A 10% compressive strength loss due to incorporation of bacteria (B.pseudo firmus) was observed in this study. However, such a loss in strength may be acceptable when this is compensated for by a substantial increase in the materials self (crack)-healing capacity. The two-component self healing system tested here (incorporated bacteria plus calcium lactate) resulted in the formation of 100-μm sized calcite particles on specimen surfaces in contrast to controls (no additions or calcium lactate only), where much smaller sized particles were formed. The results of this preliminary study thus indicate that the two-component system may be characterized by a superior crack-healing potential, as much larger cracks can theoretically be sealed by the larger calcite particles produced. It remains to be evaluated, however, to what extent increased bacterial mineral production on (crack) surfaces results in decreased permeability, and thus better protection of the underlying material matrix. A lowered permeability due to healing of cracks would result in a decreased ingress rate of aggressive chemicals, which could lead to premature matrix degradation or corrosion of embedded steel reinforcement. Self-healing with the aid of incorporated bacteria could thus result in a better healing (sealing of larger cracks) compared to autogenous healing of non-amended pastes.

Mayur Shantilal Vekariya , Prof. Jayeshkumar Pitroda. "Bacterial Concrete: New Era For Construction Industry". International Journal of Engineering Trends and Technology (IJETT). V4(9):4128-4137 Sep 2013: Micro-cracks are the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of biomineralization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete -

embedded self-healing agent was studied and results from ongoing studies are discussed. Synthetic polymers such as epoxy treatment etc. are currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused. Recently, it is found that microbial mineral precipitation resulting from metabolic activities of favourable microorganisms in concrete improved the overall behaviour of concrete. Hence in this paper define the bacterial concrete, its classification and types of bacteria, chemical process to fix the crack by bacteria, advantages and disadvantages and possibilities of application of MICP (Microorganism used for Calcium Carbonate Precipitation in Concrete) in construction area by literature review are discussed.

Conclusion: Microbial concrete technology has proved to be better than many conventional technologies because of its eco- friendly nature, self-healing abilities and increase in durability of various building materials.

Work of various researchers has improved our understanding on the possibilities and limitations of biotechnological applications on building materials.

Enhancement of compressive strength, reduction in permeability, water absorption, reinforced corrosion have been seen in various cementitious and stone materials.

Cementation by this method is very easy and convenient for usage. This will soon provide the basis for high quality structures that will be cost effective and environmentally safe but, more work is required to improve the feasibility of this technology from both an economical and practical viewpoints.

Akshay Phogat, Abhishek Thakur, Khushpreet Singh, Bacterial Concrete And Effect Of Different Bacteria On The Strength And Water Absorption Characteristics Of Concrete: The concrete structures have various durability issues due to the different physiological conditions and it results to irretrievable damage to the structure and eventually reduction in thestrength of concrete structure. The main reason behind the downgrading of the durability and mechanical aspects of concrete is the pore structure of concrete. In the recent years MICCP(microbiologically induced calcium carbonate precipitation) by the bacteria considered as an environment friendly method to enhance the properties of concrete, also for the repair of concrete structure and to consolidate different construction materials. This paper presents a review of different researches in the recent years on the use of bacterial concrete/bio-concrete for the enhancement in the durability, mechanical and permeation aspects of concrete. It contains studies on different bacteria‟s, their isolation process, different approaches for addition of bacteria in concrete, their effects on compressive strength and water absorption properties of concrete and also the SEM and XRD analysis of concrete containing bacteria.

Conclusion : Currently, the designing of bacterial concrete is the most popular research topic for the researchers. Till now it has been found that the use of bacterial concrete can enhance the durability, mechanical and permeation aspects of concrete. According to the previous researches till now, it has been found that the maximum increase in the compressive strength is achieved by the addition of Bacillus cereus that is upto 50% for the cell concentration of 106 cells/ml, and the maximum decrease in water absorption is in case of S. pasteurii that is 80-85% than the conventional concrete sample after the 28 days curing time period.

According to the previous researches, some of the bacteria are not good for human health but some other bacteria like bacillus Sphaericus, bacillus pasteurii, bacillus subtilis, and bacillus flexus does not impose any bad effect on human health and also shows higher ability of calcite precipitation, this property makes these bacteria as ideal bacteria for the designing of bacterial concrete. As from the study is predicted that the life of bacterial concrete is more than conventional concrete. So, the use of biological concrete can create new job opportunities for the experts. The cost of the bacterial concrete, according to the opinions of other researchers can increase up to 30% than the conventional concrete, depending upon the type and concentration of bacteria. But the maintenance cost can be reduced by the use of bacterial concrete.

This method is easy and convenient in the whole process of cementation. This technology will provide long life to the structure due to its good durability properties but more work is required on the following mentioned issues to improve the feasibility of this technology from practical viewpoints. Issues related to its economical factors and qualities related to bacteria are still to be finding out.

- Studies are required to focus on different types of metabolic products and nutrients used for growing calcifying microorganisms.
- More work is required to be done on the retention of nutrients and metabolic products in the building material.

PROBLEM IDENTIFICATION AND PROJECT OBJECTIVES

Need of Study : The major problem the construction industry concurs with is the high maintenance cost of the concrete. Various natural processes such as weathering, faults, land subsidence, earthquake, changes in moisture and temperature, have the tendency to create cracks in concrete. Therefore, to counter these effects, it has become necessary to come up with ways which will not only help in counteracting but also in improving the quality of concrete. In the present experiment, Bacillus Subtilis, which has the property of bio calcification and can secrete calcium carbonate as an extracellular product has been used to prepare M25 concrete. This product is found to be responsible for filling the pores and cracks internally making the structure more compact and resistive to seepage. Also, laboratory investigations will be carried out to compare the different parameters of bacterial concrete with ordinary concrete. In recent years, there is increasing interest in the phenomenon of mechanical property recovery in concrete construction using self-healing concrete. The study is motivated by the need to find a solution for the problem of cracking approaching the concept of self-healing concrete. The study is carried out on a bacteria based self-healing concrete using Bacillus Subtilis bacteria. The present project describes the effect of these bacteria on the strength of concrete. An investigation on the strength assessment of the bacteria-based self-healing concrete by finding out the optimum amount of bacterial content to be added to obtain maximum strength is depicted in this project.

Objectives

- To compare the self healing bacterial concrete with conventional concrete.
- To study the durability of the concrete along with effects on various properties like compressive strength, tensile strength, etc. of self healing concrete.
- To identify the different problems faced during preparation of self healing concrete.
- To Study procedure for the preparation of self healing concrete.

Applications: Thus, bacterial material as a smart material than it can be utilise in various construction area to improve the performance if structure in new era.

- The use of bacterial concrete in Civil Engineering has become increasingly popular.
- Enhancement in durability of cementious materials to improvement in sand properties.
- Repair of limestone monuments.
- Sealing of concrete cracks.
- Used in construction of low cost durable housing.

Preparation of Bacteria

- Primarily 12.5g of Nutrient broth (media) is added to a 500ml 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.
- 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.

Figure: Solution without Bacteria (Only Media)

Figure :Solution with Bacteria

Preparation of Bacterial Concrete

Self healing bacterial concrete can be prepared in two ways.

By Direct Application By the method of direct application bacterial spores and calcium lactate are added directly while making the concrete and mixed. Here when the crack occurs in the concrete bacterial spores broke and bacteria comes to life and feed on the calcium lactate and limestone is produced which fill the cracks.

By Encapsulation in Light Weight Concrete

By encapsulation method the bacteria and its food, calcium lactate, are placed inside treated clay pellets and concrete is made. About 6% of the clay pellets are added for making bacterial concrete. When concrete structures are made with bacterial concrete, when the crack occurs in the structure and clay pellets are broken and bacterial treatment occurs and hence the concrete is healed. Minor cracks about 0.5 mm width can be treated by using bacterial concrete Among these two methods encapsulation method is commonly used, even though it‟s costlier than direct application. Bacillus bacteria are harmless to human life and hence it can be used effectively.

Preparation of Test Specimens

Bacterial concrete casted by using ordinary Portland cement mixed with bacterial concentration 10^6 cells/ml of water. Conventional concrete samples are also casted in parallel.

The specimens are cured under tap water at room temperature and tested at 7, and 28 days.

Testing of Bacterial Concrete

Concrete disks are prepared containing the porous aggregates filled with food only and with food and bacteria. The specimens are cured for 56 days and then tested in a deformation controlled tensile splitting loading to crack them partially. After this cracking the specimens are placed in a permeability test setup in which water is applied at one side of the specimen for 24 hours.

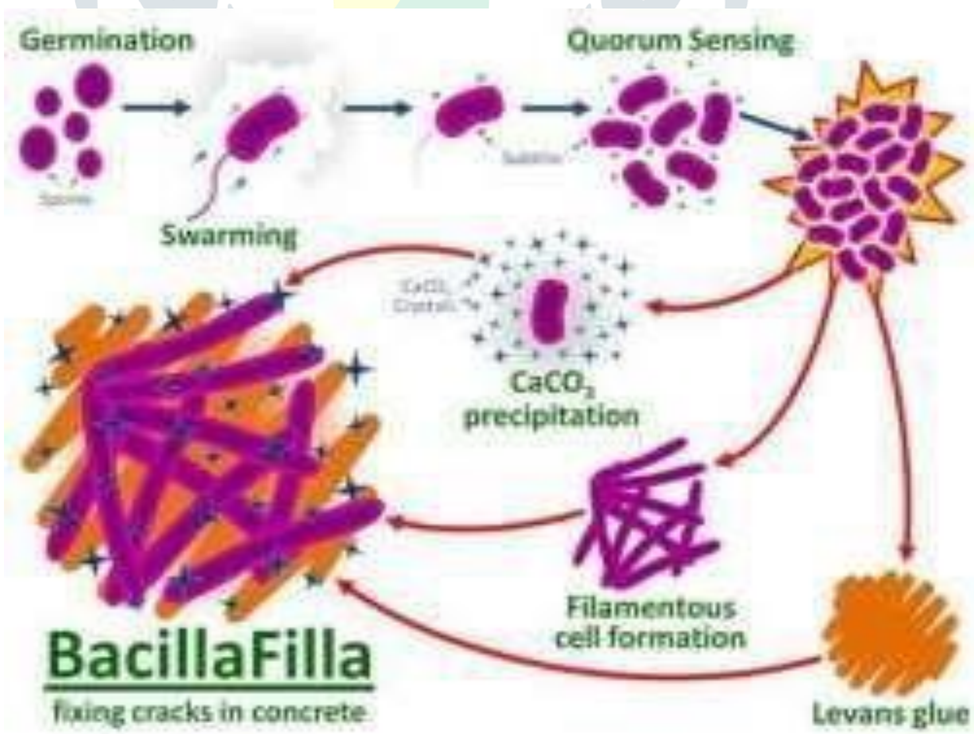

Figure :Process of Fixing Cracks In Concrete By Bacteria

Also the permeability of the healed specimens will determine. The outcome of this study shows that crack healing in bacterial concrete is much more efficient than in concrete of the same composition but without added biochemical healing agent.

The reason for this can be explained by the strictly chemical processes in the control and additional biological processes in the bacterial concrete. On the crack surface of control concrete some calcium carbonate will be

formed due to the reaction of CO_2 present in the crack ingress water with Portlandite (calcium hydroxide) present in the concrete mixture according to the following reaction:

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H2O$$

The amount of calcium carbonate production in this case in only minor due to the limited amount of CO_2 present. As Portlandite is a rather soluble mineral in fact most of it present on the crack surface will dissolve and diffuse out of the crack into the overlying water mass.

Subsequently, as more CO_2 is present in the overlying water, dissolved Portlandite will as yet precipitate in the form of calcium carbonate but somewhat away from the crack itself, as can be seen. The self healing process in bacterial concrete is much more efficient due to the active metabolic conversion of calcium lactate by the present bacteria:

$$Ca(C_3H5O_2)_2 + 7O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O$$

This process does not only produce calcium carbonate directly but also indirectly via the reaction of onsite produced CO2 with Portlandite present on the crack surface. In the latter case, Portlandite does not dissolve and diffuse away from the crack surface, but instead reacts directly on the spot with local bacterially produced CO2 to additional calcium carbonate. This process results in efficient crack sealing as can be seen

Advantages

- Incorporation of the agent in the concrete will be relatively cheap as well as easy when the aggregate is immobilized in porous light weight aggregate prior to addition to the concrete mixture.
- The self healing bacterial concrete helps in reduced maintenance and repair costs of steel reinforced concrete structures.
- Oxygen is an agent that can induce corrosion, as bacteria feeds on oxygen tendency for the corrosion of reinforcement can be reduced.
- Self healing bacteria can be used in places where humans find it difficult to reach for the maintenance of the structures. Hence it reduces risking of human life in dangerous areas and also increases the durability of the structure.
- Formation of crack will be healed in the initial stage itself thereby increasing the service life of the structure than expected life.
- Better resistance to freeze-thaw cycle.

Disadvantages

- If the volume of self healing agents (bacteria and calcium lactate) mixed becomes greater than 20%, the strength of the concrete is reduced.
- Preparation of self healing concrete needs the requirement of bacteria and calcium lactate. Preparation of calcium lactate from milk is costlier. Hence preparation of self healing concrete costs double than conventional concrete.

- **MATERIAL & GRADE OF CONCRETE MIX**

Grade of concrete: M35

Following are the material:-

Cement: PPC 53 Grade [Ambuja Cement]

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.

Aggregate : C.A.= 20mm sized crushed angular aggregate. F.A. = Natural sand.

Water: Clean water free from salt

MIX DESIGN: The process of selecting suitable ingredients of concrete and determining their relative proportion with the object of producing concrete of certain minimum strength as economically as possible is known as Mix Design. The mix design is carried out to achieve specified age, workability of fresh concrete and durability requirements by using IS 102622009. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

Concrete Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportion with the object of producing in concrete of certain minimum strength and durability as economically as possible. An integral part of concrete mix proportioning is the preparation of trial mixes and effect adjustment to such trials to strike a balance the requirements of placement, that is, workability and strength, simultaneously satisfying durability requirement. Concrete has to be of satisfactory quality both in its fresh and hardened states. This task is best accomplished by trial mixes arrived at by the use of certain established relationships among different parameters and by analysis of data already generated thereby providing a basis for judicious combination of all the ingredients involved.

CONCLUSION : In this project we used M 35 grade concrete to study. For the bacterial concrete we selected Bacillus Subtilis as the bacteria and calcium lactate as substrate for bacteria to work with. We used M35 grade concrete as a control and for bacterial concrete we kept the mix design same but and in we replaced the cement by calcium lactate at the rate of 5% by weight. In bacterial concrete the water was also reduced by volume equal to the bacterial solution so that the final amount of water added is as required by the control sample.

1) The compressive strength shows a decrease of about 21 – 23%.
2) So target mean strength should be increased nearly 23% at 28 days for ordinary, standard and high grades of concrete when compared to controlled concrete at the time of mix designing.
3) Addition of Bacillus Subtilis bacteria shows increase in the split tensile strength of concrete. The strength increase is clearly visible for 14 th day and 28 th day split tensile strength test and is about 15 – 21 %.
4) The cracked samples when kept wet and allowed to cure further with the help of gunny bags showed sealing of the cracks with what appears to be the biominaralized calcium carbonate ($CaCO_3$), as observed in other studies.
5) The width of cracks that can be effectively sealed appears to be from 0.25 to 0.75 mm as observed in our tests.
6) This sealing of cracks suggests that the cracks can be kept in check from the very beginning which prevents further exposure of reinforcement to oxygen and moisture and ultimately corrosion. This increases the useful life of a structure and increases durability.
7) This should also reduce leakages and long term maintenance.
8) The preparation of bacterial concrete seemed to be a tedious work as it involved some additional steps and precautions such as preparation of bacterial solution, addition of calcium lactate and careful handling of bacterial solution.
9) Preparation of bacterial concrete involves some additional steps as compared to the conventional concrete such as- Preparation of the bacterial solution which has to be done in laboratory which takes about 2 to 3 days. Addition of calcium lactate as a food for the bacteria to work with and form the calcium carbonate precipitates. This calcium lactate costs about 500 to 800 rupees a kilogram.

To conclude we can state that the application of bacteria as a self-healing agent in concrete appears promising. We expect that concrete-immobilized bacterial spores revive and produce copious minerals after stimulation by suitable medium, i.e. water containing an organic growth substrate such as calcium lactate.

REFERENCES

1. Arp G, Reimer A, Reitner J (2001) *Photosynthesis-induced biofilm calcification and calcium concentrations in Phanerozoic oceans. Science 292:1701–1704.*
2. Akshay Phogat, Abhishek Thakur, Khushpreet Singh, U.G. Student, Department of Bio-Technology, Chandigarh University, Gharaun, Punjab, India. *Bacterial Concrete And Effect Of Different Bacteria On The Strength And Water Absorption Characteristics Of Concrete.*
3. Bang SS, Galinat JK, Ramakrishnan V (2001) *Calcite precipitation induced by polyurethane-immobilized Bacillus pasteurii. Enzyme and Microbial Technology 28:404-409.*
4. "*CONCTERE TECHNOLOGY*"; BY M.S.SHETTY; S.CHAND; TEXT BOOK-SEVENTH REVISED EDITION 2013.
5. "*CONCRETE TECHNOLOGY*"; BY NISHANT A.UPADHYE; TECH-MAX PUBLICATIONS, PUNE, SECOND REVISED EDITION: JUNE 2011.
6. Concrete Technology by A.N.Neville, J.J.Brooks ,Addition Wesley. TEXT BOOK-SEVENTH REVISED EDITION.
7. *Concrete Technology* by M.L.Gambhir, TMH Publication. TEXT BOOK-FIFTH REVISED EDITION.
8. DeGraef B, DeWindt W, Dick J, Verstraete W, DeBelie N (2005) *Cleaning of concrete fouled by lichens with the aid of Thiobacilli. Materials and Structures 38(284):875-882.*
9. Dick J, DeWindt W, DeGraef B, Saveyn H, VanderMeeren P, DeBelie N, Verstraete W (2006*) Bio-deposition of a calcium carbonate layer on degraded limestone by Bacillus species. Biodegradation 17:357-367.*
10. S.Soundharya ,Dr.K.Nirmalkumar, *Study on the Effect of Calcite-Precipitating Bacteria on Self-Healing Mechanism of Concrete(July- 2014).*
11. E. Schlangen, H. Jonkers, S. Qian & A. Garcia Delft University of Technology, Microlab, Delft, Netherlands.
12. G.T. Suthar, Dr. K.B.Parikh, PG Student, Government Engineering College, Dahod389151, India. *A Study of Microorganism (Bacteria) on Concrete Strength and Durability.*
13. H. M. Jonkers, *Bacteria-based self-healing concrete Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department.*
14. *Indian Standard* (IS 3085- 1965*) Method Of Test For Permeability Of Cement Mortar And Concrete.*
15. *International Journal Of Civil Engineering And Technology (IJCIET),* Abhishek Thakur, P.G. Student, Department of Civil Engineering, Chandigarh University,

Gharaun, Punjab, India, Akshay Phogat, U.G. Student, Department of BioTechnology, Chandigarh University, Gharaun, Punjab, India. Khushpreet Singh, Assistant Professor, Department of Civil Engineering, Chandigarh University, Gharaun, Punjab, India.

16. Koustubh A. Joshi , Madhav B. Kumthekar , Vishal P Ghodake, *"Study of Self Healing Mechanism and its Impact on Bacillus Bacteria."*
17. Mayur Shantilal Vekariya , Prof. Jayeshkumar Pitroda. *"Bacterial Concrete: New Era For Construction Industry". International Journal of Engineering Trends and Technology (IJETT)*. V 4(9):4128-4137 Sep 2013.
18. Meera C. M.1, Dr. Subha V.2 1(Department of Civil Engineering, Shree Narayana Gurukulam College of Engineering, India) 2(Department of Civil Engineering, SOE, Cochin University of Science and Technology, India).
19. M. Kishore, Dr. S. Thenmolzhi. M.E. ,Ph.D, Dr. N.Unnamalai. Ph.D *Performance Study Of Bacterial Concrete.*
20. Mayur Shantilal Vekariya, Prof. Jayeshkumar Pitroda, *Bacterial Concrete: New Era for Construction Industry.*
21. Ravindranatha, N. Kannan, Likhit M. L, *Self-Healing Material Bacterial Concrete.*