A Thesis on

A COMPARATIVE STUDY ON COMPRESSIVE AND TENSILE STRENGTH OF CONVENTIONAL CONCRETE WITH BIO-CONCRETE

Submitted in Partial Fulfillment for the Award of degree of

MASTER OF TECHNOLOGY

In

STRUCTURAL ENGINEERING

Submitted by

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INTEGRAL UNIVERSITY, LUCKNOW

2019 – 2020

DECLARATION

We declare that the Project entitled **"A Comparative Study on Compressive & Tensile Strength of Conventional Concrete with Bio-Concrete",** is the bonafide work carried out by me, under the guidance of **Mr. Mohd Bilal Khan, Assistant Professor, Department of Civil Engineering, Integral University, Lucknow.** Further we declare that this has not previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

Date: Mohd Salman Khan

Place: Lucknow Roll. No. 1801431011

CERTIFICATE

This is to certify that the entitled **"A Comparative Study on Compressive & Tensile Strength of Conventional Concrete with Bio-Concrete"**, is being submitted by Mohd Salman Khan (Roll No. 1801431011), in partial fulfillment of the requirement for the award of the **Master of Technology in Structural Engineering of Integral University, Lucknow** is a record of candidate's own work carried out by him under our supervision and guidance.

The results presented in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

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ABSTRACT

Concrete is the most widely used construction material because of its high compressive strength, relatively low cost, etc. One adverse property of concrete is its sensitivity to crack formation as a consequence of its limited tensile strength. For that reason, concrete is mostly combined with steel reinforcement to carry the tensile loads. Although these rebar restrict the crack width, they Concrete is very sensitive to crack formation. As wide cracks endanger the durability, repair may be required. However, these repair works raise the life-cycle cost of concrete as they are labour intensive and because the structure becomes in disuse during repair. In the following years, several researchers started to investigate this topic. The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that can constantly precipitate calcite. Cracking in the surface layer of concrete mainly reduces its durability, since cracks are responsible for the passage of liquids and gasses that could potentially contain deleterious substances. When micro-cracks migrates towards the reinforcement, not only the concrete itself may be damaged, but also corrosion occurs in the reinforcement due to exposure to water and oxygen, and possibly CO_2 and chlorides too. Micro-cracks are therefore 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 bio-mineralization of bacteria in concrete. 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. In the present paper, an attempt is made to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength and durability of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophiles spore forming bacteria may be able to survive in this environment and increase the strength and durability of cement concrete. Overview of development of bioengineered concrete using bacterial strain Bacillus Cereus and its enhanced mechanical and durable characteristics will be briefly described in this paper.

ACKNOWLEDGEMENT

I would like to express my gratitude to all the people behind the screen who helped us to transform an idea into a real application.

I owe a dept of gratitude to ***Mr. Mohd Bilal Khan*** *for his excellent guidance, valuable supervision, timely suggestion, stimulating discussions, constructive criticism has enable me to complete this project.*

I warmly thank to ***Mr. Juned Ahmad,*** *for their valuable advice and support me at regular intervals and also, I would like to thank Head of Department* ***Dr. Syed Aqeel Ahmad*** *for his unconditional support and guidance at every stage of my work.*

The satisfaction and euphoria that accompany the successful completion of the task would be great but incomplete without the mention of the people who made it possible with their constant guidance and encouragement crowns all the effort with success. In this context, we would like to thank all other staff members, both teaching and non-teaching, which have extended their timely help and eased our task.

Worlds may fail us, when we think of all, that our parents have done for us.

Throughout life, they have always been a constant source of inspiration and whose administration helps us in our academic pursuits. Their sacrifices, prays and good wishes made us to reach at this stage.

Mohd Salman Khan
M. Tech (Structural Engineering)

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CHAPTER 1: INTRODUCTION

The current demand for the concrete is massive. For centuries, one of the most common materials used in construction has been concrete. Formed from hardened cement, concrete has been used for everything from driveways to home foundations. However, as technology advances concrete has not remained the end-all tool for building. It has a variety of disadvantages that should be considered before use. One main disadvantage of concrete is that all structures made from it will crack at some point. Concrete can also crack as a result of shrinkage, which happens when it dries out.

Earlier strength was the main criteria considered during construction. In recent years, it has been focused out that not only structural safety but also durability is significant when designing building or concrete structures.

In concrete, cracking is a common phenomenon due to the relatively low tensile strength. Durability of concrete is also impaired by these cracks, since they provide an easy path for the transport of liquids and gasses that potentially contain harmful substances. For crack repair, a variety of techniques is available but traditional repair systems have a number of disadvantageous aspects such as different thermal expansion coefficient compared to concrete and environmental and health hazards. Cracking in conventional reinforced concrete is virtually unavoidable, and is generally caused by thermal effects, early-age shrinkage, mechanical loading, freeze-thaw effects or a combination of these factors.

Although concrete is the world’s most used building material, it has a serious flaw. It can easily crack under tension. The researchers said, if these cracks become too large, they will lead to corrosion of the steel reinforcement, which not only results in an unattractive appearance but also jeopardizes the structure’s mechanical qualities. Crack prevention is often employed by steel reinforcement which is highly expensive and requires large amounts of steel which will never be acceptable. Another disadvantage is, in case of larger constructions such as big dams or projects, if there we observed any crack or corrosion, it becomes deadly difficult to go there and repair it. Although it is known that it is costly to inspect, monitor and repair cracks.

Therefore, it would be desirable if concrete cracks could be healed autonomously by releasing healing agents inside the matrix when cracks appear and coming with up the solution Bio-concrete.

Bio-concrete is said to be the new formulation of the concrete with bacteria. Bio-concrete is also known as self-healing concrete and bio-engineered concrete. In the biosphere, bacteria can function as geo-chemical agents promoting the dispersion, fractionation and concentration of materials. Microbial mineral precipitation is resulted from metabolic activities of microorganisms. Based on this, bio-mineralogy concept, an attempt has been made to develop bio-concrete material incorporating of an enrichment culture of thermophilic and alkaliphilic bacteria within cement sand mortar/concrete.

The results showed a significant increase in compressive strength. The astonishing advantage of this bio-concrete is its self-healing capacity and also environmental friendly. Self-healing concrete is a product that will biologically produce limestone to heal itself the cracks that appear on the surface of concrete structures. However it is as durable and strong as conventional concrete and can be used as a better replacement for the normal concrete. So it is more beneficial if we used the bio-concrete in such cases where the repair is tedious such as large dams.

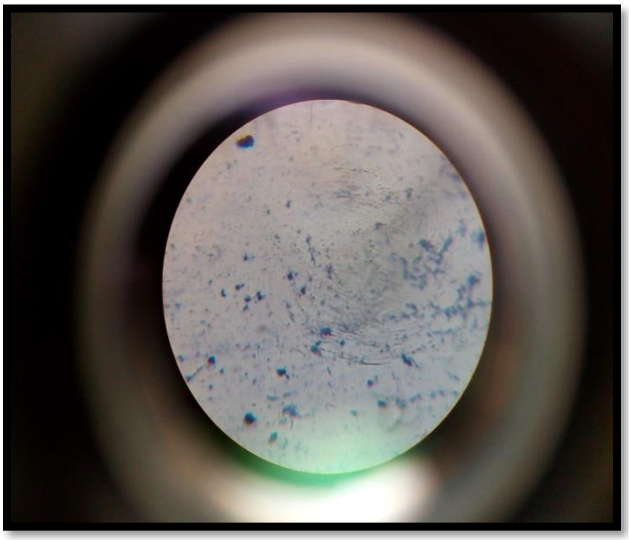


Fig 1.1- Microscopic View of Bacteria Strain

MAIN INGREDIENT OF BIO-CONCRETE

The main components of bio-concrete are cement, sand, aggregate and addition of bacterial culture with its nutrient so that it can persist in unaesthetic medium of concrete.

FINDING RIGHT BACTERIA

The starting point of the research is to find bacteria capable of surviving in an extreme alkaline environment. Cement and water have a pH value of up to 13 when mixed together, usually a hostile environment for life most organisms die in an environment with a pH value of 10 or above. The search concentrated on microbes that thrive in alkaline environments which can be found in natural environments, Samples of endolithic bacteria (bacteria that can live inside stones) will be collected along with bacteria found in sediments in the lakes. Strains of the bacteria genus Bacillus will be found to thrive in this high-alkaline environment. It is found that the only group of bacteria that will be able to survive is the ones that produced spores comparable to plant seeds. Such spores have extremely thick cell walls that enable them to remain intact for up to 200 years while waiting for a better environment to germinate. They would become activated when the concrete starts to crack, food is available, and water seeps into the structure. This process lowers the pH of the highly alkaline concrete to values in the range (pH 10 to 11.5) where the bacterial spores become activated.

BACTERIA CEREUS

Bacillus cereus is a large, 1 x 3-4 µm, Gram-positive, rod-shaped, endospore forming, facultative aerobic bacterium. It was first successfully isolated in 1969 from a case of fatal pneumonia in a male patient and was cultured from the blood and pleural fluid. RNA comparison reveals Bacillus cereus to be most related to Bacillus anthraces, the cause of anthrax, and Bacillus thuringiensis, an insect pathogen used as pesticide. Although they have similar characteristics, they are distinguishable as Bacillus cereus is most motile bacteria.

Bacillus cereus is mesophilic, growing optimally at temperatures between 20°C and 40°C, and is capable of adapting to a wide range of environmental conditions. It is distributed widely in nature and is commonly found in the soil as a saprophytic organism. B. cereus is also a contributor to the micro flora of insects, deriving nutrients from its host, and is found in the rhizosphere of some plants.

As a soil bacterium, Bacillus cereus can spread easily in too many types of foods such as plants, eggs, meat, and dairy products, and is known for causing 2-5 % of food-borne intoxications due to its secretion of emetic toxins and enterotoxins. Food poisoning occurs when food is left without refrigeration for several hours before it is served. Remaining spores of contaminated food from heat treatment grow well after cooling and are the source of food poisoning.

CEREUS STRAIN CHARACTERISTICS
MTCC NO- 430

Name- Bacillus Organism- Bacteria Genus

Species Name- Cereus Strain designation- 11778

Temperature- 30^o C

Incubation- 24 hours Growth Media- 3

Growth condition- Aerobic

Sub culturing period- 30 day

Special features- Assay of Chlortetracycline, Oxytetracycline and tetracycline.

Fig 1.2- Rod like Structure of Bacillus
` **Cereus**

USING BACTERIA TO SELF-HEAL CRACKS IN CONCRETE

Bacteria added to concrete mix in suspension state must meet certain criteria. Concrete is a highly alkaline building material, so bacteria used as self-healing agent should be able to survive in this high alkaline environment for long durations and be able to form spores (highly resistant structures) withstanding mechanical forces during concrete mixing. In the concrete technology laboratory, a bacterial concrete mix is prepared using alkali-resistant soil bacteria Bacillus Cereus, along with nutrients from which the bacteria could potentially produce calcite based bio-minerals. 28 days cured bacterial specimens are examined visually to establish evidence for the precipitation of calcite crystals in concrete. It was found that strains of the bacteria genus Bacillus were found to thrive in this high-alkaline environment. Such gram positive bacteria have extremely thick outer cell membrane that enables them to remain viable until a suitable environment is available to grow. They would become lively when the cracks form on concrete surface allowing water to ingress into the structure. This phenomenon will reduce the pH of the concrete environment where the bacteria incorporated become activated5. A peptone based nutrients supplied along with bacteria in suspension helps in producing calcite crystals. It is found that this bio-mineralization process will not interfere with the setting time of the concrete. The most expensive ingredient in developing bacterial concrete is nutrients. So any inexpensive alternative for laboratory growth media would potentially bring down the cost of the bacteria based self-healing sustainable concrete. Only factor need to be checked is the effect of nutrients media on the setting time of cement.

ADVANTAGES OF BACTERIA

- Remediation of cracks in concrete.
- Preservation and restoration of historic heritage structure
- Places which are hazardous for human being to reach repair work such as nuclear power plants, repair of waste water sewage pipes etc.

- The astonishing advantage of this bio-concrete is its self-healing capacity. Self-healing concrete is a product that will biologically produce limestone to heal itself the cracks that appear on the surface of concrete structures.
- Isolation of bacteria is not very complex
- Many methods have been described for adding bacteria to concrete. On the other hand, bacteria are not enough resistance against harsh condition of concrete such as high pH, low level of water, high temperature and etc.
- However it is as durable and strong as conventional concrete and can be used as a better replacement for the normal concrete.
- Increases compressive and tensile strength
- Reduces the corrosion of reinforcement.
- Environmental friendly.

CHAPTER 2: LITERATURE REVIEW

H.M Jokers and Erik (2009) - Concrete structures usually show some self-healing capacity, i.e. the ability to heal or seal freshly formed micro-cracks. This property is mainly due to the presence of non-hydrated excess cement particles in the materials matrix, which undergo delayed on secondary hydration upon reaction with ingress water. In this research project we develop a new type of self-healing concrete in which bacteria mediate the production of minerals which rapidly seal freshly formed cracks, a process that concomitantly decreases concrete permeability, and thus better protects embedded steel reinforcement from corrosion. Initial results show that the addition of specific organic mineral precursor compounds plus spore-forming alkaliphilic bacteria as self- healing agents produces up to100. I-sized calcite particles which can potentially seal micro- to even larger- sized cracks. Further development of this bio-concrete with significantly increased self-healing capacities would represent a new type of durable and sustainable concrete with a wide range of potential applications.

[1] S. Sunil Pratap Reddy et.al (2010) - Studied the performance of the standard grade bacterial (Bacillus subtilis) concrete. Its main focus was on how the right conditions can be created for the bacteria not only to survive in the concrete but to produce proper calcite to repair cracks. Cement mortar cubes with four different cell concentrations and control specimen were casted. Results shows that compressive strength of concrete increased significantly by 14.92% at 28 days due to the addition of bacteria for a cell concentration of 105 cells per ml of water. Addition of bacteria improves the hydrated structure of cement mortar. From SEM analysis, it was noted that pores were partially filled up by material growth with the addition of the bacteria. Bacillus subtil is bacteria showed significant improvement in the split tensile strength than the conventional concrete.

[2] M S Vekariya1, Prof. J. Pitroda (2013)- They presented that the microorganisms used in concrete to enhance the all properties of concrete by the biological mechanisms. Bio concrete have eco- friendly, self-healing and rise in durability of several construction material this gives good technology than other normal technologies. Study of several researchers has enhanced our understanding of the possibilities and limitations of biotechnological applications on building materials. Decreasing in permeability, improving of compressive strength, corrosion of reinforcement, water absorption has been observed in several stone and cementations material. Cementation by this method is very simple and suitable for usage. Finally, they concluded that more work is regarding to economical and practical viewpoint to enhance the possibility of biotechnology with high- quality structures.

[3] Jagadeesha Kumar B G, R Prabhakara and Pushpa H5 (2013) –They published a paper on effect of bacterial calcite precipitation on compressive strength of mortar cubes. This paper describes about the experimental investigations carried out on mortar cubes which were subjected to bacterial precipitation by different bacterial strains and influence of bacterial calcite precipitation on the compressive strength of mortar cube on 7, 14 and 28 days of bacterial treatment. Three bacterial strains bacillus flexus, isolated from concrete environment, Bacillus pasturii and Bacillus sphaericus were used. The cubes were immersed in bacterial and culture medium for above mentioned days with control cubes immersed in water and was tested for compressive strength. The result indicated that there was an improvement in the compressive strength in the early strength of cubes which were reduced with time. It was studied that the increase in compressive strengths is mainly due to consolidation of the pores inside the cement mortar cubes with micro biologically induced calcium carbonate precipitation.

[4] M ShVekariya1, Prof. J. Pitroda (2013)- This paper was presented that the microorganisms used in concrete to enhance the all properties of concrete by the biological mechanisms. Bio concrete have eco- friendly, self-healing and rise in durability of several construction material this gives good technology than other normal technologies. Study of several researchers has enhanced our understanding of the possibilities and limitations of biotechnological applications on building materials. Decreasing in permeability, improving of compressive strength, corrosion of reinforcement, water absorption has been observed in several stone and cementations material. Cementation by this method is very simple and suitable for usage. Finally, they concluded that more work is regarding to economical and practical viewpoint to enhance the possibility of biotechnology with high- quality structures.

[5] N. Chahal and R.Siddique (2013) - This study has been presented that with use of Sporosarcina pasteurii which would make it, self-healing. They observed that newly formed cracks healed by the presence of bacteria. In the concrete mix 10%, 20% and 30% and also 5% and 10% dosage of fly ash and silica fume respectively replacing cement in the bacterial solution of 103, 105 and 107 cells/ml. They did tests on the water absorption and porosity, chloride permeability and compressive strength by using upto age 91 days. They concluded that by the presence of S. pasteruii increase compressive strength, cut downs the permeability and porosity of silica fume and fly ash concrete.

[6] Vijeth N Kashyap, Radhakrishna (2103) - They studied effect of Bacillus Sphaericus and Sporosarcina Pastuerii bacteria on cement concrete. After experimental investigation It was found that these bacteria when added at 106 concentration of cells/ml of water to cement composites increased by about 39.8% and 33.07% in paste. The strength increment was found to be 18.3% and 12.2% for Bacillus Sphaericus and Sporosarcina Pastuerii respectively for concrete. It was concluded that Bacillus Sphaericus and Sporosarcina Pastuerii stains can improve the characteristics of cement composites due to calcite precipitation inside the cement composite specimens which are produced microbial.

[7] Ravindranatha, N. Kannan, Likhit M.L3 (2014) - They have published a paper on self-healing material bacterial concrete. In this paper a comparative study was made with concrete cubes and beams subjected to compressive and flexural strength tests with and without the bacterium Bacillus pasteurii. The concrete cubes and beams were prepared by adding calculated quantity of bacterial solution and they were tested for 7 and 28 days compressive and flexural strengths. It was found that there was high increase in strength and healing of cracks subjected to loading on the concrete specimens. The microbe proved to be efficient in enhancing the properties of the concrete by achieving a very high initial strength increase.

The calcium carbonate produced by the bacteria has filled some percentage of void volume thereby making the texture more compact and resistive to seepage.

[8] SakinaNajmuddinSaifee et.al1 (2015) - Published a paper on Critical appraisal on Bacterial Concrete. In this paper they discussed about the different types of bacteria and their applications. The bacterial concrete is very much useful in increasing the durability of cements materials, repair of limestone monuments, sealing of concrete cracks to highly durable cracks etc.It also useful for construction of low cost durable roads high strength buildings with more bearing capacity, erosion prevention of loose sands and low cost durable houses. They have also briefed about the working principle of bacterial concrete as a repair material. It was also observed in the study that the metabolic activities in the microorganisms taking place inside the concrete results into increasing the overall performance of concrete including its compressive strength and tensile strength. This study also explains the chemical process to remediate cracks.

[9] A.T.Manikandan1, A.Padmavathi4 (2015) - They have published a paper on an experimental investigation on improvement of Concrete Serviceability by using Bacterial Mineral Precipitation. In this paper, the bacteria bacillus subtilis strain 121 was from microbial type culture collection and gene bank, Chandigarh. Samples were prepared in sets of three for a water cement ratio of 0.5 by mass for conventional concrete and a water cement ratio of 0.25 and bacterial culture of 0.25 for bacterial concrete by mass. The cubes were tested by Non-Destructive Testing and HEICO compression testing machine on the 3rd, 7th and 28th days after casting. There was an improvement in compressive strength by B. subtilis strain 121 due to deposition of Calcite ($CaCO_3$) in cement-sand matrix of microbial concrete which remediate the pore structure within the mortar. The temperature sustainability test of B. Subtilis in bacterial concrete was carried out at various temperatures and found that the subtilis was found to be alive at –30 C low temperatures to 700 C, high temperatures. There is increase in compressive strength of the bacterial concrete with B.Subtilis bacteria with microbial calcite precipitation in the crack sample was examined in SEM.

[10] V Srinivasa Reddy, M V SeshagiriRao and S Sushma8 (2015) -They have published a paper on feasibility study on bacterial concrete as an innovative self-crack healing system. This paper describes about the effect of bacterial cell concentration of Bacillus subtilis JC3, on the strength, by determining the compressive strength of standard cement mortar cubes of different grades, incorporated with various bacterial cell concentrations. This shows that the improvement in compressive strength reaches a maximum at about 105/ml cell concentration. The cost of using microbial concrete analysis showed an increase in cost of 2.3 to 3.9 times between microbial concrete and conventional concrete with decrease of grade. And nutrients such as inexpensive, high protein-containing industrial wastes such as corn steep liquor (CSL) or lactose mother liquor (LML) effluent from starch industry can alsobe used, so that overall process cost reduces dramatically. Precipitation of these crystals inside the gel matrix also enhances the durability of concrete significantly.

[11] Mohit Goyal and P.Krishna Chaitanya9 (2015) - They have published a paper on behaviour of Bacterial Concrete as self-healing material. In this paper they have carried out laboratory investigations to compare the differentparameters of bacterial concrete with ordinary concrete and concrete,in which 70% cement was partially replaced with 30% of Fly Ash and 30% of GGBS. In this paper, Bacillus pasteurii, is used to prepare M25 concrete. Various tests such as slump flow test, compressive strength flexural strength and split tensile strength were conducted for different specimens of, bacterial concentrations of 40ml, 50ml and 60ml for each specimen. There was significant improvement of compressive strength by 30% in concrete mix with bacteria and more than 15% in fly ash and 20% in GGBS. It was observed that bacterial concrete achieves maximum split tensile strength and flexural strength when 40 ml and 50 ml bacterial solution was used but loses this trend after 14 days with 60ml bacterial solution when flexural strength test was performed. Also, 50ml bacterial solution proved to be effective in increasing the split tensile strength, compressive strength and flexural strength of the specimen as compared to 40ml and 60 ml bacterial solution.

[12] S. Krishnapriyaa, D. Babub, G. Arulrajc(2015) – They have published a paper and found that significant rise in strength and cracks healing in concrete sample cast B. megaterium B. licheniformis and bacillus megaterium MTCC 1684. They observed that because of presence of bacterial in the concrete strength and other properties of concrete rise and also production of calcite in concrete healing a crack.

[13] Chithra P Bai and Shibi Varghese7 (2016) - They have published a paper on an experimental investigation on the strength properties of fly ash based Bacterial concrete. In this paper, the bacteria bacillus Subtilis was used for study with different cell concentrations of 103, 105 and 107 cells/ml for preparing the bacterial concrete. Cement was partially replaced by 10%, 20% and 30% of fly ash by weight for making the bacterial concrete. Concrete of grade M30 was prepared and tests such as Compressive strength, Split tensile strength, Flexural strength and Ultrasonic Pulse Velocity were conducted after 28 and 56 days of water curing. For fly ash concrete, maximum compressive strength, split tensile strength, flexural Strength and Ultrasonic Pulse Velocity values were obtained for 10% fly ash replacement. For bacterial concrete maximum compressive strength, split tensile strength, flexural strength, and UPV values were obtained for the bacteria cell concentration of 105cells/ml. The improvement in the strength properties of fly ash concrete is due to the precipitation of calcium carbonate (CaCO3) inthe micro environment by the bacteria Bacillus Subtilis.

[14] N.Ganesh Babu and Dr.S.Siddiraju10 (2016) - They have published a paper on an experimental study on strength and fracture properties of self-healing concrete. In this paper they have made an attempt is made to arrest the cracks in concrete using bacteria and calcium lactate. The percentages of bacteria selected for the study are 3.5% and 5% by weight of cement. In addition, calcium lactate was used at 5% and 10% replacement of cement by weight. Bacillus pasteurii is used for different bacterial concentrations for M40 grade of concrete. Various tests such as compressive strength, elastic modulus and fracture of concrete were analyzed. The cubes of dimensions of 100x100x100 mm were used for compressive strength test. It was observed that compressive strength for controlled concrete using calcium lactate, at 7 days and 28 days were 19.8 MPa and 40.53 MPa respectively. With the addition of calcium lactate, there is considerable decrease in compressive strength. Compressive strength of concrete with 5% bacteria was found to be 49.5 MPa at 28 days, which is more than controlled concrete. With the addition of calcium lactate at 10% (optimum percentage) and bacteria to concrete, there is considerable increase in compressive strength. Hence calcium lactate along with 3.5% and 5% bacteria can be used as an effective self-healing agent.

[15] S. Sanjay, S. Neha, and R. Jasvir (2016)- This paper was presented as the experimental investigation on bacterialconcrete to increase the strength of bio-concrete and toinform the process involved in the bacterial concrete. Toknow the calcite crystals formed in bacterial concreteanalysis of microstructure has been done that is used for thepotential to recovery the cracks in bacterial concrete andalso to inform the biological reaction in concrete. As a resulthas been got because of good adaptability of nutrient brothmedium of bio concrete at 28 days attained better strengthwhen compared to urea medium.

[16] K. Chintalapudi, R Mohan Rao.P (2016)- This paper has been presented the bio technology that gains the satisfactory outcomes in remedying the micro cracks in concrete and informed that micro- cracks sealed by process of hydration in continuous situation. For better outcomes in strength and durability the improvement of pore structure and optimum bacterial solutions were did. They concluded that by the introducing of bacteria in concrete achieved reduction of permeability, keeping pH under favourable situations rise durability and compressive strength and also the potential to seal and heal the micro-cracks in concrete was found. The compressive strength observed for 91 days given satisfying results than compared to 28-day compressive strength observed for a bacterial concentration of 105 cells/ml. B. pasteurii used in concrete that improve the durability and cut down the water absorption in concrete structure. The bacterial solutions are the ability used as admixtures in concrete helps in enhancing the mechanical performance of concrete.

[17] R. Siddique, K. Singh, M. Singh, et al (2016) -They have been published paper, they cover on this paper bio concrete of 5%, 10%, 15% and 20% rise husk is replacing cement with bacterial solution of 105 cells/ml and type bacterial used is B. aerius. They did tests are for specimen up to 56 days. They found that better compressive strength is attained for rise Rusk concrete at 10% replacement and higher strength is gain for rise husk concrete with bacteria than without bacterial and also porosity, water absorption and permeability are decrease due to bacteria. Generally, they put that improved the life span of structure due to rise Rusk and bacterial present in concrete.

[18] Farzaneh Nosouhian et.al (2016) - studied concrete durability improvement in sulphate environment using two different bacterial strains in various concentrations bacteria. Seven groups of 70-mm concrete prisms were made using two different bacterial strains accompanied with mixing water; the effects of sulphate solution exposure on durability properties of tested specimens including variations in mass, volume, water absorption and compressive strength were then determined. Bacteria incorporation was found to produce an increase in the bulk density (dry) of concrete and to lower the voids. Bacteria not only produced higher compressive strength but also improved the strength development. Average compressive strength of concrete contained bacteria was increased up to 16.2 and 20.8% at the ages of 28 and 270 days, respectively. S. pasteurii and B. subtilis was observed to reduce concrete chloride penetration, mass, volume variation and water absorption which finally increases compressive strength of bacterial concrete.

[19] Nijo Baven et.al. (2016) – discuss workability and compressive strength of bacteria enriched steel fibre reinforced self-compacting concrete. Steel fibres has no blocking in J-ring test when it is in between the range of 0-25 mm. SCC with 20 % replacement of cement with micro silica has better compressive strength. The bacteria enriched steel fibre reinforced concrete is a practical concept with good compressive strength and flow ability.

[20] N. Balam, M. Eftekhar, D. Mostofinejad (2017) - This paper has been presented bacterial based LWAC with 106 cells/ml bacterial solution of S. pasteruii bacteria and they did tests on rapid chloride and water permeability, water absorption and compressive strength. They found that water absorption and chloride permeability cut downs by 10% and 20% respectively and also compressive strength rise by 20% in the experimental specimens relative to the similar properties in the control ones. Furthermore, LWAC specimens with bacteria is porosity is low and denser than concrete mix with bacterial only.

[21] M. Monishaa and Mrs. S. Nishanthi (2017) –They investigated strength of concrete using Bacillius subtilis and polyethylene fiber.M20 grade concrete is prepared with different bacterial cell concentration of 104, 105 and 106cells per ml of water and polyethylene fiber added constant as 0.4%. The strength and durability of self-healing concrete using Bacillius subtilis and polyethylene fibre has investigated and compared with control concrete. The optimum strength is obtained at 105 cells concentration, which increases the compressive strength by 13.2%, split tensile strength by 21.4% and flexural strength by 16.04% and polyethylene fibre were bridging over the crack. The more CaCO3 precipitations, the better the self-healing effect.

[22] K. Pappupreethi, A. Rajisha and P. Magudeaswaran (2017-This paper has been presented that using bacterial in concrete to enhancing the properties of bacterial concrete when it compared to normal concrete such as compressive and flexural strength and within the same time to decrease the water absorption, permeability and reinforcement corrosion. This paper enhanced the knowledge about bacterial concrete by defining the type, merit, and demerit and how it's used as repair material and also used different admixtures such fly ash, silica fume in bacterial concrete due to this condition bio concrete achieved improved durability and strength.

CHAPTER 3: METHODOLOGY & EXPREMENTAL STUDY

STUDY AREA

Before starting any research work some preliminary test or work has to be done in lab or at site. The detailed experimental procedure is discussed below:

- Collecting all the basic materials like cement, sand and aggregate as per Indian Standard Specification.
- Finding all the basic properties of cement, sand and aggregate by performing basic tests on it.
- Getting cement: sand: aggregate ratio by defining w/c ratio by IS mix design procedure.
- Casting of non-microbial concrete cubes without addition of bacteria of size 150mm×150mm×150mm for performing different tests of 3,7 and 28 days.
- Casting of microbial concrete cube of size 150mm×150mm×150mm with different concentration of bacterial culture i.e. 50%, 75% and 100% for performing different tests on 3,7 and 28 days.
- Conducting slump test, pH test, EDTA test and water absorption test on bacterial concrete.

PRELIMINARY TEST

TEST ON FINE AGGREGATE

SIEVE TEST

Sieve Analysis of the fine aggregate is carried out in the laboratory as per IS 383-1870. The sand is first sieved through 4.75mm sieve to remove any particle greater than 4.75 mm sieve and then washed to remove the dust. For performing the sieve test 1kg of fine aggregate is taken. The fine aggregates used for the experimental work is locally procured and comply with grading zone IV.

SPECIFIC GRAVITY

Specific gravity is defined as the ratio of unit weight of substance to the standard substance at standard temperature i.e. 4^{o}C. This test is performed with the help of pycnometer.

1. Empty wt. of pycnometer (W_1)= gm
2. wt. of pycnometer + wt. of fine aggregate (W_2)= gm
3. wt. of pycnometer + wt. of fine aggregate + wt. of water (W_3)= gm
4. wt. of water filled in pycnometer up to full level (W_4)=gm

TEST ON COARSE AGGREGATE

SIEVE TEST

Crushed stone aggregate of maximum size 20 mm are used as coarse aggregate throughout the experimental study. The aggregates are washed to remove dust and dirt and are dried to surface dry condition. The aggregates are tested as per IS: 383-1970. For performing the sieve test 2kg of coarse aggregate is taken.

Fig 1.3: Fine Aggregate **Fig 1.4 : Coarse Aggregate**

SPECIFIC GRAVITY

Specific gravity is defined as the ratio of unit weight of substance to the standard substance at standard temperature i.e. 4°C. This test is performed with the help of pycnometer.

1. Empty wt. of pycnometer (W_1)=
2. wt. of pycnometer + wt. of coarse aggregate (W_2)=
3. wt. of pycnometer + wt. of coarse aggregate + wt. of water (W_3)=
4. wt. of water filled in pycnometer up to full level (W_4)=

PH TEST OF TAP WATER

pH is defined as the negative logarithm of hydrogen ion concentration. pH test is performed by pH meter. Fresh and clean tap water is used for casting the specimens in the present study. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per Indian standard. pH of **tap water=** 8.08.

TEST ON CEMENT

Portland Pozzolana cement (PPC) is used for the present investigation. The cement is of uniform color i.e. grey with a light greenish shade and is free from any hard lumps.

Stipulations for Proportioning

i. Grade Designation- M20
ii. Type of Cement- OPC 43 grade
iii. Maximum Size of Aggregate- 20mm
iv. Exposure Condition- R.C.C (Mild)

Target Mean Strength

$f_t = f_{ck} + kS$

Where, f_t= target average compressive strength at 28 days

f_{ck}= characteristics compressive strength at 28 days

S= standard deviation

Water/Cement Ratio

Maximum Water/cement → 0.50 [Table 5 IS 456:2000]

Water/cement opted → 0.50

Amount of Water Content

Cement Quantity

Volume of Coarse and Fine Aggregate

Quantity of Materials

BACTERIAL CULTURE

Bacillus is used for this work which is extracted from CT5 strain. The inoculation of the bacteria Bacillus from CT5 strain is done by sequential order fulfilling all conditions of their growth.

INOCULATION PROCESS OF BACTERIAL CULTURE

First of all bacterial strain "**BACILLUS CEREUS"** that was in solid powder was converted in inoculum by mixing it in the broth solution.

It was done inside "laminar air flow" and suitable precautions were taken so that our bacteria do not contaminate.

It is then kept for one day inside BOD incubator for one day for the proliferation of bacteria.

Inoculum was further increased by adding more broth solution so that our bacteria can be sufficiently grown.

Quantity of Nutrient Broth (NB) added per litre for inoculum=13gm.

PREPERATION OF BACTERIAL SOLUTION

For the preparation of 1 litre bacterial solution following steps were taken.

As we are preparing 1 litre solution we need 500ml Nutrient Broth solution, therefore adding 6.5gm NB in 500 ml distilled water.

The solution is then kept in autoclave to remove any contamination present in it.

Concentration of $Ca(OH)_2$ = 74.09gm/L

Therefore adding 37.045gm $Ca(OH)_2$ in 500ml of water.

The pH of complete 1000 ml solution must be maintained between 9 to 12 which is the required pH for the growth of bacteria. The solution obtained is kept in shaker for 24hours at 27^{o}C.

After 24 hours calcium acetate, urea and inoculums is added in the solution. The amount of these chemicals and bacterial strain added is calculated below.

Calcium acetate

We required 2.5ml of 25 mM acetate solution /100ml of culture.

Therefor for 1000ml culture, acetate solution = 25ml.

For 25 mM acetate- 0.4gm per 100 ml distilled water

Therefore for 25 ml solution acetate= 0.1gm

Urea-Concentration

$40 \times X = 2 \times 100$

X = 5ml.

Inoculum is added as 10% of the total solution.

After addition of all these three components in 1000 ml solution the final which comes out is known as Bacterial culture.

This solution is kept in BOD Incubator for at least 3 days for proper growth of bacteria before using it in cube casting.

Fig 1.5 : Bacterial Solution

This solution is used to casting of cubes with three different concentrations as 50%, 75% and 100%. This causes 3 cases whose designations are:-

Table 3.1- Designation of Concrete Mixes

CASE No.	DESCRIPTION OF MIX	DESIGNATION
1	100% bacterial solution used as water	C100
2	75% bacterial solution+25% normal water	C75
3	50% bacterial solution+50% normal water	C50
4	Normal cube without any bacterial water	C0

PROCEDURE FOR CASTING BACTERIAL CUBES

To cast the cubes for N% bacterial solution we consider 30% factor of safety for material and bacterial solution. Due to improper washing of mixer a mass concentration of concrete gets stickened to the blade of the mixer due to which the students are unable to wash the mixer properly.

Quantity of cement required for 6 cubes = kg

Quantity of fine aggregate required for 6 cubes = kg

Quantity of coarse aggregate required for 6 cubes = kg

Sieve fine aggregate by using 4.75mm sieve as per required amount for casting 9 cubes. After this sieve the coarse aggregate by passing it through the 20mm sieve as required and then measure the amount of cement required. On the other hand prepare the mould for casting of cubes by tighten the bolts of mould and then do oiling inside the mould so that the concrete does stick to the mould. First of all wash the concrete mixer properly so that no impurity or extra material left inside after this dry mix the cement, fine and coarse aggregate after dry mixing add suitable amount of bacterial solution and water as binder then allow the mixer to mix all the component of concrete for 10 min. After proper mixing check the slump value of concrete and then pour the concrete in the mould after pouring concrete put the mould on mechanical vibrator so that the concrete in the mould got fully compacted and no space or gap left inside the mould after vibration left the mould for 1 day and after one day open the mould by loosen the bolts of mould take out the cubes from the mould and place the cubes in the water tank for curing and then check the strength after 7 & 28 days as per required. For checking the strength on 3rd day take out the cube from the water tank and then properly wipe out all the water from all the faces of concrete then place the cubes in the universal testing machine and note then note the readings.

Fig 1.4 : Mixing and casting of cubes

Fig 3.8: Moulded cube

Fig 3.9: Curing

TOOLS REQUIRED

- BOD Incubator
- Laminar Air Flow
- Orbital Shaker
- Auto Clave
- Incubator
- Micro Pipette
- Petri Plates
- Burner
- Pipette Tips
- Glass Rod, Flask, Measuring
- Cylinder

Fig 4.0 : Auto Clave

Fig 4.1 : Orbital Shaker

Fig 4.2 : Laminar Air Flow

PROCESS OF TESTING

Different testing processes which involved in this report are, test for compressive strength, pH value determination, estimation of calcium carbonate precipitation by EDTA, Slump, Water absorption, crack analysis.

COMPRESSIVE STRENGTH

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material and quality control during production of concrete etc**.**

- Remove the specimen from water after specified curing time and wipe out excess water from the surface.
- Take the dimension of the specimen to the nearest 0.2m
- Clean the bearing surface of the testing machine
- Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
- Align the specimen centrally on the base plate of the machine.
- Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
- Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails
- Record the maximum load and note any unusual features in the type of failure.

SPLIT TENSILE STRENGTH

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The cylinders are placed in the compression testing machine and load is applied as similar to the cube. The cylinder is placed horizontally and the test is performed. The load is increased until the specimen fails and the maximum load applied to test specimen during the test is recorded. In these 6 concrete cylinders moulds are filled with concrete at every casting or with different percentage. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long.

$$T = 2P / \pi LD$$

Where,

T = Split Tensile Strength
P = maximum Applied Load
L = Length of cylinder
D = Diameter of cylinder

Fig 4.2 : Compressive Testing Machine

pH VALUE TEST

pH value of concrete specimen determined any detrimental effect that bacteria can cause on the formation of passive layer that prevents rebar from its corrosion. For determining pH of the given samples, crushed concrete obtained after conducting compressive strength was taken were crushed in to powdered form which can pass through 300µ sieve. Powdered sample was mixed with water in ratio of 1:9 in test tube and left for overnight, next day this sample was tested by pH meter to get pH of the mix. The pH was noted corresponding to two layers on concrete cubes. One sample was taken for the top surface to represent surface concrete and other was taken from near the Centre of concrete to represent bulk concrete for 3,7 and 28 days.

EDTA

To confirm calcium carbonate precipitation, EDTA test were performed on powdered sample of top surface were tested on 28 days 0.5gm powdered sample were taken in a beaker and 3ml of HCl were mixed in that. Then 43 ml of water were mixed in to the solution obtained and 4 ml of NaOH were added to prepare complete solution. A drop of indicator hydroxyl naphtha blue were added which turns whole solution in to light pink colour. The pink solutions obtained were titrated against EDTA which at a point converts pink solution in to blue colour. This conversion shows the presence of calcium carbonate.0.1ml of EDTA used correspond to 5.006 mg of $CaCO_3$ per gram of samples.

SLUMP

Slump test of concrete is carried out to check the workability of concrete. It is carried out in freshly mixed concrete. Mixed concrete is poured into the frustum of cone in three layers with 25 blows on each layer. The size of frustum is Upper diameter-100mm Lower diameter-200mm Height-300mmAfter pouring the concrete full into the frustum of raise the mould from the concrete slowly in vertical direction and measure the fall from the top of the concrete. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

WATER ABSORPTION

One of the most important properties of a good quality concrete is low permeability,
A concrete with low permeability resists ingress of water and is not as susceptible to freezing and thawing. Water enters pores in the cement paste and even in the aggregate.
For checking water absorption weigh the cube after demoulding them.

This is called dry weight → W_1.

Put them in curing tank for 24 hours and then again weigh them.

This is called wet weight → W_2.

Water absorption is given by → W_2-W_1/W_1

CHAPTER 4: RESULTS AND DISCUSSIONS

RESULTS

STRENGTH COMPARISON OF NORMAL AND BACTERIAL CUBES

NORMAL CUBES

Table 3.2- Compressive Strength of Normal Cubes

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	18.72	19.46	19.22	19.13
28	27.44	25.00	26.24	26.22

CASE 1: 25%BACTERIAL SOLUTION

Table 3.3- Compressive Strength of Bacterial Cubes for 25% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	19.84	18.00	20.10	19.31
28	30.66	29.96	29.84	30.15

CASE 2: 50%BACTERIAL SOLUTION

Table 3.4- Compressive Strength of Bacterial Cubes for 50% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	24.50	23.10	22.60	23.40
28	31.40	33.50	34.10	33.00

CASE 2: 75%BACTERIAL SOLUTION

Table 3.5 Compressive Strength of Bacterial Cubes for 75% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	22.56	23.10	23.20	22.95
28	32.50	33.00	32.30	32.60

CASE 4: 100%BACTERIAL SOLUTION

Table 3.6- Compressive Strength of Bacterial Cubes for 100% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	23.40	22.90	23.80	23.36
28	29.00	31.10	28.50	29.53

Fig 4.3: Testing of Cube

Fig 4.4: Tested Cubes

STRENGTH COMPARISON OF NORMAL AND BACTERIAL CYLINDERS

NORMAL CYLINDERS

Table 4.1 Split Tensile Strength of Normal Cylinders

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	1.36	1.49	1.56	1.47
28	2.18	2.38	2.41	2.32

CASE 1: 25%BACTERIAL SOLUTION

Table 4.2- Split Tensile Strength of Bacterial Cylinders for 25% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	1.34	1.54	1.60	1.49
28	2.28	2.46	2.56	2.43

CASE 2: 50%BACTERIAL SOLUTION

Table 4.3 Split Tensile Strength of Bacterial Cylinders for 50% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	1.40	1.64	1.78	1.60
28	3.68	3.42	3.56	3.55

CASE 3: 75%BACTERIAL SOLUTION

Table 4.4- Split Tensile Strength of Bacterial Cylinders for 75% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	1.42	1.54	1.68	1.54
28	3.24	3.36	3.10	3.23

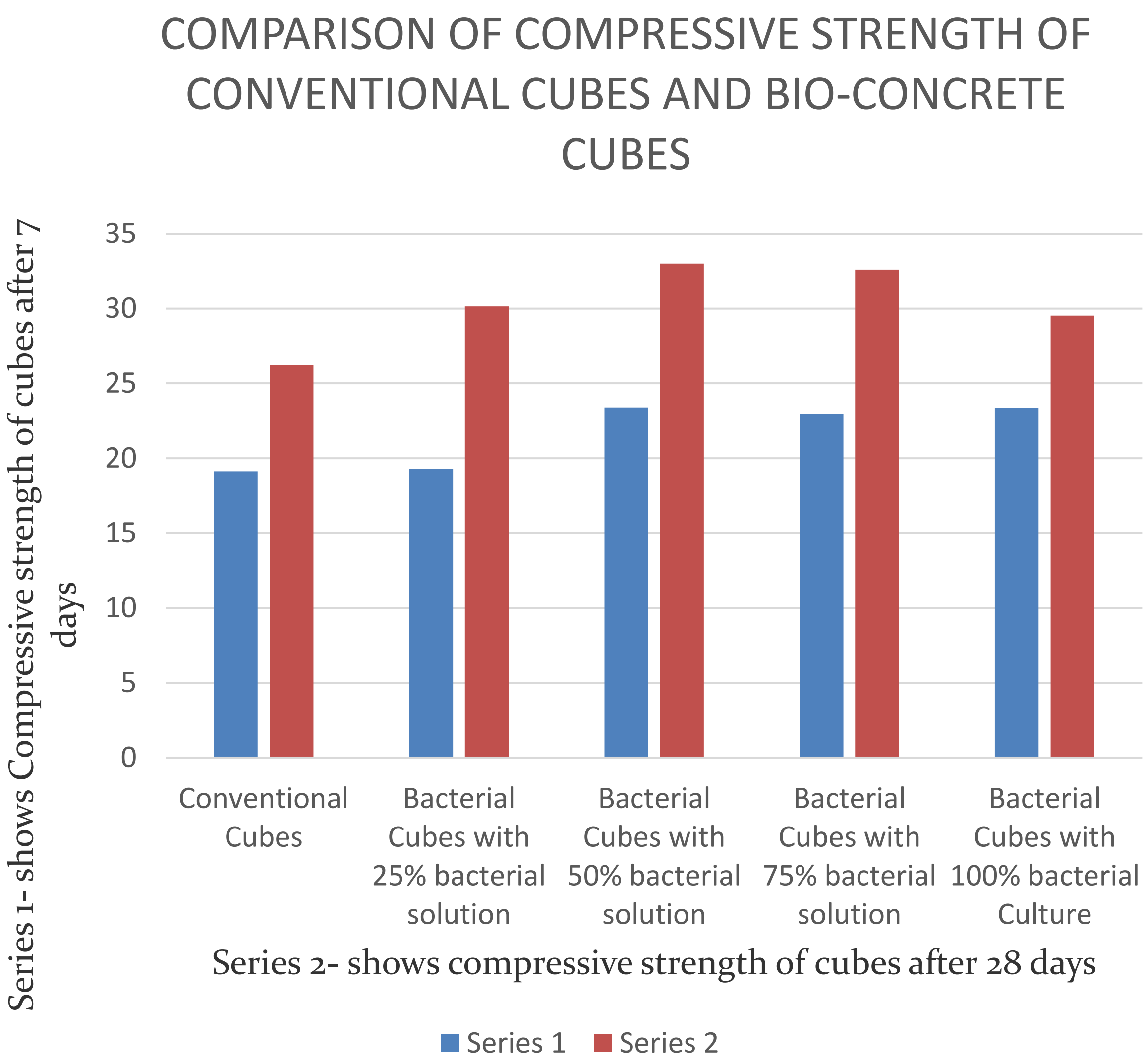
CASE 4: 100%BACTERIAL SOLUTION

Table 4.5- Split Tensile Strength of Bacterial Cylinders for 100% Bacterial Culture.

DAYS	A(N/mm2)	B(N/mm2)	C(N/mm2)	Average Strength(N/mm2)
7	1.24	1.44	1.58	1.42
28	2.82	3.16	2.96	2.98

Fig 4.5: Testing of Cylinder

Fig 4.6: Tested Cylinder



COMPARISON OF COMPRESSIVE STRENGTH OF CONVENTIONAL CUBES AND BIO-CONCRETE CUBES
Series 1- shows Compressive strength of cubes after 7 days
35
30
25
20
15
10
5
0
Conventional Cubes
Bacterial Cubes with 25% bacterial solution
Bacterial Cubes with 50% bacterial solution
Bacterial Cubes with 75% bacterial solution
Bacterial Cubes with 100% bacterial Culture
Series 2- shows compressive strength of cubes after 28 days
Series 1
Series 2

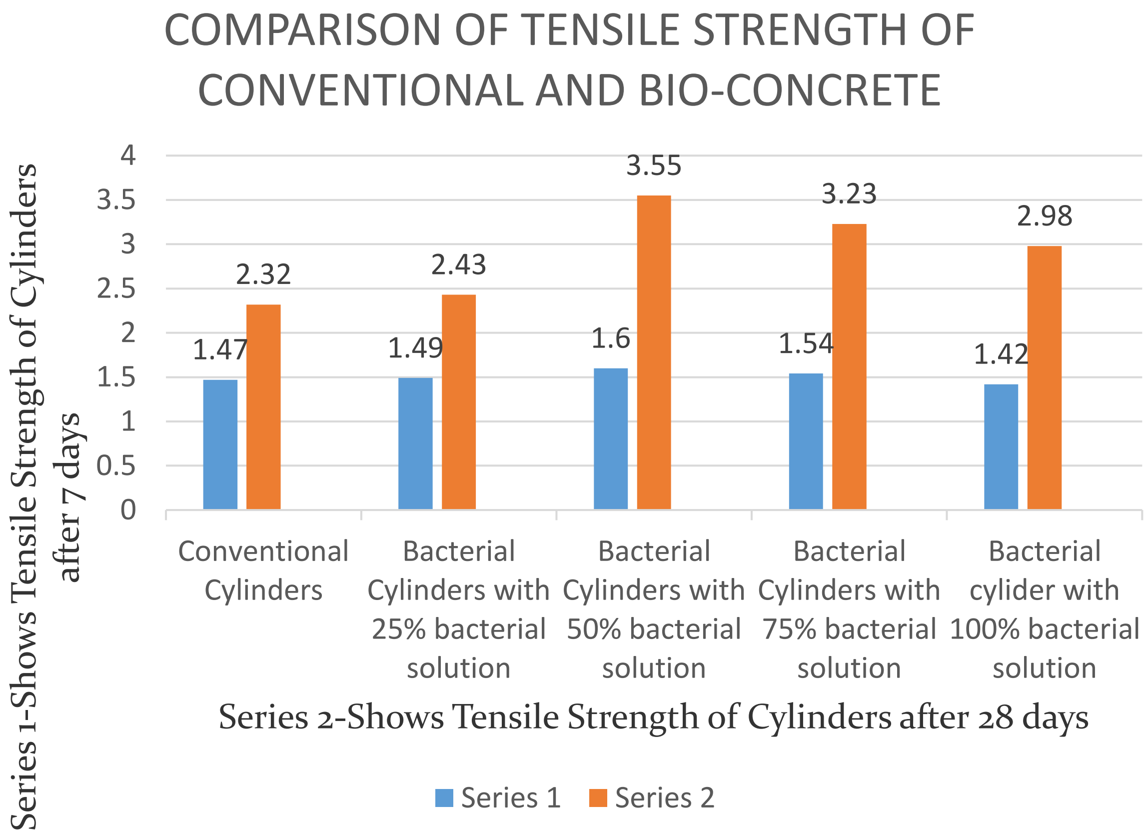

COMPARISON OF TENSILE STRENGTH OF CONVENTIONAL AND BIO-CONCRETE
Series 1-Shows Tensile Strength of Cylinders after 7 days
4
3.5
3
2.5
2
1.5
1
0.5
0
1.47
2.32
1.49
2.43
1.6
3.55
1.54
3.23
1.42
2.98
Conventional Cylinders
Bacterial Cylinders with 25% bacterial solution
Bacterial Cylinders with 50% bacterial solution
Bacterial Cylinders with 75% bacterial solution
Bacterial cylider with 100% bacterial solution
Series 2-Shows Tensile Strength of Cylinders after 28 days
Series 1
Series 2

Table 4.6- Standard deviation

S.no.	Reading (x)	Mean (μ)	Difference From Mean	Square of Difference from Mean
1.	27.44	30.30	-2.86	8.179
2.	25.00		-5.30	28.09
3.	26.24		-4.06	16.48
4.	30.66		0.36	0.13
5.	29.96		-0.34	0.12
6.	29.84		-0.46	0.21
7.	31.40		1.10	1.21
8.	33.50		3.20	10.24
9.	34.10		3.80	14.44
10.	32.50		2.20	4.84
11.	33.00		2.70	7.29
12.	32.30		2.00	4.00
13.	29.00		-1.30	1.69
14.	31.10		0.80	0.64
15.	28.50		-1.80	3.24

Mean (μ) = [27.44+25.00+26.24+30.66+29.96+29.84+31.40+33.50+34.10+32.50+33.00+32.30+29.00+31.10+28.50] / 15

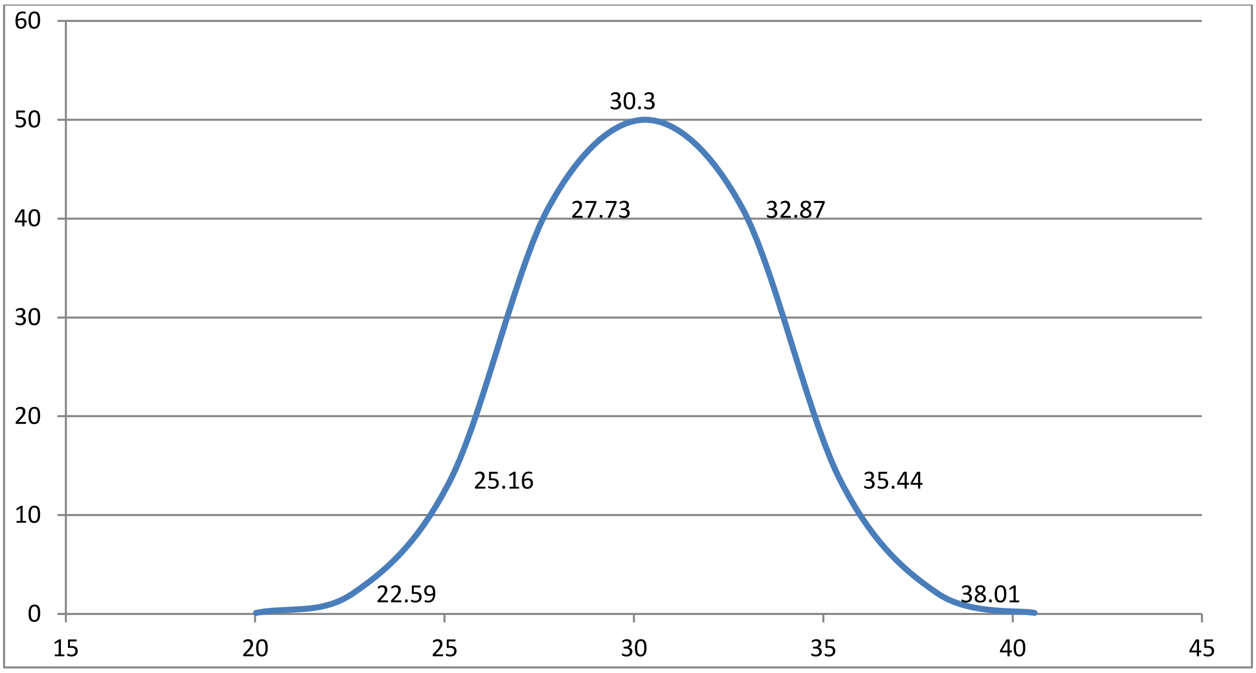
μ = 30.30

Variance = 99.58 / 15
Variance = 6.64

Standard deviation = $\sqrt{\text{Variance}}$

$= \sqrt{6.64}$

Standard deviation = 2.57



Standard Deviation curve

On the basis of the above results it is clearly shown that there is an increment in the compressive strength of concrete cubes and cylinders and the calcium carbonate precipitation also starts forming on surface.

Figure- Calcium carbonate precipitation formed

Figure- Pores start filling up by calcium carbonate

If we compare all the three results case i.e. producing the best result is third case in which the concentration of bacterial solution is 50% and rest is normal water. If we look at the strength after seven days for 100% bacterial solution the increment in strength is 34% and for 75% solution it is 10.18% but there is an immense increment in strength after three days for 50% bacterial solution i.e. 47.08%. The results follow the same trend for the seventh day 50% case has the maximum compressive strength. The third case is also suitable from the economic point of view.

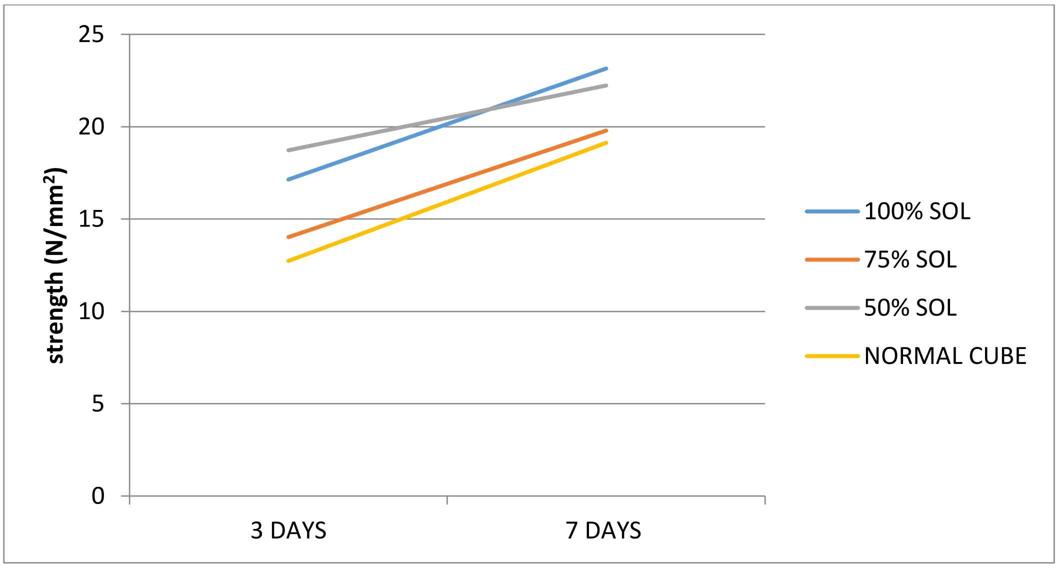


Figure- Graph of Strength Comparison for Different Cases

COST ESTIMATION OF PROJECT
COST OF DIFFERENT CHEMICALS:

1. NUTRIENT BROTH 460 Rs per 100gm
2. CALCIUM HYDROXIDE 229 Rs per 500gm
3. CALCIUM ACETATE 463 Rs per 500gm
4. UREA 314 Rs per 500gm

COST OF BACTERIA (BACILLUS CEREUS) = 1030 Rs strain

CASE 1: FOR 100% BACTERIAL SOLUTION

Size of standard cube= 150mm x 150mm x 150mm

In per m^3 =1000mm x 1000mm x 1000mm

No. of cubes = (1000 x 1000 x 1000/150 x 150 x 150) =296.29 cubes

MATERIAL PER CUBIC METRE

Factor of safety 30 %

For 6 cubes = 5.33 litre solution

For 1 cube = 0.8893

TOTAL AMOUNT OF BACTERIAL SOLUTION PER METRE CUBE = 296.29 x 0.8893

CULTURE REQUIRED = 239.538litre

NUTRIENT BROTH = 1556.997gm in 119.769 litre

(13gm in 1L)

CALCIUM HYDROXIDE = 8873.685gm in 119.769 litre

(74.09gm in 1L)

CALCIUM ACETATE

(We need 2.5 ml of 25 mille molar acetate solution per 100ml of culture.)

For 1litre culture = 0.1gm of calcium acetate in 25ml distilled water.

For 239.538 litre culture = 23.9538gm of calcium acetate in 5988.45ml of distilled water.

UREA

(In 1 litre culture 20gm of urea in 50ml of distilled water)

For 239.538litre culture = 4790.76gm of urea in11976.9ml of distilled water

Cost of nutrient broth = (460 x 1556.997/100 = 7162.1862Rs

Cost of calcium hydroxide = (229 x 8873.685/500)

= 4064.14773Rs

Cost of calcium acetate = (463 x 23.9538/500)

= 22.1812Rs

Cost of urea = (314 x 4790.76/500)

= 3008.59728Rs

Cost of bacillus cereus strain = Rs 1030

Solution of broth required for making bacteria to be used in the solution is 10%= 23.9538 litre

Amount of nutrient broth as inoculum = 23.9538 x 13 = 311.3994gm

Cost of nutrient broth as inoculum = (460 x 311.3994/100) = Rs 1432.43724

TOTAL COST OF BACTERIAL SOLUTION PER m^3 (considering 30% FOS)= Rs16719.54965

COST PER m^3 FOR 100% BACTERIAL SOLUTION (considering no FOS) = Rs12861.192

CASE 2: FOR 75% BACTERIAL SOLUTION

TOTAL COST OF BACTERIAL SOLUTION PER M^3 (considering 30% FOS)= Rs 12539.6624

COST PER m^3 FOR 75% BACTERIAL SOLUTION (CONSIDERING NO FOS) = Rs 9645.894029

CASE 3: FOR 50% BACTERIAL SOLUTION

TOTAL AMOUNT OF BACTERIAL SOLUTION PER m^3 (considering 30% FOS)= Rs 8359.774825

COST PER m^3 FOR 50% BACTERIAL SOLUTION (considering no FOS) = Rs 6430.596

CASE 4: FOR 25% BACTERIAL SOLUTION

TOTAL AMOUNT OF BACTERIAL SOLUTION PER m^3 (considering 30% FOS)= Rs 4179.88741

COST PER m^3 FOR 50% BACTERIAL SOLUTION (considering no FOS) = Rs 3215.298

CHAPTER 5: CONCLUSIONS

- Introducing bacteria to the concrete makes it very beneficial by improving the property of the concrete which is more than the conventional concrete.
- Bacteria repair the cracks in concrete by producing the calcium carbonate crystal which block the cracks and repair it inside out.
- Many researchers done their work on the self-healing nature of concrete and they had found the following result that bacteria improves the property of conventional concrete such as increase in 13.75% strength increased in 3 days, 14.28% in 7 days and 18.35% in 28 days.
- Bio concrete is the best solution for the demand of sustainable concrete. Due to its ability of self-repair and durability. In future self-healing concrete is going to play the most important role in concrete technology.
- Bio concrete is eco-friendly and Enhance compressive strength and reduce the permeability.
- Bacterial concrete technology has proved to be better than many conventional technologies.
- Bio concrete enhance the life time of a structure by more than the expected value.

FUTURE SCOPE

- To study the effect of bacteria on high strength concrete.
- To study the durability of concrete under various weathering conditions.
- To determine the maximum width of crack healing using bacterial concrete under various weathering condition.
- To grow the bacterial culture on commercial level.
- Finding the alternate way for the source of bacteria to make it economic.

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A COMPARATIVE STUDY OF COMPRESSIVE AND TENSILE STRENGTH OF CONVENTIONAL CONCRETE WITH BIO-CONCRETE

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A COMPARATIVE STUDY OF COMPRESSIVE AND TENSILE STRENGTH OF CONVENTIONAL CONCRETE WITH BIO-CONCRETE

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ABSTRACT :It is a 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 are responsible for the passage of liquids and gasses that could potentially contain deleterious substances. When micro-cracks migrates towards the reinforcement, not only the concrete itself may be damaged, but also corrosion occurs in the reinforcement due to exposure to water and oxygen, and possibly CO_2 and chlorides too. Micro-cracks are therefore 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 bio-mineralization 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. In the present paper, an attempt is made to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength and durability of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophilic spore forming bacteria may be able to survive in this environment and increase the strength and durability of cement concrete. Overview of development of bioengineered concrete using bacterial strain Bacillus Cereus and its enhanced mechanical and durable characteristics will be briefly described in this paper.

Key Words: **compressive strength, tensile strength, bacteria solution, media.**

I. INTRODUCTION

It is special type of concrete invented by a group of micro biology researchers under the head of Henk Jonkers. Bio-concrete is specially made to increase the life span, strength, and durability of concrete structures by the self-healing action of that concrete. The Bio-concrete is dead concrete that awakens when crack appears. Then they produce limestone that fills the crack in a matter of weeks. 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 project 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. The selection of bacteria was according to their survival in the environment such as B. pasteurii, Bacillus subtilis and Bacillus cereus which are mainly used for experiments by different researchers for their study. The condition of growth is different for different types of bacteria. For the growth of bacterial solution which is to be used in bio-concrete were put in medium containing different chemicals at a particular temperature for a particular period of time. It contains studies on different bacteria's, their isolation process, different approaches for addition of bacteria in concrete, their effects on compressive strength and tensile strength of concrete containing bacteria.

II. LITERATURE REVIEW

[1] S. Sunil Pratap Reddy et.al (2010) - Studied the performance of the standard grade bacterial (Bacillus subtilis) concrete. Its main focus was on how the right conditions can be created for the bacteria not only to survive in the concrete but to produce proper calcite to repair cracks. Cement mortar cubes with four different cell concentrations and control specimen were casted. Results shows that compressive strength of concrete increased significantly by 14.92% at 28 days due to the addition of bacteria for a cell concentration of 105 cells per ml of water. Addition of bacteria improves the hydrated structure of cement mortar. From SEM analysis, it was noted that pores were partially filled up by material growth with the addition of the bacteria. Bacillus subtilis bacteria showed significant improvement in the split tensile strength than the conventional concrete.

[2] M S Vekariya1, Prof. J. Pitroda (2013) - They presented that the microorganisms used in concrete to enhance the all properties of concrete by the biological mechanisms. Bio concrete have eco- friendly, self-healing and rise in durability of several construction material this gives good technology than other normal technologies. Study of several researchers has enhanced our understanding of the possibilities and limitations of biotechnological applications on building materials. Decreasing in permeability, improving of compressive strength, corrosion of reinforcement, water absorption has been observed in several stone and cementations material. Cementation by this method is very simple and suitable for usage. Finally, they concluded that more work is regarding to economical and practical viewpoint to enhance the possibility of biotechnology with high- quality structures.

[3]- Jagadeesha Kumar B G, R Prabhakara and Pushpa H5 (2013) – They published a paper on effect of bacterial calcite precipitation on compressive strength of mortar cubes. This paper describes about the experimental investigations carried out on mortar cubes which were subjected to bacterial precipitation by different bacterial strains and influence of bacterial calcite precipitation on the compressive strength of mortar cube on 7, 14 and 28 days of bacterial treatment. Three bacterial strains bacillus flexus, isolated from concrete environment, Bacillus pasturii and Bacillus sphaericus were used. The cubes were immersed in bacterial and culture medium for above mentioned days with control cubes immersed in water and was tested for compressive strength. The result indicated that there was an improvement in the compressive strength in the early strength of cubes which were reduced with time. It was studied that the increase in compressive strengths is mainly due to consolidation of the pores inside the cement mortar cubes with micro biologically induced calcium carbonate precipitation.

[4]-Ravindranatha, N. Kannan, Likhit M.L3 (2014) - They have published a paper on self-healing material bacterial concrete. In this paper a comparative study was made with concrete cubes and beams subjected to compressive and flexural strength tests with and without the bacterium Bacillus pasteurii. The concrete cubes and beams were prepared by adding calculated quantity of bacterial solution and they were tested for 7 and 28 days compressive and flexural strengths. It was found that there was high increase in strength and healing of cracks subjected to loading on the concrete specimens. The microbe proved to be efficient in enhancing the properties of the concrete by achieving a very high initial strength increase. The calcium carbonate produced by the bacteria has filled some percentage of void volume thereby making the texture more compact and resistive to seepage.

[5]-Sakina Najmuddin Saifee et.al1 (2015) - Published a paper on Critical appraisal on Bacterial Concrete. In this paper they discussed about the different types of bacteria and their applications. The bacterial concrete is very much useful in increasing the durability of cements materials, repair of limestone monuments, sealing of concrete cracks to highly durable cracks etc. It also useful for construction of low cost durable roads high strength buildings with more bearing capacity, erosion prevention of loose sands and low cost durable houses. They have also briefed about the working principle of bacterial concrete as a repair material. It was also observed in the study that the metabolic activities in the microorganisms taking place inside the concrete results into increasing the overall performance of concrete including its compressive strength and tensile strength. This study also explains the chemical process to remediate cracks.

[6]A.T.Manikandan1, A.Padmavathi4 (2015) - They have published a paper on an experimental investigation on improvement of Concrete Serviceability by using Bacterial Mineral Precipitation. In this paper, the bacteria bacillus subtilis strain 121 was from microbial type culture collection and gene bank, Chandigarh. Samples were prepared in sets of three for a water cement ratio of 0.5 by mass for conventional concrete and a water cement ratio of 0.25 and bacterial culture of 0.25 for bacterial concrete by mass. The cubes were tested by Non-Destructive Testing and HEICO compression testing machine on the 3rd, 7th and 28th days after casting. There was an improvement in compressive strength by B. subtilis strain 121 due to deposition of Calcite (CaCO3) in cement-sand matrix of microbial concrete which remediate the pore structure within the mortar. The temperature sustainability test of B. Subtilis in bacterial concrete was carried out at various temperatures and found that the subtilis was found to be alive at –30 C low temperatures to 700 C, high temperatures. There is increase in compressive strength of the bacterial concrete with B.Subtilis bacteria with microbial calcite precipitation in the crack sample was examined in SEM.

[7]- Chithra P Bai and Shibi Varghese 7 (2016) - They have published a paper on an experimental investigation on the strength properties of fly ash based Bacterial concrete. In this paper, the bacteria bacillus Subtilis was used for study with different cell concentrations of 103, 105 and 107 cells/ml for preparing the bacterial concrete. Cement was partially replaced by 10%, 20% and 30% of fly ash by weight for making the bacterial concrete. Concrete of grade M30 was prepared and tests such as Compressive strength, Split tensile strength, Flexural strength and Ultrasonic Pulse Velocity were conducted after 28 and 56 days of water curing. For fly ash concrete, maximum compressive strength, split tensile strength, flexural Strength and Ultrasonic Pulse Velocity values were obtained for 10% fly ash replacement. For bacterial concrete maximum compressive strength, split tensile strength, flexural strength, and UPV values were obtained for the bacteria cell concentration of 105cells/ml. The improvement in the strength properties of fly ash concrete is due to the precipitation of calcium carbonate (CaCO3) in the micro environment by the bacteria Bacillus Subtilis.

[8] M. Monishaa and Mrs. S. Nishanthi (2017) – They investigated strength of concrete using Bacillius subtilis and polyethylene fiber. M20 grade concrete is prepared with different bacterial cell concentration of 104, 105 and 106cells per ml of water and polyethylene fiber added constant as 0.4%. The strength and durability of self-healing concrete using Bacillius subtilis and polyethylene fibre has investigated and compared with control concrete. The optimum strength is obtained at 105 cells concentration, which increases the compressive strength by 13.2%, split tensile strength by 21.4% and flexural strength by 16.04% and polyethylene fibre were bridging over the crack. The more CaCO3 precipitations, the better the self-healing effect.

MAJOR FINDINGS FROM LITERATURE REVIEW:

After the literature study, the following findings can be drawn:

- The majority of Bacillus bacteria have a positive effect on the compressive strength, tensile strength of concrete and on bending strength compared to conventional samples.
- The use of a mixture (consortium) of Bacillus pseudofirmus and Bacillus cohnii resulted increase in compressive strength.
- The Bacillus sphaericus species showed a reduction in water absorption.
- Inorganic porous materials such as ceramite, zeolites and others are used to protect the bacteria from high.
- The use of various substances, e.g., silica gel, protects bacteria from alkaline reactions.
- The use of autoclaved bacteria or their dispute reduces porosity and thus permeability.
- The durability of concrete is increased and the permeability of chlorides is reduced.
- Many researchers done their work on the self-healing nature of concrete and they had found the following result that bacteria improve the property of conventional concrete such as increase in 13.75% strength increased in 3 days, 14.28% in 7 days and 18.35% in 28 days.

III. CONCLUSIONS

- Introducing the bacteria into the concrete makes it very beneficial it improves the property of the concrete which is more than the conventional concrete.
- Bacteria repair the cracks in concrete by producing the calcium carbonate crystal which block the cracks and repair it.
- Bio concrete is the best solution for the demand of sustainable concrete. Due to its ability of self-repair and durability. In future self-healing concrete is going to play the most important role in concrete technology.
- Bio concrete is eco-friendly and Enhance compressive strength and reduce the permeability.
- Bacterial concrete technology has proved to be better than many conventional technologies.
- Bio concrete enhance the life time of a structure by more than the expected value

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AN EXPERIMENTAL STUDY ON STRENGTH BEHAVIOUR OF BIO-CONCRETE CUBES CYLINDERS AND BEAMS

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ABSTRACT: Concrete is the most widely used construction material because of its high compressive strength, relatively low cost, etc. One adverse property of concrete is its sensitivity to crack formation as a consequence of its limited tensile strength. For that reason, concrete is mostly combined with steel reinforcement to carry the tensile loads. Although these rebar restrict the crack width, they Concrete is very sensitive to crack formation. As wide cracks endanger the durability, repair may be required. However, these repair works raise the life-cycle cost of concrete as they are labour intensive and also the structure becomes in disuse during repair. In view of the above, several researchers started to investigate this topic. The "Bacterial Concrete" is a concrete which can be made by embedding bacteria in the concrete that can constantly precipitate calcite. Cracking in the surface layer of concrete mainly reduces its durability, since cracks are responsible for the passage of liquids and gasses that could potentially contain deleterious substances. When micro-cracks migrates towards the reinforcement, not only the concrete itself may be damaged, but also corrosion occurs in the reinforcement due to exposure to water and oxygen, and possibly CO_2 and chlorides too. Micro-cracks are therefore 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 bio-mineralization of bacteria in concrete. 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. In the present paper, an attempt is made to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength and durability of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophiles spore forming bacteria may be able to survive in this environment and increase the strength and durability of cement concrete. Overview of bioengineered concrete using bacterial Bacillus Cereus and its enhanced mechanical and durable characteristics will be briefly described in this paper.
Keywords: MICP, Compressive, tensile and Flexural strength bacteria solution, media.

1. INTRODUCTION

It is special type of concrete invented by a group of micro biology researchers under the head of Henk Jonkers.Bio-concrete is specially made to increase the life span, strength, and durability of concrete structures by the self-healing action of that concrete. The Bio-concrete is dead concrete that awakens when crack appears. Then they produce limestone that fills the crack in a matter of weeks. 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 project 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. The selection of bacteria was according to their survival in the environment such as B. pasteurii, Bacillus subtilis and Bacillus cereus which are mainly used for experiments by different researchers for their study. The condition of growth is different for different types of bacteria. For the growth of bacterial solution which is to be used in bio-concrete were put in medium containing different chemicals at a particular temperature for a particular period of time. It contains studies on different bacteria's, their isolation process, different approaches for addition of bacteria in concrete, their effects on compressive strength and tensile strength and flexural strength of concrete containing bacteria.

Principle of self-healing concrete-

Self-healing concrete was invented by Henk Jonkers, a microbiologist and professor as Delft University of Technology in the Netherlands. Jonkers began developing self-healing concrete in 2006. After three years of experimenting, he found the perfect healing agent –bacillus. "You need bacteria that can survive the harsh environment of concrete," Jonkers said in an interview with CNN. "It's a rock like, stone-like material, very dry."

Bacillus is a perfect match for the job. The bacteria will thrive in a high-alkaline conditions of concrete and produces spores than can live up to four years without any food or oxygen. Jonkers finalized his creation by adding calcium lactate to the limestone concrete mixture in order to feed the bacillus so that they can produce limestone to repair cracks in the concrete. "It is combining nature with construction materials," Jonkers said. "Nature is supplying us a lot of functionality for free. In this case, limestone-producing bacteria. Self-healing concrete could solve the problem of concrete structures deteriorating well before the end of their service life. Concrete is still one of the main materials used in the construction industry, from the foundation of buildings to the structure of bridges and underground parking lots. Traditional concrete has a flaw, it tends to crack when subjected to tension.

Objective:

The main objectives of the work are-

- To compare the compressive, tensile and flexural strength of normal concrete and bio concrete.
- To develop self- healing bio concrete using biological based techniques.

2. FUNCTION OF BACTERIA

Research has shown that autogeneous healing happens due to hydration of non-reacted cement particle present in the concrete matrix when comes in contact with ingress water resulting in closure of micro-cracks, studies also stated that only spore forming gram positive bacteria can survive in high pH environment of concrete sustaining various stresses. Therefore, bacterially induced calcium carbonate precipitation has been proposed as an alternative and environmental friendly crack repair technique. Microbial calcite precipitation is mainly due to urealytic activity and carbonate bio-mineralization of bacteria. The bacteria used in this research produce urease which catalyzes the hydrolysis of urea ($CO(NH_2)_2$) into ammonium (NH_4^+) and carbonate (CO_3^{2-}), First, 1mol of urea is hydrolysed intracellular to 1mol of carbonate and 1mol of ammonia (Eq. (1)).

$CO(NH_2)_2 + H_2O$ --- $NH_2COOH + NH_3$ (1)

Carbonate spontaneously hydrolyses to form additionally 1mol of ammonia and carbonic acid (Eq. (2)).

$NH_2COOH+H_2O$ ---- $NH_3+H_2CO_3$ (2)

These products subsequently form 1mol of bicarbonate and 2mol of ammonium and hydroxide ions (Eq. (3) and (4)).

H_2CO_3 -------- $HCO_3^- + H^+$ (3)

$2NH_3+2H_2O$ ----- $2NH_4^+ +2OH^-$ (4)

The last 2 reactions give rise to a pH increase, which in turn shifts the bicarbonate equilibrium, resulting in the formation of carbonate ions (Eq. (5)).

$HCO_3^- + H^+ + 2NH_4^+ + 2OH^-$ ------ $CO_3^{2-} + 2NH_4^+ +2H_2O$ (5).

Since the cell wall of the bacteria is negatively charged, the bacteria draw cat ions from the environment, including Ca^{2+}, to deposit on their cell surface. The Ca^{2+} ions subsequently react with the CO_3^{2-} ions, leading to the precipitation of $CaCO_3$ at the cell surface that serves as a nucleation site (Eq. (6) and (7))

$Ca^{2+} + Cell \rightarrow Cell\ Ca^{2+}$ (6)

$Cell\ Ca^{2+} + CO_3^{2-} \rightarrow Cell\ CaCO_3\downarrow$ (7)

Several bacteria have the ability to precipitate calcium carbonate. These bacteria can be found in soil, sand, natural minerals. This strain showed a high urease activity, a continuous formation of dense calcium carbonate crystals and a very negative zetapotential. Self-healing concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures. Specially selected types of the bacteria genus Bacillus, along with a calcium-based nutrient known as calcium lactate, and nitrogen and phosphorus, are added to the ingredients of the concrete when it is being mixed. These self-healing agents can lie dormant within the concrete for up to 200 years.

3. MATERIALS

3.1 Concrete and concrete specimens

Pozzolana Portland cement of M20 was used for all mixtures. Depending on the type of experiment, concrete samples were chosen for reasons of practical convenience. Standardized concrete cubes (150×150×150mm) prepared, were grounded in powder form for pH, EDTA and SEM experiments. For M20, the Cement: Sand: Aggregate ratio should bein1:1.5:3 i.e.1partofcement, 1.5part of sand and 3 part of aggregate.IS: 456-2000 has recommended that minimum grade of concrete shall be not less than M20 in reinforced concrete work. Design mix concrete is preferred to nominal mix. If design concrete cannot be used for any reason on work for grade M20 or lower, nominal mixes may be used with the permission of engineer-in charge, which however is likely to involve a higher is likely to involve a higher cement content.

3.2 Micro-organism and growth conditions

A thermophilic, anaerobic microorganism Bacillus Cereus isolated from CT5 strain was used in this study. This microorganism was cultured anaerobically in a modified medium (pH 11) before adding to the cement sand and aggregate concrete. Bacillus microorganism grown in Nutrient Broth (NB) medium having pH of 11 was used to study their effect on concrete. 3.3 Mix proportion Microorganism in different ways was added to concrete. The cement to sand to aggregate ratio was used as 1:1.26:2.56 (by weight), and water to cement ratio was fixed at 0.45. A cube mould of 150 mm was used, as per IS 4031-1988 [11]. Three different cases including non-bacterial treated and bacterial treated were studied. 3.4 Culture media Bacillus Cereus was cultivated under aerobic batch conditions in a culture media.100 ml culture media was prepared.0.65 gms of Nutrient broth was added in 50 ml of water and kept for autoclaving. 3.7045 gms of calcium hydroxide was added in 50 ml of water. Both the above solutions were mixed together and a complete 100 mL solution were obtained. 2.5 mL of calcium acetate and 5 mL of urea were added in 100 mL of solution.0.5 % of bacterial strain were added in 100 mL of solution to obtain compete bacterial culture. The culture so obtained was kept in shaker for 24 hrs.

3.3 PREPERATION OF BACTERIAL SOLUTION-

For the preparation of 1 litre bacterial solution following steps were taken-

- As we are preparing 1 litre solution we need 500ml Nutrient Broth solution, therefore adding 6.5gm NB in 500 ml distilled water.
- The solution is then kept in autoclave to remove any contamination present in it.
- Concentration of $Ca(OH)_2$ = 74.09gm/L
- Therefore adding 37.045gm $Ca(OH)_2$ in 500ml of water.
- The pH of complete 1000 ml solution must be maintained between 9 to 12 which is the required pH for the growth of bacteria. The solution obtained is kept in shaker for 24hours at 27^oC.
- After 24 hours calcium acetate, urea and inoculum is added in the solution.

Bacteria Cereus Culture

Bacterial Solution

4. METHOD OF INVESTIGATION

4.1 Compressive Strength

This test was carried out on six specimens of each sample in which three of them were tested at 7 days and rest three were tested at 28 days with following the procedure described by compression testing machine. Compressive strength measurements were carried out using five tones German Bruf Pressing Machine with a loading rate of 100 kg/min. The compressive strength is frequently used as a measure of the resistance because this strength is the most convenient to measure. The cement mortar/concrete properties of various ingredients of the mixture are usually measured in terms of their compressive strength. The compressive strength of concrete/mortar is usually determined by submitting a specimen of constant cross-section to a uniformly distributed increasing axial compression load in a suitable testing machine.

4.2 Flexural Strength

The durability of concrete/mortar is related to the characteristics of its pore structure. Furthermore, permeability of concrete/mortar is dependent on the porosity and the connectivity of the pores. The degradation mechanisms often depend on the way potentially aggressive substances can penetrate the cement-based material, possibly causing damage. The more open the pore structure and connectivity of the pores, the more vulnerable it is to degradation caused by penetrating substances. One of the predominant causes of the corrosion of steel in cement-based structures is chloride attack. Chloride ions may be present in a cementitious material either as a result of aggressive ions ingress or incorporation of the aggressive ions during concrete/mortar preparation. Chloride ions may also penetrate from external sources such as seawater or dicing salts. In the marine environment, the in Chloride is bound if it has reacted with cement and is free if it is available in pore solution. Bio-cementation in OPC lowers chloride ingress and permeability into the cement matrix. This is due to the refinement of the pore structure. Chloride ions penetrate a pore system and form chloride salts which may crystallize within the pores inducing internal cracks. The cracks affect the mechanical and durability properties of concrete/mortar.

4.3 Scanning electron microscopy (SEM)

The scanning electron micrographs of freshly fractured specimens were taken with Inspect S (FEI Company, Holland) equipped with an energy dispersive X-ray analyzer (EDAX) at the accelerating voltage of 200 V to 30 kV. SEM micrographs were obtained using a Jeol JSM5600LV apparatus. Samples were gold coated with a JFC1200 fine coater prior to examination.

4.4 pH

pH test was conducted on powder specimen. Water and powder sample were taken in 1:9 ratios and kept for a overnight. Then the pH of each individual case was determined by using pH meter. Third important factor is ph which influences calcite precipitation. Urea hydrolysis will occur only when urease enzyme will attain specific pH values which would result in Calcite precipitation, which is subjective to pH. Many researchers have proclaimed that the optimum pH in favor of urease is 8.0, beyond which the activity of enzyme dwindles. An increased pH is imperative for ammonia creation via urea hydrolysis.

4.5 EDTA

Powder samples, 0.5 gms of each individual case in addition with 3 ml HCl, 4 ml NaOH and 43 ml water were titrated against EDTA. Hydroxy napthol blue indicator was used. Variation in solution colour from pink to blue confirms the presence of calcium carbonate in the solution.

4.6 Slump Value Test

Mixed bacterial concrete was poured into the frustum of cone in three layers with 25 blows on each layer. The size of frustum is Upper diameter-100mm Lower diameter-200mm and Height-300mm After pouring the concrete full into the frustum of raise the mould from the concrete slowly in vertical direction and measure the fall from the top of the concrete. Slump as the difference between the height of the mould and that of height point of the specimen being tested

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5. RESULTS AND DISCUSSIONS

5.1 Compressive strength and Tensile Strength

Control cubes and microbial cubes for four different percentage of addition of bacterial culture such as C100 – specimens were mixed with 100 % bacterial culture in place of water cement ratio.; C75- specimens were mixed with 25 % water and 75% bacterial culture; C50-specimens were mixed with 50% water and 50% bacterial culture; C25-specimens were mixed with 75% water and 25% bacterial culture After casting, curing of cubes readings were taken on each 7 and 28 days. The results obtained from the testing are tabulated in Table 1.It can be seen that increase in strength is maximum at 7 days in all the cases. It shows that till 7 days, bacteria grow properly and has completely adopted the atmosphere inside concrete cube. As a bacterium grows, calcium carbonate precipitation starts and increases the compressive strength of concrete. Since the bacteria grow only in aerobic condition, the maximum precipitation occurs on the surface of concrete. Slowly after 7 days increase in compressive strength were observed due to formation of calcite layer. Layer of calcium carbonates so obtained as shown in Fig 1 on concrete cube is known as microbial induced calcite precipitation. A significant increase of 39%, 41%, and 38.88% were observed for different cases i.e. case1, case2, case3 and case4 at initial 7 days in comparison to control case respectively. After 28 days it was observed that, the effective increase in compressive strength was less as compared to 7 days strength. Because once all the pores on surface is blocked, anaerobic condition arises in the concrete and the activity of bacteria slows down, with bacteria converting themselves in to spores. A very important point can be seen from Table1, which no matter in what percentage w/c ratio were replaced with bacterial culture, it shows same increase in strength for7 and 28 days. This means microbial effect influence concrete in same manner whether it is used in any percentage.

5.2 Flexural Strength

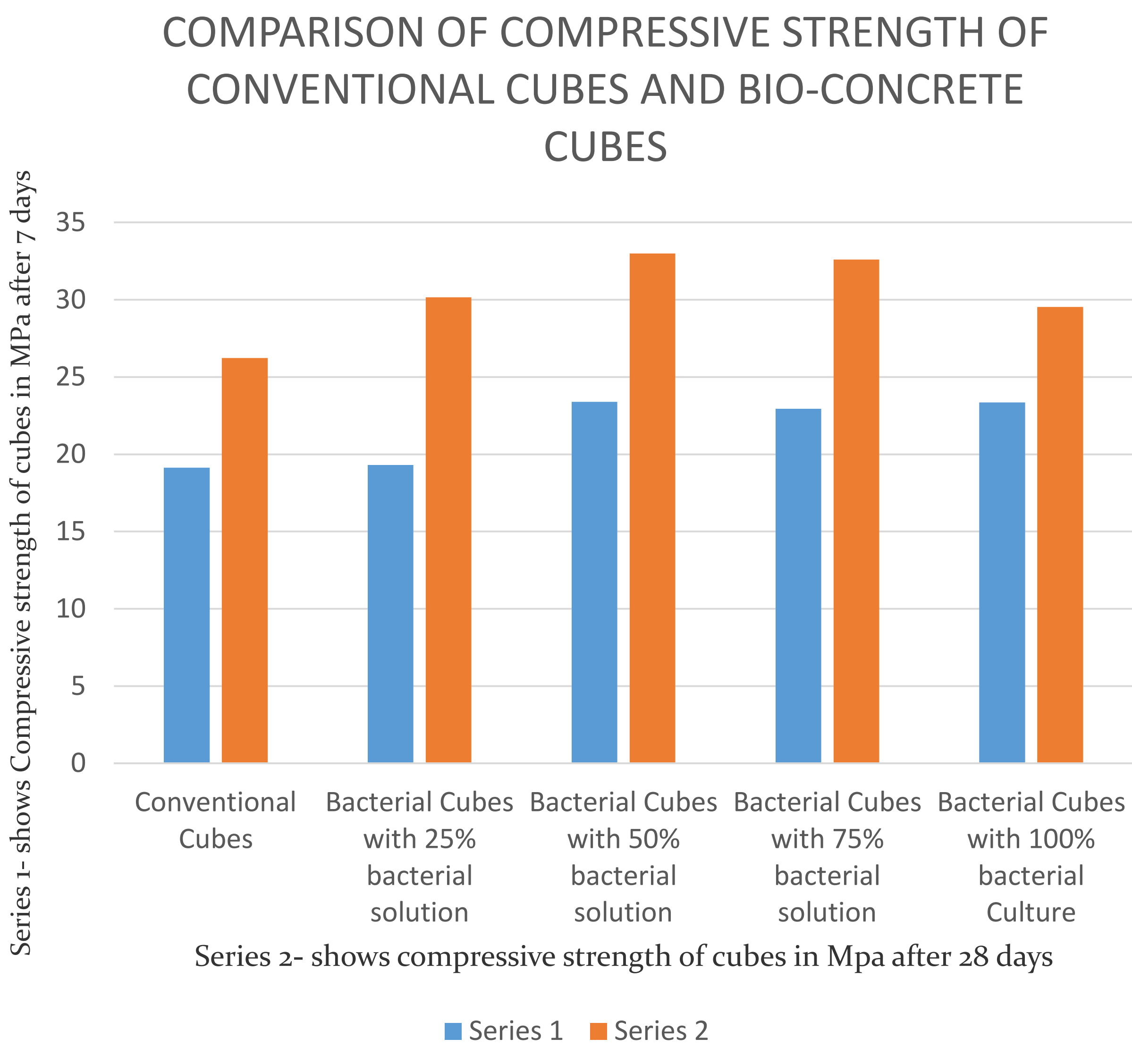
In the present study Bio-Concrete beams were casted with different percentages of bacterial solution i.e. 15%, 25% and 50% , after the proper curing of beams were put to test at 14 days on Flexural Testing Machine by applying partial crack on it when load is applied till the initial cracks were observed on the beam surface. The partially cracked beams were again tested on Flexural Testing Machine at 28 days of curing and the rest of the beams samples were tested directly after 28 days. The results obtained clearly indicate that the load carrying capacity and hence the flexural strength of Bio-Concrete beam regains although beams were partially cracked. It is also observed that regain in strength is more for B3 in which 25% bacterial solution was used. This observation clearly shows the comparison between the conventional concrete beams and bacterial concrete beams for flexural strength of concrete, and also to optimize the better result on a particular percentage to resist lifelong structures.

5.3 pH measurement

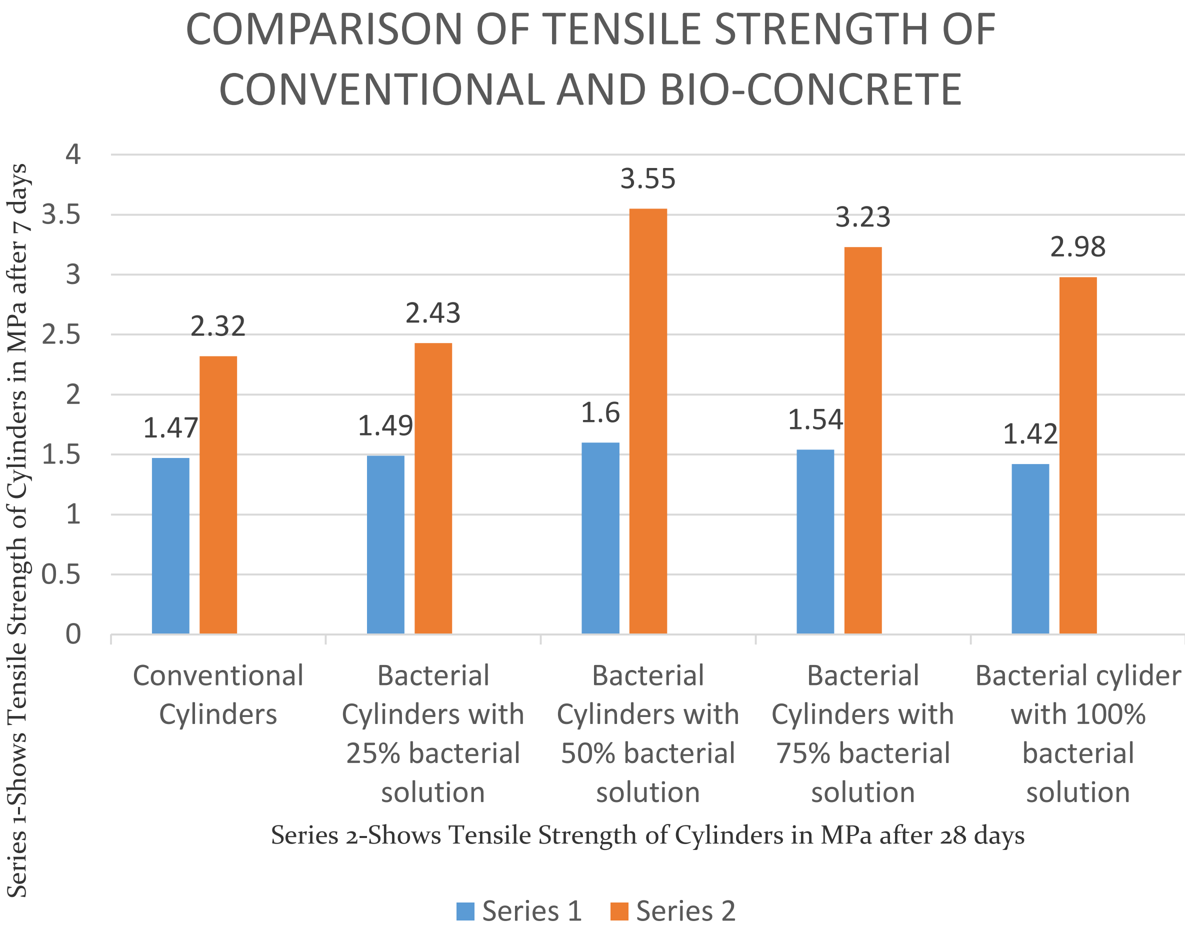
For determining pH of the given samples, crushed concrete obtained after conducting compressive strength was taken were converted in to powdered form which can pass through 300µ sieve. Powdered sample was mixed with water in ratio of 1:9 in test tube and left for overnight, next day this sample was tested by pH meter to get pH of the mix.

5.4 Slump Test Result

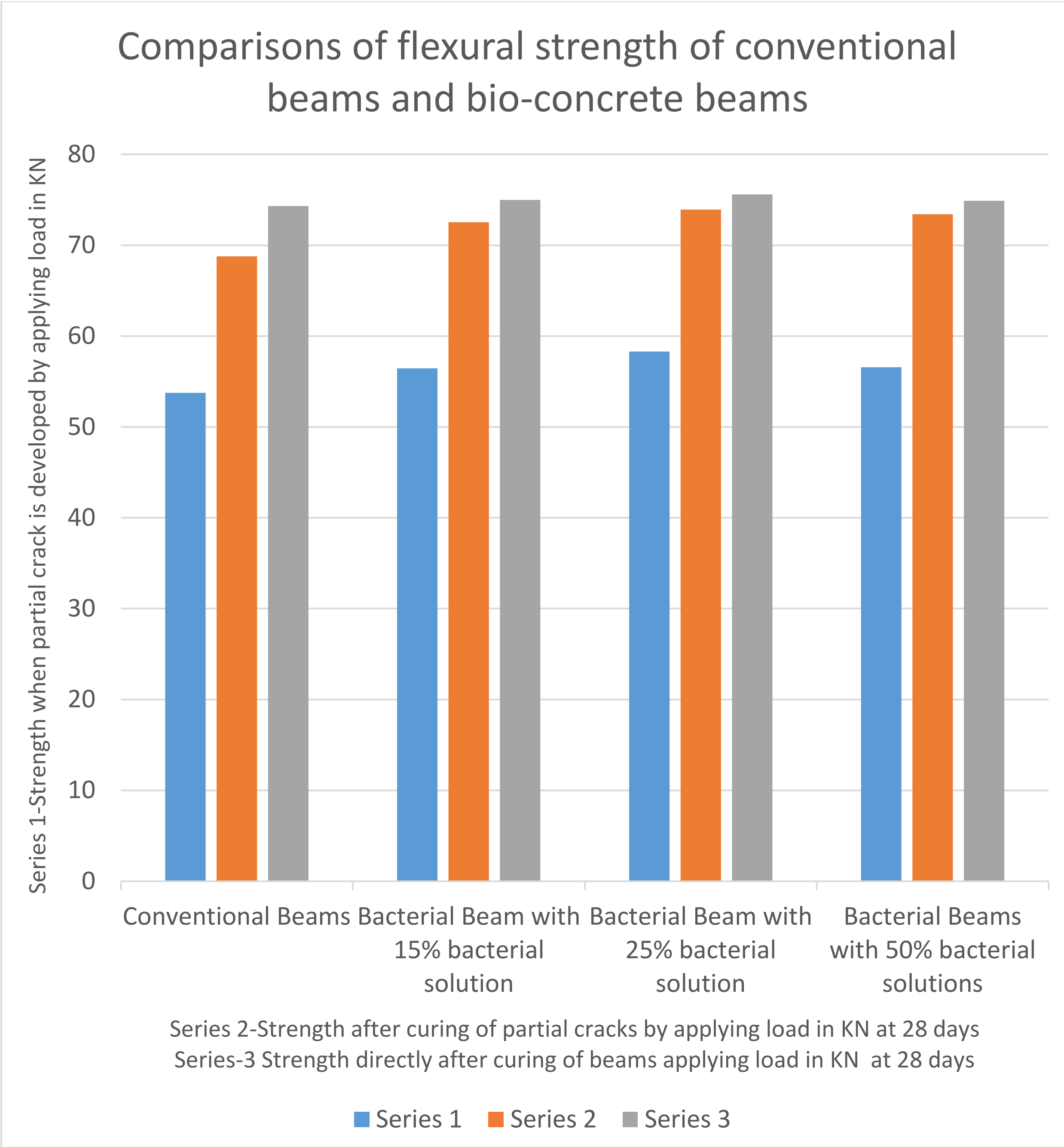
Decrease in height of concrete to that of mould was noted and it was found to be 114mm for conventional concrete and 65, 63, 67and 68 mm for bacterial concrete for C100, C75, C50 and C25 respectively.



Bar Graph of Compressive strength of various cube samples



Bar Graph of Tensile strength of various cylindrical samples



Bar Graph of flexural strength of various beam samples

6. CONCLUSION

On the basis of the above results it is clearly shown that there is an increment in the compressive and tensile strength of concrete cubes and cylinders and the calcium carbonate precipitation also starts forming on surface.

Fig-Calcium carbonate precipitation formed

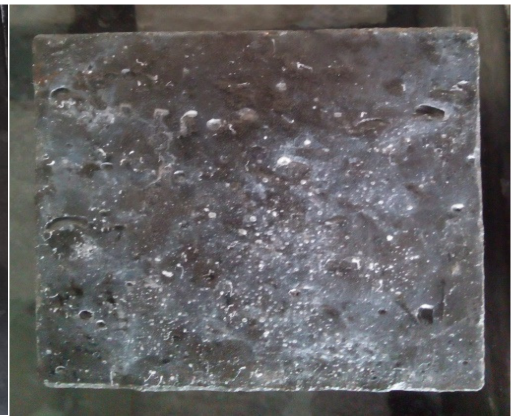


Fig-Pores start filling up by calcium carbonate

If we compare all the five results case i.e. producing the best result is third case in which the concentration of bacterial solution is 50% and rest is normal water. If we look at the strength after seven days for 100% bacterial solution the increment in strength is 22% and for 75% solution it is 19.96% but there is an immense increment in strength after seven days for 50% bacterial solution i.e. 23%. The results follow the same trend for the 28 days 50% case has the maximum compressive strength. The third case is also suitable from the economic point of view.

The test results of Bio-Concrete beams clearly indicate that the load carrying capacity and hence the flexural strength of Bio-Concrete beam regains although beams were partially cracked. It is also observed that regain in strength is more for B3 in which 25% bacterial solution was used. This observation clearly shows the comparison between the conventional concrete beams and bacterial concrete beams for flexural strength of concrete.

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