BACTERIA-BASED SELF-HEALING CONCRETE INCORPORATED WITH INDUSTRIAL WASTE (FLY ASH) FOR THE DEVELOPMENT OF SUSTAINABLE CONCRETE

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Abstract- Fractures in concrete are unpreventable, and also it's intrinsic weak point of concrete. By means of the splits, bath among others salts can easily run. It initiates oxidation, even further lowering the lifetime on the concrete. Therefore, there seemed to be a necessity to create an intrinsic bio material, a self-repairing method which is able to rectify the splits as well as fissures produced within concrete. Bio-concrete is a substance which could effectively rectify fractures within concrete. This particular method is extremely appealing as the pastime of break remediation is natural and eco-friendly. The undertaking covers the plugging of man-made break of cement concrete by using Bacillus megaterium, Bacillus subtilis, Bacillus sphaericus, Bacillus pasteurii etc, the impact on compressive toughness, drinking water absorption as well as liquid permeability of cement concrete cubes as a result of the blending of bacteria also is talked about within this specific task. It was actually discovered that the usage of Bacillus Megaterium as well as Bacillus subtilis advances the compressive power as well as stiffness of concrete. Additionally, it demonstrates that there's decrease in water absorption as well as liquid permeability in comparison with traditional concrete. The bacteria that are likely to be created with concrete must have the home of alkali resistance also additionally, it need to develop endospore, such which it is able to stand up to the stresses manufactured in concrete while blending, placing and transporting. This particular analysis is focused on look into the suitability of blending these self-healing calcite depositing bacteria with concrete with fly ash to be able to boost the compressive sturdiness of concrete, bring down its seepage and permeability of water by bio mineralization procedure. Sizable increased power is found to concrete examples when casted with bacterial fix. The analysis has invented ways or methods to evaluate the outcome of utilization of bacteria in concrete. Outcomes are in contrast to typical concrete. Natural adjustments of building substances are definitely the demand on the hour for long term and strength improvement sustainability. In this project bacteria is used, the research is carried out by using M25 grade concrete with replacement of 2.5%,5%,7.5%,10%, Bacteria by keeping Fly ash as 5%,7.5%,10%,12.5% constant and is carried out to determine the optimum percentage of replacement at which maximum compressive strength is achieved, the properties of the material are analyzed.
Keywords: Self-healing concrete, Natural and also natural self-healing procedure, Biological precipitation of calcium carbonate

1. INTRODUCTION

1.1 Introduction

Concrete, a thoroughly old substance contained building tasks, is additionally a significant contributor to Depletion of environmental pollution and natural resource with the generation of the major Component-cement. It's study adequate to fight compressive ton but vulnerable to cracking because of poor inside stress which in turn eventually decrease the lifetime of building. Thus, any kind of attempt to enhance the life span of system will indirectly enhance the sustainability on the ecosystem.

1.2 Approaches to Self-Healing concrete

Autogenously self- healing relies on the make -up of concrete and it is unblemished by hydration response of cementations goods inside the concrete matrix. Inside the majority of the traditional concrete matrix, 15-25 % on the cement is still left unhydrated. In the event that cracking of the concrete happens, unhydrated cement cereals might subjected to fluids penetrating the break. If so the hydration procedure may begin once again advertisement hydration solutions might run & cure the crack. This particular natural self-healing mechanism is though since extended as well as recognized as autogenously recovery. It's mainly efficient for really narrow splits.

1.3 Mechanism of Self-Healing concrete

The procedure for employing bacteria in deep bio concrete is recognized as Microbial Induced Calcium Carbonate Precipitation (MICCP) or maybe Bio mineralization. Following activation, bacteria go through a few metabolic procedure like sulphate minimization, photosynthesis as well as urea hydrolysis leads to calcium carbonate because their by merchandise. Different bacteria are able to precipitate calcium carbonate like Bacillus Pasteurii, Bacillus Pseudofirmus, Bacillus Cohnii, Bacillus Sphaericus, Bacillus Subtilis, Bacillus Halodurans etc. within each laboratory and normal problems. Precipitation is primarily governed by ph worth, Calcium focus, DIC (Dissolved Inorganic Carbon) focus. For achievement of self-healing occurrence, it's very essential that the bacteria must be in a position to transform the organic and natural nutrition to insoluble inorganic calcite crystal that fills the splits. Self-healing representative features bacteria that serve as catalyst as well as calcium calcite designed to change into calcium carbona.

1.4 Suitability of self-healing concrete of India

The local weather of India is different area to area due to the topography of its as well as getting a broad range of alteration of heat coming from mountains, flatlands, woodlands to shorelines. A lot of urban centres love New Delhi, Lucknow , Patna, Jalandhar etc. encountering climate switches out of pretty comfortable local weather of April to mid-June to really chilly local weather between February and November. Serious local weather is able to decline as well as often fractures to come down with concrete framework which might eventually lessen the way of life span of building. Bio concrete could be the greatest substitute for fight these intense climatic factors. Inside India love acquiring concrete, infrastructure advancement is able to perform a crucial part therefore bio concrete is often utilized with building deliver the results. Bacterial induced concrete is environmentally friendly pleasant carbonate precipitation self-healing strategy also it's extremely appealing within offshore structure etc. and underground exactly where small break is damaging .Aside from this particular bio concrete is often utilized for building sprinkler system building.

1.5 Bacterial Concrete

A. Classification of bacteria:

Bacteria are generally classification in three category Basis on shape, Basis on gram stain and Basis on oxygen demand which is shown in figure.

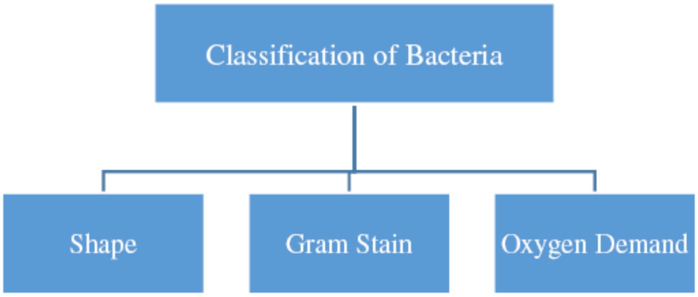


Figure 1.1 Classification of Bacteria

B. Various types of bacteria used in concrete-

There are various type of bacteria were used in construction area from literature review.

1. Bacillus Pasteurii.
2. Bacillus Sphaericus
3. Escherichia Coli
4. Bacillus Subtilis
5. Bacillus Cohnii
6. Bacillus Pseudofirmus

C. How does concrete works-

Self-healing concrete is a product that will biologically produce lime stone to heal cracks that appear on the surface of concrete structure. Specially selected types of bacteria genus Bacillus, along with calcium based nutrients known as calcium lactate & nitrogen 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. However, when a concrete structure is damaged water start to seep through the cracks that appear in the concrete the spores of the bacteria germinate on contact with the water and nutrients. Having been activated, the bacteria start to feeds oxygen is consumed and the soluble calcium lactate is converted to insoluble limestone. –

D. Bacillus Subtilis Description –

Bacillus Subtilis is a Gram – Positive bacterium rod - shaped and catalase positive .it was originally named vibrio subtilis by Christian Gottfried Ehrenberg and renamed bacillus subtilis by Ferdinand Colom in 1872. Bacillus subtilis are typically rod shaped and are about 4 to 10 micrometres long and 0.25 to 1 micrometre in diameter with a cell volume of about 4.6 FL at stationary phase. As with other members of the genus bacillus, it can form an endospore to survive extreme environmental condition of temperature and desiccation.

E. Reproduction –

Bacillus subtilis can divide symmetrically to make two daughter cells (Binary Fission) , or symmetrically producing a single endospore that can remain viable for decades and is resistant to unfavourable environmental condition such as drought , salinity , extreme pH , radiation. It is found in soil, water, air decomposing plant matter.

F. Uses –

Bacillus Subtilis is widely used laboratory studies, but more for genetic research as oppose to health research.

1. Bacillus Subtilis is to produce many antibiotics such as Diffcidin, Oxydiffcidin, Bacilli and Bacitracin which is helpful in treating bacterial skin infections and preventing infection in minor cuts and burns.
2. As an important source of industrial enzymes and polymers.
3. As a Probiotic.

1.6 Disadvantages and advantages of Bio Concrete

Advantages

The utilization of bio concrete considerably influences the sturdiness of concrete.

- It has reduced permeability than typical concrete.
- It has excellent opposition to freeze thaw strikes.

- Remedying of fractures can be performed effectively.
- The likelihood of oxidation in reinforcement are lowered.
- Maintenance expense on this concrete is reduced.

Disadvantages

- Design of bacterial concrete isn't brought up around Is codes or perhaps some different codes.
- Cost on this concrete is comparatively above typical concrete i.e. approximately 7-28 % much more than typical concrete.
- The investigations interested in calcite precipitation are not cheap.

1.7 Problem Statement

In this project bacteria is used, the research is carried out by using M25 grade concrete with replacement of 2.5%,5%,7.5%,10%, Bacteria by keeping Fly ash as 5%,7.5%,10%,12.5% constant and is carried out to determine the optimum percentage of replacement at which maximum Compressive strength is achieved. Also the samples of optimum mix of bacteria and fly ash are observed for self healing by bacteria action.

1.8 Scope of project

In this research self healing system with micro encapsulated healing agent have been used into the concrete to obtain a self healing capacity to improve the crack resistance and toughness under fatigue loading. This microbial agent has a promising potential for a wide range of engineering application such as crack repairs ,water tightness of concrete structure etc. which is also considered as environmental friendly and economical material.this study includes the effect of bacteria anf fly ash on compressive strength and self healing ability of concrete.

1.9 Objective

The primary goal of existing analysis is labelled as to enhance the engineering qualities of regular toughness cement mortar utilizing one bacterial species. This particular primary goal is split directly into next sub objectives:

1. Develop affordable self-healing methods which allow the research of various bacteria for self-healing method on industrial waste based concrete.
2. Develop a methodology to show effect of self-healing technologies on the economic system, environment and society.
3. Study impact of various bacteria on power qualities of industrial waste based concrete.

1.10 Limitations

The followings are the limitations

- Cost of Fly ash
- Cost of bacteria

1.11 Future Challenges

Even though, self-healing tasks that contain chemical and natural are nicely proven to develop self-healing concrete, natural procedure is a promising know-how, and that hasn't been completely known just yet. Till today, numerous bacteria may be remote of the natural world which is beneficial for developing self-healing concrete. Utilizing bacteria have numerous benefits like as

- Bacteria are not hard to way of life.
- Isolation of bacteria isn't really complicated and
- A lot of techniques are discussed for incorporating bacteria to concrete.

2. LITERATURE REVIEW

[1] J.Y. Wang et al(2014)[1] studied Microcapsules have been put on to encapsulate bacterial spores for self-healing concrete. The viability of the influence and encapsulated spores of microcapsules on mortar specimens have been studied first. Breakage of the microcapsules upon cracking was verified by Scanning Electron Microscopy. Self-healing capacity was examined by crack healing ratio as well as the water permeability. The results suggested that the healing ratio within the examples with bio microcapsules was much higher (48%-80 %) than in those with no bacteria (18%-50 %). The maximum crack width healed in the examples on the bacteria series was 970 μm, approximately four times that of the non-bacteria series (max 250 μm). The general water permeability within the bacteria series was approximately ten times less than that in non-bacteria series. Wet-dry cycles have been found to activate self-healing in mortar specimens with encapsulated bacteria. No self-healing was noticed in most specimens stored at 95%RH, indicating that the presence of liquid water is a crucial part for self-healing.

[2] Wei Zhang et al(2020)[2] author research the Cement concrete is a weak material with lower tensile strength and also is uncomplicated to crack because of shrinkage, creep, harsh service environment and load. Asphalt concrete pavement is apt to crack and wear because of the temperature instability and very poor aging resistance of asphalt concrete. Crack boosts moisture, corrosive medium transports and oxygen internally, decreasing the durability and safety of infrastructures. In comparison with traditional repair method, self-healing technology is able to heal fractures which are invisible to the naked eye and also it's anticipated to lengthen the service life of infrastructures. It's considerable benefits for repairing marine infrastructures, concrete infrastructures and underground concrete storing hazardous materials.

[3] E. Tziviloglou et al(2016)[3] studied The revolutionary engineering of self-healing concrete lets the components to restore the open micro-cracks which can endanger the durability of the framework, because of ingress of intense gasses and also liquids. Different ideas of self-healing concrete were produced, with goal on the recuperation of water tightness after cracking. Among all those, bacteria based self-healing concrete has found results that are promising concerning the enhancement of crack sealing performance. In this particular study, the bacteria-based healing agent is integrated into lightweight aggregates and combined with new mortar. By this implies, autogenously healing of concrete is improved and upon cracking the content is able to recuperate water tightness.

[4] Hana Schreiberov et al(2019)[4] explained & investigates the structure of the natural self-healing agent primarily based on the impact of its own material qualities of concrete. An immediate inclusion of the agent - a combination of bacterial spores and nutrients - into concrete matrix continues to be examined by several studies in recent years. Under specific problems, the applied microorganisms proved to have the ability to create CaCO3, and investigators employed the bio calcification process to autonomously seal micro cracks in concrete. Consequently, this bio based material could possibly heal itself and also lead to an economic and durable more structure. Nevertheless, it's been found the selfhealing agent, particularly the essential nutrition, could negatively or positively affect the material characteristics.

[5] Luciana Restuccia et al(2017)[5] research paper explain investigations concerning cement based substances was concentrated not just on the toughness and the strength but also on the durability. In reality, the interest on concrete's self-healing method is growing, on account of the quickly deterioration of that particular substance and that is likely to crack and therefore easily deteriorate. In this newspaper, a brand new self-healing technology for cement based materials is proposed. This concept is dependent on the encapsulation approach to restoring agent placed in randomly distributed layer inside the content during its planning.

[6] Henk M. Jonkers et al(2017)[6] The application of concrete is quickly increasing therefore and worldwide the improvement of renewable concrete is urgently required for green factors. As currently approximately seven % of the complete anthropogenic atmospheric CO2 emission is a result of cement production, mechanisms that might bring about an extended service life of concrete buildings would try to make the substance not just stronger but additionally much more sustainable. One particular mechanism which gets increasing interest in the past few years will be the capability for self-repair, i.e. the independent healing of fractures in concrete .

[7] Xuan Zhang et al(2020)[7] In this paper, the engineering application of microbial self-healing concrete in ship lock engineering was studied. Researches like the layout and batch preparation of microbial self-healing agent, and lab assessments of microbial self-healing concrete were brought away. A category of self-healing agents with microbial spores and also calcium sources was created and also batch produced by spray drying technique, and was proven to demonstrate that the inclusion of self-healing agent in concrete does not have any great impact on the functionality of the concrete combination, and also the improvement of the compressive power of the harden concrete specimens.

[8] Jing Xu et al(2018)[8] studied Self-healing dependent on microbial induced calcium carbonate precipitation continues to be recommended as an intelligent and eco helpful technique of the fix of concrete cracks. It's recommended to include bacteria based healing agents in state concrete that is fresh during mixing. Although the selected bacteria are alkaliphilic spore forming strains, they're currently susceptible to the harsh environment of concrete. In this paper, we created a shielding carrier of the bacteria by utilizing calcium sulphoaluminate cement, which happens to be a kind of minimal alkali, fast hardening cementations material. By regulating the composition of the carrier material as well as the content of healing agents, the compatibility of the carrier with both healing representatives as well as the concrete matrix was optimized.

[9] Erik Schlangen et al (2013) [9] Infrastructures cover a really wide spectrum of various substances. This paper concentrates on civil engineering structures, concrete along with asphalt in particular. The public need for such infrastructures is extremely high amount of performance and service, considerable minimum and durability negative ecological impact. New emerging self-healing materials science offers answers on the issue. An overview is provided of new advancements gotten in researching on self-healing of fractures in cement-based materials and asphalt concrete. At Delft Faculty different jobs are running to learn self-healing mechanisms.

[10] T. Chandra Sekhara Reddy et al(2017) [10] The civil research society continues to be drawn to concrete with self-healing qualities since they're an intelligent alternative for sustainable infrastructures with lengthy length. The existing study is studying the self-healing ability of structural cracks and early age in concrete using crystalline admixture as self-healing agent under 4 completely different exposure conditions by evaluating the regained physical qualities of concrete. Physical (chemical composition and morphological) of the hardened pastes, were examined using Fourier transform infrared spectroscopy (Energy-Dispersive spectroscopy and ftir) (EDS). The analysis demonstrated that for most exposure conditions the compressive power as well as split tensile strength of the examined concrete with crystalline admixture (CCA) samples regains after earlier age and also structural cracks. This's because of considerable rise in the calcite articles that is apparent from FTIR and SEM-EDS analysis.

[11] Thanh Ha Nguyen, et al(2019)[11] Bacterial self-healing is a cutting-edge technology allowing repairing open micro cracks in concrete by CaCO3 precipitation. This bio technology improves the durability of the framework. In this paper, peptone, yeast extract and Bacillus Subtilis have been included as microbial adjuvant in concrete mix design. This resulted in a lessening in porosity causing a rise of power, dynamic modulus and a decrease in warm water uptake, gas permeability and also chloride permeation. Scanning electron microscopy, energy dispersive spectroscopy and also Raman spectroscopy proved that the microbial precipitations in the crack were CaCO3.

[12] Virginie Wiktor et al(2011) [12] Crack formation is a generally found trend in concrete buildings. Although micro crack formation rarely affects structural qualities of constructions, improved permeability because of micro crack networking could considerably decrease the longevity of concrete buildings because of danger of ingress of intense things especially in hydrated locations. To boost the typically observed autogenously crack healing potential of concrete, specific healing representatives might be integrated within the concrete matrix. The target of the analysis was to know the crack healing opportunity associated with a certain and novel two-component bio-chemical self-healing agent lodged in porous expanded clay particles, that serve as reservoir dust particles and change a part of average concrete aggregates. Upon crack formation the two component biochemical agent comprising of bacterial spores and calcium lactate are discharged from the particle by crack ingress water. Subsequent bacterially mediated calcium carbonate formation leads to bodily closure of micro cracks.

[13] Hao Ling et al(2017)[13] The microbial self-healing concrete is a brand new technology to fix splits, the former analysis demonstrated that the precipitated CaCO3 might fill up the splits and minimize the permeability coefficient of cracks. On this particular foundation, the impacts on resisting transmission of chloride were examined to assess the protective benefits of microbial self-healing cracks, through many characterization techniques such as for instance electrochemical test, visible examination of cracks surface area, weight loss ratio of reinforcements and also chloride ion content. Aside from the approach to electro migration was accustomed hasten the transmission of chloride. The final results indicate that the microbial self-healing cracks could really impede the transmission of chloride in cracks and also have protective effects for reinforcements within the concrete.

[14] Wasim Khaliq et.al progression and al(2016)[14] Crack formation under tensile stress is a significant weakness of concrete. These cracks likewise make concrete susceptible to deleterious setting because of ingress of harmful elements. Crack healing in concrete may be useful in mitigation of propagation and development of fractures in concrete. This paper provides the procedure of crack healing phenomenon in concrete by microbial activity of bacteria, Bacillus subtilis. Bacteria have been launched in concrete by direct incorporation, plus comprehensive different carrier compounds which is lightweight aggregate plus graphite Nano platelets. In all of the strategies, calcium lactate was utilized as an organic and natural precursor. Specimens were created for every blend to know crack healing and to evaluate changes in compressive strength of concrete. Results confirmed that bacteria immobilized in graphite Nano platelets gave much better outcomes in specimens pre cracked at 3 and 7 times while bacteria immobilized in lightweight aggregates had been much more successful in samples pre cracked at 14 and 28 days. Additionally, concrete incorporated with bacteria immobilized in lightweight aggregate, likewise exhibited great development in compressive strength of concrete.

[15] Chereddy Sonali Sri Durga et al(2019)[15] Conventional concrete features a fault, it's put through cracking during tension. The cracks which look on surface that is concrete enable the liquids to penetrate inside and also cause decay of concrete buildings. As restoration and renovation of concrete buildings are time consuming, costly and a difficult problem, self-healing concrete overcomes the problem by healing the fractures over the concrete surface. This concrete has green in nature and seals the internal part of fractures by releasing calcium carbonate. The primary goal of this newspaper is indicating the speed of crack healing using natural elements to improve the impermeable nature of concrete. The physical and durability tests are performed to calculate the rate of self-healing in concrete. The research reveals that bio concrete mixes after 28 many days of curing attained an improvement in compressive strength of 22 %, split tensile strength of 16 % and also flexural strength of 11 % as compared to traditional concrete. The heavy nature of concrete has examined by ultrasonic pulse velocity values. Sorpitivity and water absorption tests assessed the longevity qualities of both traditional and bacterial concrete samples, that presence of bacteria enriched durability properties of bacterial based concrete specimens

3. METHODOLOGY

3.1 Material used and its properties:

3.1.1 Cement

The binding materials used in concrete are ordinary Portland cement. This cement is of 53 grades conforming to IS 456-2000 and is having desired properties. The properties of cement were determined by adopting standard procedure. The normal consistency, initial and final setting time, specific gravity and fineness are main basic properties which were determined.

Fig. 3.1 Cement

- **Physical Property Cement:**

a) Normal consistency - 32 %
b) Initial setting time (min) - 55
c) Final setting time (min) - 340
d) Specific gravity - 3.15
e) Fineness - 8 %
f) Compressive strength – 53 MPa

3.1.2 Fine Aggregate

Fine aggregate used is M-sand. fine aggregates of physical properties as per IS 2386 (part-3)-1963(Reaffirmed 2002) is being used The fineness is obtained using the sieve analysis and the result is such that the fine aggregate is confirming to IS 383 – 1970. Natural River Sand was used as fine aggregate, confirming to Zone-II of IS 383. The physical properties of fine aggregate as per IS 2386-3 are as follows

Properties of Fine Aggregate:

a) Specific Gravity - 2.65
b) Fineness modulus –2.86
c) Water Absorption - 1.8%

Figure 3.2 Fine Aggregate

3.1.3 Coarse Aggregate

The coarse aggregate for the work is crushed stone. Angular shape aggregate of size is 20mm and below. The aggregate which passes through 75mm sieve and retain on 4.75mm are known as coarse aggregate. The grading of coarse aggregates should be as per specifications of IS 383-1970..

Properties Coarse Aggregate

a) Specific Gravity - 2.67
b) Sieve Analysis As per IS code limit
c) Water Absorption - 0.349

Fig 3.3 Coarse Aggregate

3.1.4 Water

The water should be fit for drinking. The water is used for mixing as well as for curing the samples. It should not have high concentrations of sodium and potassium and there is a danger of alkali-aggregate reaction. Natural waters that are slightly acidic are harmless, but water containing humic or other organic acids may adversely affect the hardening of concrete. Such water as well as highly alkaline water should be tested. Water satisfactory for mixing is also suitable for curing purposes. However, it is essential that curing water should be free from substances that attack hardened concrete like free CO2 etc.

3.1.5 Bacterial species

Bacillus species used in the research work are B. subtilus, The commercial product of he set bacteria is bactaheal-pr. The product information is as follows

Fig 3.4 bacteria used (bactaheal-pr)

Cracks in concrete are a common phenomenon due to the relatively low tensile strength. Durability of concrete is impaired by these cracks since they provide an easy path for the transportation of liquids and gasses that potentially contain harmful substances. If micro-cracks grow and reach the reinforcement, not only the concrete itself may be attacked, but also the reinforcement will be corroded. Therefore, it is important to control the crack width and to heal the cracks as soon as possible. PRIONS BIOTECH offers enzyme blend BACTAHEAL-PR. BACTAHEAL-PR is concrete self-healing agent. The BACTAHEAL-PR is a new concept in the cement industry. BactaHeal-PR contains a biodegradable polymeric mineral precursor compound and a bio-based enzymatic catalyst (Multi enzymes + Nutrient supplements +Spore forming Bacilli) which fills the crack by forming calcium carbonate. BactaHeal-PR can be applied in ready mixes, prefab applications, or added directly to the truck mixer on site.

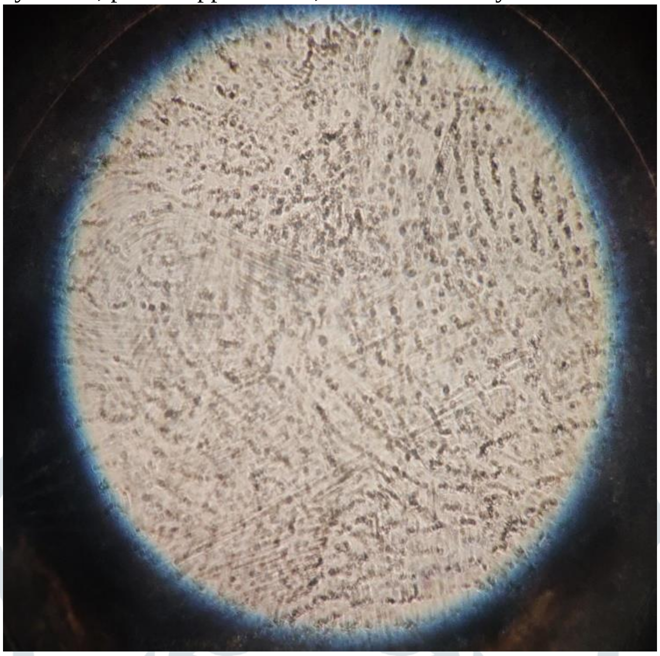


Figure 3.5: MICROSCOPIC VIEW OF BACTAHEAL PR

3.2 Cultivation of bacteria (only for research purpose)

The pure culture of bacteria Bacillus Subtilis and Bacillus Sphaericus is conserved on nutrient agar slants that forms irregular desiccated white colonies on them. Inoculation of four different colonies of the bacteria into nutrient broth each of 2 ml in ml conical flask is carried out. t is incubated at the temperature of C and 170 rpm in orbital shaker incubator. The medium composition used for bacterial culture's growth consists of NaCl Peptone, yeast extract. Processes include sterilization, inoculation and incubation. Sterilization is done to achieve sterile environment by killing the microbes. t's done in an autoclave or pressure cooker at a temperature of 121 C for 25 to 30 minutes. Inoculation is the streaking of the bacteria on to the media with the help of an open loop. Incubation is done to grow and maintain the bacterial cultures. Fig 3.4 and Fig 3.5 showcase the process of bacteria cultivation carried out in biological sciences laboratory.

Figure 3.6: Pictorial representation of bacterial cultivation process

Figure 3.7: Cultivated bacterial solution

3.3 working of bacteria:

The bacterial concrete is a concrete which can be made by adding bacteria in the concrete that is able to constantly precipitate calcite this phenomwnon is called microbiologically created calcite precipitation. It is the process by which living organisms forms an inorganic solids. It is same process as we people are producing teeth are bones.

Bacillus is a common bacteria which can continuously precipitate a new impermeable calcite layer over the surface of concrete. In extreme alkaline environment ph of 12 is not fevorable for the growth of this bacteria, its optimum PH for growth is 9 but bacteria has an ability to produce such material to maintain PH

Bacterial concrete is made by directly adding encapsulated bacteria in to concrete mix. The use of this bacteria and calcium lactate doesn't change the properties of concrete as crack occurs in a structure the moisture comes in contact with bacterial capsule and this capsule breaks, then they germinate and feed on calcium lactate and produces limestone

As we know bacteria has an ability to precipitate calcite in environment. The chemical reaction is

$CA\ (C_3H_5O_2)_2 + 7O_2$ -------------------------$CACO_3 + 5CO_2 + 5H_2O$

(CALCIUM LACTATE) (LIME)

3.4 Experimental Investigation:

3.4.1 Materials and mix proportions:

Materials used include ordinary Portland cement (53 grade, conforming to is 8112- 1989), coarse aggregate of crushed rock (maximize, 20mm), fine aggregate of clean river sand (zone II of is: 383-1970) and portable water, was accurately weighted in an electronic balance and water absorbed after 24h of continuous impression was determined .a mix was designed as per is 10262-1982 to achieve a concrete grade of M25.A sieve analysis conforming to IS 383-1970 was carried out for both fine and coarse aggregates. The concrete mix was designed so as to achieve cube strength of 25 MPa (28 days). bacteria of weight 2.5%, 5%, 7.5 % & 10% and fly ash of weight 5%,7.5%,10%,12.5% of concrete was mixed homogeneously .

3.4.2. Mixing and casting:

Hand mixing was used for convenient handling of the concrete. Sand and cement were mixed dry and kept separately. Then coarse aggregates, flyash and bacteria and dry mix of cement and sand were kept in three layers and approximate amount of water was sprinkled on each layer and mixed thoroughly. Mixing procedure was felt to be extremely tedious due to formation of small lumps. In order to avoid the formation of lumps the particles were randomly oriented in the mix. The cubes (150mm x 150mm x150mm), of both conventional and fly ash and bacteria concrete specimens were casted. Each layer was compacted with 25 blows with 16 mm diameter steel rod and then each cube is subjected to vibration through a mechanical vibrator to achieve uniform compaction.

The proportions of the Fly ash for experiment are kept as:

5% of Fly ash
7.5% of Fly ash
10% of Fly ash
12.5 % of Fly ash

3.4.3 Mix proportion of M25 grade concrete:

M25 grade of concrete has been designed as per IS code and the mix proportions is given as follows:

3.4.4 Selection of water cement ratio:

Various parameters like type of cement, aggregate, maximum size of aggregate, surface texture of aggregate etc are influencing the strength of concrete, when water cement ratio remain constant, hence it is desirable to establish a relation between concrete strength and free water cement ratio with materials and condition to be used actually at site.

From Table 5 of IS 456, maximum water cement ratio for M25 mix = 0.55

From the trial mixes, water cement ratio is fixed as 0.50

0.50 <0.55, hence OK

3.5 Workability properties:

3.5.1 Slump Cone Test-

This test is used to determine the workability of concrete. The apparatus is a cone of 10cm top diameter, 20cm bottom diameter and 30cm height. It has two handles for lifting purposes. Initially, the cone is cleaned and oil is layers. Each layer is compacted 20 times by a standard tamping rod. After filling the cone, it is lifted slowly and carefully in the vertical direction. Concrete is allowed to subside and this subsidence is called slump.

If the slump is even, then it is termed as true slump. If one half of cone slides, it is called shear. If entire concrete slides, it is called collapse. Shear slump indicates that concrete is non-cohesive and shows a tendency for segregation. Generally, the slump value is measured as the difference between the height of the mould and the average height after subsidence. Slump test is found to be the simple test and is widely used

3.5.2 Compaction Factor Test:

The compaction factor test was developed at the Road Research Laboratory, it is one of the most efficient tests for measuring the workability of concrete. This test is more precise and sensitive than the slump test and is particularly useful for concrete mixes of low workability as are normally encountered when concrete is to be compact by vibration.

3.6 Tests on cement:

1) Standard Consistency –

The standard consistency of a cement paste is defined as that consistency which will permit the Vicat plunger of 10 mm diameter and 50 mm length to penetrate to a point 5 to 7 mm from the bottom of the Vicat mould Figure 3.1. The experiment was done as per IS 4031-Part IV.

2) Initial Setting Time Initial setting time is regarded as the time elapsed between the moments that the water is added to the cement to the time that the paste starts losing its plasticity. Experiment was done as per IS -269:1989, clause 6.3

3) Final setting time Final setting time is the time elapsed between the moments that the water is added to the cement and when the paste has completely lost its plasticity. Experiment was done as per IS -269:1989, clause 6.3

4) Fineness of Cement Fineness is a measure of total surface area of cement. For finer cements surface area will be more. Fineness influences the rate of hydration, rate of strength development, shrinkage and rate of evolution of heat. Experiment was done as per IS 4031-Part I-1996.

5) Density of Cement Le Chatelier's flask is used to determine density of cement. Kerosene which does not react with cement is used. Experiment is done in Le Chatelier's flask.

6) Soundness of Cement The testing of soundness of cement is to ensure that the cement does not show any applicable subsequent expansion. Unsoundness in cement is due to excess of lime, magnesia or excessive proportion of sulphates. Experiment is done by Le Chatelier method. And the value of soundness is 1mm.

3.7 Tests on hardened concrete:

1) Compressive strength test (IS 5816: 1999)-

Compressive strength is the capacity of a material or structure to withstand axial loads tending to reduce the size. It is measured using the Universal Testing machine.

Concrete can be made to have high compressive strength, e.g. Many concrete Structures have compressive strengths in excess of 50 MPa. Here the compressive strength of concrete cubes for the plain concrete and bacterial concrete are found out using Compression testing machine. Three cubes were cast for each percentage of fly ash and bacteria and the average of the two compressive strength values was taken. A Compression testing machine is shown.

2)alkali aggregate reaction-

Samples of all the combinations were placed in moist cabinet for 24 hrs and cured for 7 days then the reading are taken on 7 and 28 days. It is observed that there is less expansion in bacterial concrete cube than conventional concrete cube due to formation of calcite on the surface and internal part of concrete.

3.8 Batching of Material

3.8.1 Batching of material for Fly ash and bacterial concrete cubes:

From various research papers, we have selected following mix proportions for casting and testing the cube samples. First of all, we have decided to test the mix proportions Fly ash and bacterial concrete cubes as follows for obtaining M25 grade.

3.8.2 Casting of concrete cube

Concrete mix of M25 grade was used. Mix design of concrete (1:2.09:2.84) was adopted. Casting of 108 cubes was done. The standard IS Moulds of size 15 × 15 ×15 cm was used for casting. At the time of casting, the aggregates, cement, 2.5%,5%,7.5%,10% of Bacteria and Fly ash as 5%,7.5%,10%,12.5% in required quantity were mixed on a clean platform. Then the required amount of water was added to the mix. The mix is thoroughly mixed till uniform color is obtained. The compaction was done by mechanical vibrator. The surface of block is leveled properly using a trowel. These blocks were kept submerged in water for curing for 28 days after casting. The temperature of water used in curing tank was room temperature.

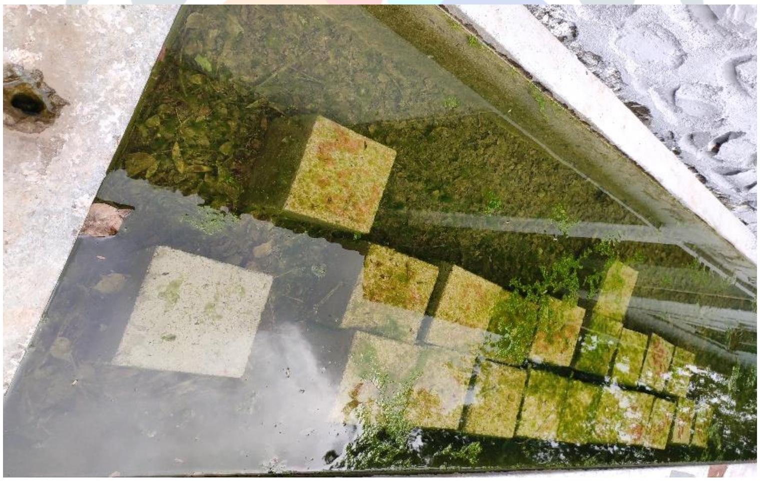


Figure 3.8: Curing of cube

4. RESULT AND DISCUSSION

4.1 General

The compressive performance of concrete confined with flyash and Bacteria structures will be investigated in detail. The mass content of Flyash considered will be 5% and 7.5%, 10% and 12.5% and Bacteria considered will be 2.5% and 5%, 7.5% and 10% of total mix proportion. Test results for the both (conventional and Flyash & bacteria based mixed concrete) for axial compressive strength. This experimental investigation is carried out under mix proportion i.e. M25 and the results of the durability tests are compared with the same mix proportionated concrete cubes.

4.2 Results of Compressive strength test on Cubes

The compressive force tell us the material quality gives a strength of will be unswervingly of correlated of the hydrated structure which is the cement glue. The test is conducted to determine the strengths of hardened state concrete which is for developing the specimens of the concrete is very much important concrete. This test is most common test which is the concrete is hardened state of concrete. To get the compressive strength cube specimen are casted which of concrete is in the size of about 150mmX150mmX150mm. All over specimens are kept into water & are submerged into the water tank which is in the state of soaking condition. The cubes are taken out from the water tank after desired curing and is held in dry condition for 4-8 hours after that it is taken for testing. The testing will be conducted of those cubes which have been kept for 7, 28 days of curing . The sample (Normal concrete mould) will be fixed in between the jaws of compressive testing machine it will have a load capacity of about 2000KN. After placing the load is applied from the compression testing machine through jaws to the cubes. The load is applied continuously up to the specimen i.e. mould fails to attain the compression load , The maximum load resisted by specimen is recorded.

The compressive strength is calculated by
Compressive strength = P/A (N/mm^2)
where P = Load in N
A=c/s area in mm^2
Following table showing the test results -6 samples are tested for each combination. 3 for 7 days strength and 3 for 28 days strength then average is taken to get approx value.

Table 4.1 Result of 7 days Compressive Strength using 5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 7 Days (N/mm2)	Average strength(N/ mm^2)
1	CC	1	22500	326.7	14.52	14.67
		2	22500	323.1	14.36	
		3	22500	340.4	15.13	
2	MIX 1 (2.5%, 5%)	1	22500	315.9	14.04	13.54
		2	22500	300.8	13.37	
		3	22500	297.2	13.21	
3	MIX 2 (5%, 5%)	1	22500	327.4	14.55	14.75
		2	22500	330.5	14.69	
		3	22500	337.7	15.01	
4	MIX 3 (7.5%, 5%)	1	22500	381.8	16.97	16.43
		2	22500	364.7	16.21	
		3	22500	362.5	16.11	
5	MIX 4 (10%, 5%)	1	22500	355.1	15.78	15.29
		2	22500	361.8	16.08	
		3	22500	315.2	14.01	

Table 4.2 Result of 28 days Compressive Strength using 5% Flyash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 28 Days (N/mm2)	Average strength(N/ mm^2)
1	CC	1	22500	605.5	26.91	27.38
		2	22500	619.7	27.54	
		3	22500	623.0	27.69	
2	MIX 1 (2.5%, 5%)	1	22500	554.9	24.66	24.87
		2	22500	556.0	24.71	
		3	22500	567.9	25.24	
3	MIX 2 (5%, 5%)	1	22500	582.3	25.88	26.14
		2	22500	591.5	26.29	
		3	22500	590.6	26.25	
4	MIX 3 (7.5%, 5%)	1	22500	682.4	30.33	30.62
		2	22500	685.1	30.45	
		3	22500	699.3	31.08	
5	MIX 4 (10%, 5%)	1	22500	639.5	28.42	27.73
		2	22500	627.5	27.89	
		3	22500	604.8	26.88	

Table 4.3 Final results of 7 and 28 days Compressive Strength using 5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	Compressive Strength @ 7 Days (N/mm2)	Compressive Strength @ 28 Days (N/mm2)
1	CC	14.67	27.38
2	MIX 1 (2.5%, 5%)	13.54	24.87
3	MIX 2 (5%, 5%)	14.75	26.14
4	MIX 3 (7.5%, 5%)	16.43	30.62
5	MIX 4 (10%, 5%)	15.29	27.73

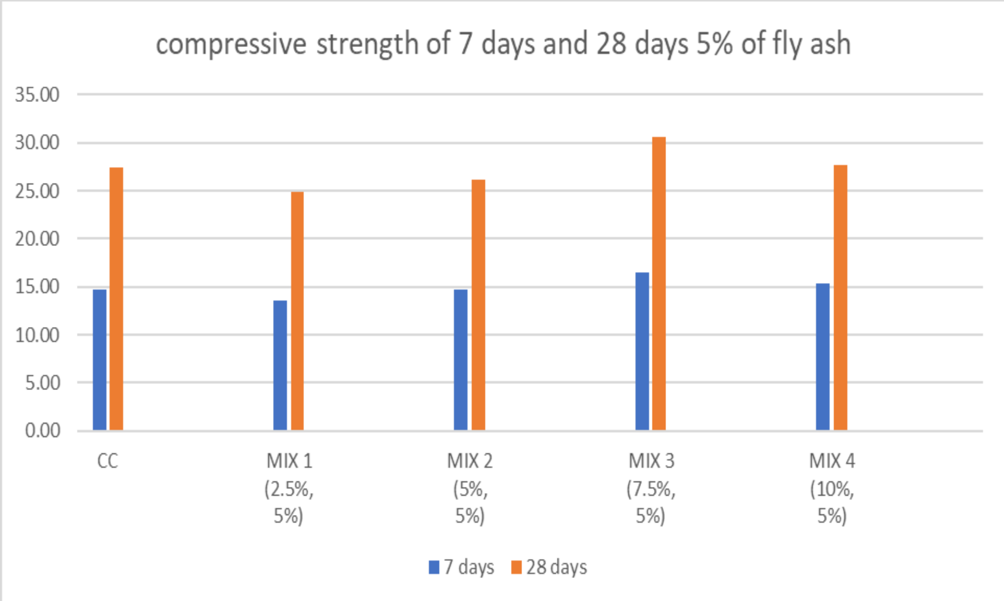


Fig No 4.1 Shows 7 days and 28 days compressive strength results with 5% of fly ash and varying Bacteria %

Table 4.4 Result of 7 days Compressive Strength using 7.5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 7 Days (N/mm2)	Average strength(N/mm^2)
1	CC	1	22500	326.7	14.52	14.67
		2	22500	323.1	14.36	
		3	22500	340.4	15.13	
2	MIX 1 (2.5%, 7.5%)	1	22500	336.8	14.97	14.72
		2	22500	334.8	14.88	
		3	22500	322.0	14.31	
3	MIX 2 (5%,7.5%)	1	22500	327.2	14.54	14.93
		2	22500	353.9	15.73	
		3	22500	326.7	14.52	
4	MIX 3 (7.5%, 7.5%)	1	22500	333.7	14.83	15.02
		2	22500	352.6	15.67	
		3	22500	327.6	14.56	
5	MIX 4 (10%, 7.5%)	1	22500	399.6	17.76	17.11
		2	22500	374.6	16.65	
		3	22500	380.7	16.92	

Table 4.5 Result of 28 days Compressive Strength using 7.5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 28 Days (N/mm2)	Average strength(N/mm^2)
1	CC	1	22500	605.5	26.91	27.38
		2	22500	619.7	27.54	
		3	22500	623.0	27.69	
2	MIX 1 (2.5%, 7.5%)	1	22500	623.9	27.73	27.77
		2	22500	619.4	27.53	
		3	22500	631.1	28.05	
3	MIX 2 (5%,7.5%)	1	22500	597.2	26.54	27.14
		2	22500	617.9	27.46	
		3	22500	617.0	27.42	
4	MIX 3 (7.5%, 7.5%)	1	22500	641.5	28.51	28.76

		2	22500	650.5	28.91	
		3	22500	649.4	28.86	
5	MIX 4 (10%, 7.5%)	1	22500	697.3	30.99	31.48
		2	22500	703.8	31.28	
		3	22500	723.8	32.17	

Table 4.6 final Result of 7 and 28 days Compressive Strength using 7.5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Flyash)	Compressive Strength @ 7 Days (N/mm2)	Compressive Strength @ 28 Days (N/mm2)
1	CC	14.67	27.38
2	MIX 1 (2.5%, 7.5%)	14.72	27.77
3	MIX 2 (5%,7. 5%)	14.93	27.14
4	MIX 3 (7.5%, 7.5%)	15.02	28.76
5	MIX 4 (10%, 7.5%)	17.11	31.48

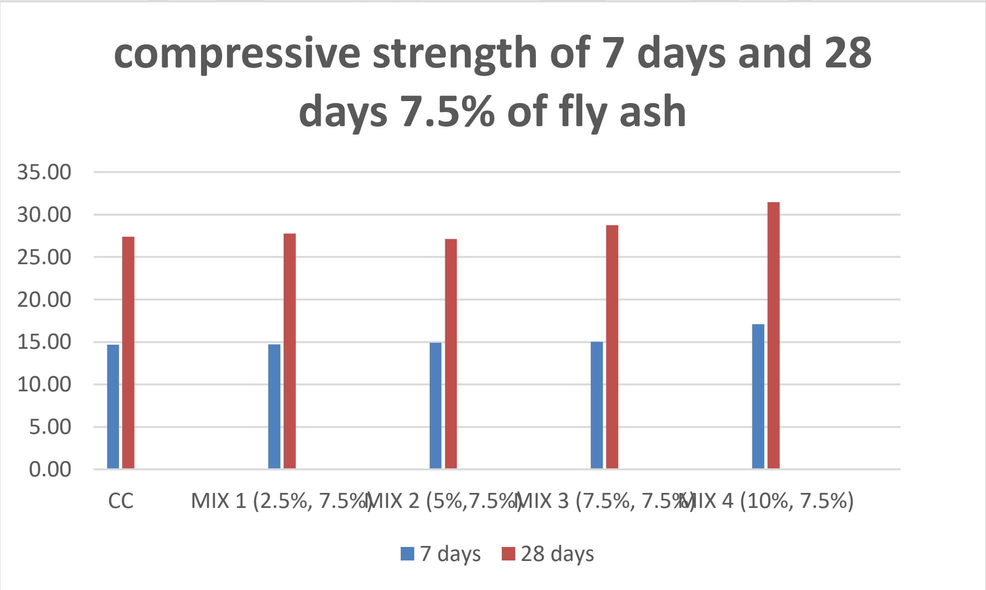


Fig No 4.2 Shows 7 days and 28 days compressive strength results with 7.5% of fly ash and varying Bacteria %

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 7 Days (N/mm2)	Average strength(N/mm^2)
1	CC	1	22500	326.7	14.52	14.67
		2	22500	323.1	14.36	

		3	22500	340.4	15.13	
2	MIX 1 (2.5%, 10%)	1	22500	305.3	13.57	13.63
		2	22500	315.2	14.01	
		3	22500	299.5	13.31	
3	MIX 2 (5%, 10%)	1	22500	353.9	15.73	15.04
		2	22500	333.9	14.84	
		3	22500	327.4	14.55	
4	MIX 3 (7.5%, 10%)	1	22500	380.0	16.89	16.77
		2	22500	363.4	16.15	
		3	22500	388.6	17.27	
5	MIX 4 (10%, 10%)	1	22500	392.6	17.45	17.47
		2	22500	397.6	17.67	
		3	22500	389.0	17.29	

Table 4.7 Result of 7 days Compressive Strength using 10% Fly ash

Table 4.8 Result of 28 days Compressive Strength using 10% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 28 Days (N/mm2)	Average strength(N/mm^2)
1	CC	1	22500	605.5	26.91	27.38
		2	22500	619.7	27.54	
		3	22500	623.0	27.69	
2	MIX 1 (2.5%, 10%)	1	22500	646.0	28.71	28.24
		2	22500	627.3	27.88	
		3	22500	632.9	28.13	
3	MIX 2 (5%, 10%)	1	22500	644.6	28.65	28.28
		2	22500	624.4	27.75	
		3	22500	639.9	28.44	
4	MIX 3 (7.5%, 10%)	1	22500	673.4	29.93	29.17
		2	22500	643.7	28.61	
		3	22500	651.8	28.97	
5	MIX 4 (10%, 10%)	1	22500	717.5	31.89	31.97
		2	22500	715.7	31.81	
		3	22500	724.7	32.21	

Table 4.9 final Result of 7 and 28 days Compressive Strength using 10% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	Compressive Strength @ 7 Days (N/mm2)	Compressive Strength @ 28 Days (N/mm2)
1	CC	14.67	27.38
2	MIX 1 (2.5%, 10%)	13.64	28.24
3	MIX 2 (5%, 10%)	15.04	28.28
4	MIX 3 (7.5%, 10%)	16.77	29.17
5	MIX 4 (10%, 10%)	17.47	31.97

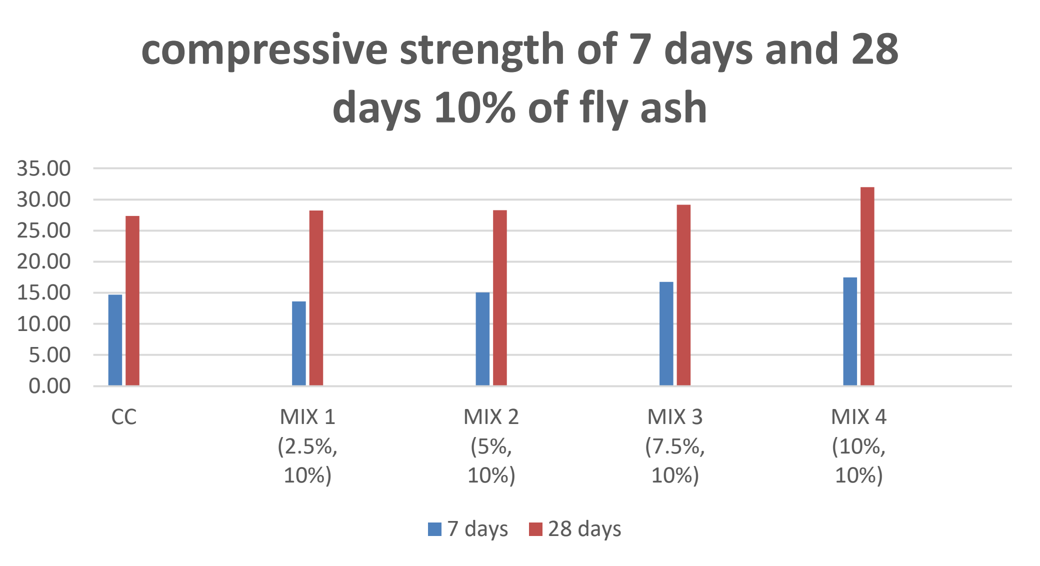


Fig No 4.3 Shows 7 days and 28 days compressive strength results with 10% of fly ash and varying Bacteria %

Table 4.7 Result of 7 days Compressive Strength using 12.5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 7 Days (N/mm2)	Average strengh(N/mm^2)
1	CC	1	22500	326.7	14.52	14.67
		2	22500	323.1	14.36	
		3	22500	340.4	15.13	
2	MIX 1 (2.5%, 12.5%)	1	22500	345.6	15.36	15.09
		2	22500	346.7	15.41	
		3	22500	326.3	14.5	
3	MIX 2 (5%, 12.5%)	1	22500	338.4	15.04	15.36
		2	22500	353.0	15.69	
		3	22500	345.4	15.35	
4	MIX 3 (7.5%, 12.5%)	1	22500	402.5	17.89	18.14
		2	22500	403.9	17.95	
		3	22500	418.1	18.58	
5	MIX 4 (10%, 12.5%)	1	22500	397.6	17.67	17.52
		2	22500	400.7	17.81	
		3	22500	384.3	17.08	

Table 4.8 Result of 28 days Compressive Strength using 12.5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 28 Days (N/mm2)	Average strengh(N/mm^2)
1	CC	1	22500	605.5	26.91	27.38
		2	22500	619.7	27.54	
		3	22500	623.0	27.69	

2	MIX 1 (2.5%, 12.5%)	1	22500	646.9	28.75	28.44
		2	22500	654.1	29.07	
		3	22500	618.8	27.5	
3	MIX 2 (5%, 12.5%)	1	22500	642.4	28.55	28.82
		2	22500	640.6	28.47	
		3	22500	662.4	29.44	
4	MIX 3 (7.5%, 12.5%)	1	22500	732.8	32.57	32.72
		2	22500	739.4	32.86	
		3	22500	736.4	32.73	
5	MIX 4 (10%, 12.5%)	1	22500	710.3	31.57	31.05
		2	22500	700.2	31.12	
		3	22500	685.4	30.46	

Table 4.9 final Result of 7 and 28 days Compressive Strength using 12.5% Fly ash

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	Compressive Strength @ 7 Days (N/mm2)	Compressive Strength @ 28 Days (N/mm2)
1	CC	14.67	27.38
2	MIX 1 (2.5%, 12.5%)	15.09	28.44
3	MIX 2 (5%, 12.5%)	15.36	28.82
4	MIX 3 (7.5%, 12.5%)	18.14	32.72
5	MIX 4 (10%, 12.5%)	17.52	31.05

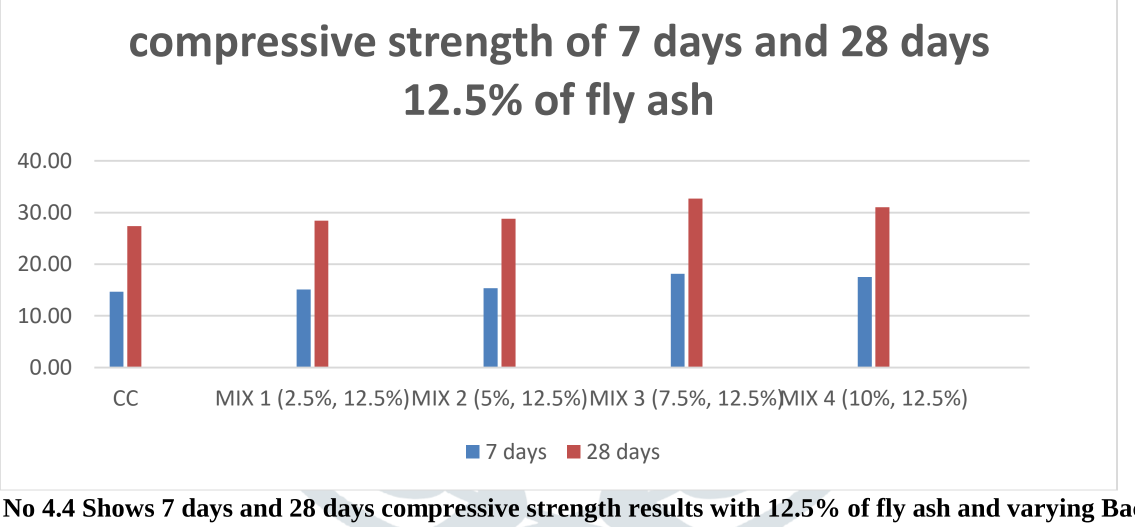


Fig No 4.4 Shows 7 days and 28 days compressive strength results with 12.5% of fly ash and varying Bacteria %

Table 4.10 table of optimum results from all the above combinations

Sr. No.	Material Mix With % of (Bacteria, Flyash)	Compressive Strength @ 7 Days (N/mm2)	Compressive Strength @ 28 Days (N/mm2)
1	MIX 1 (7.5%, 5%)	16.43	30.62
2	MIX 2 (10%, 7.5%)	17.11	31.48
3	MIX 3 (10%, 10%)	17.47	31.97
4	MIX 4 (7.5%, 12.5%)	18.14	32.72

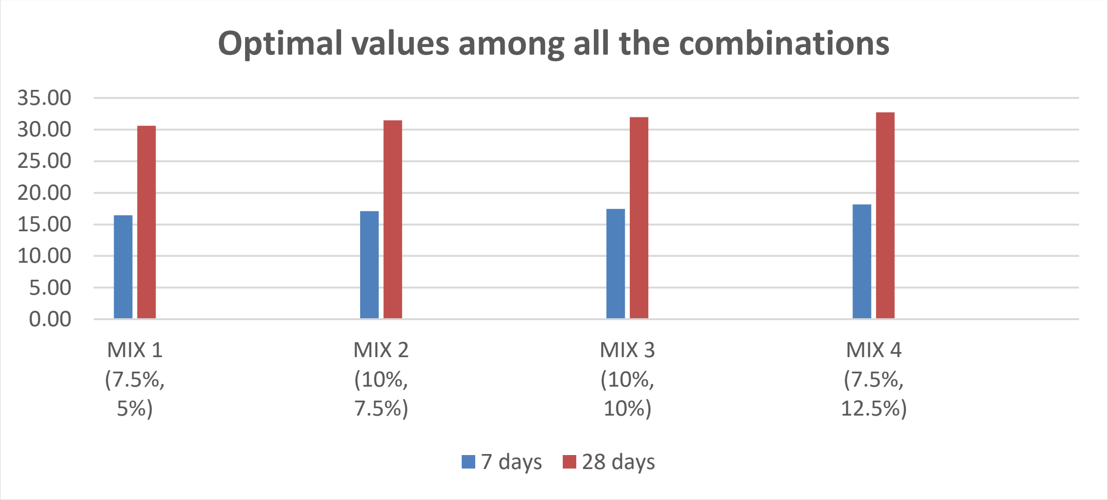


Fig No 4.5 Shows 7 days and 28 days compressive strength of optimum results from all the above combinations

4.3 Compressive strength test after self-healing of concrete

From the above result we conclude that Material Mix With % of (Bacteria, Flyash) MIX (10%, 10%) and MIX (7.5%, 12.5%) gave optimum results. So we carried out further work by loading samples of these mix in compression testing machine. these sample are loaded but not till the failure occurs. Samples are loaded until concrete block will not get a minute crack of about 1-2 mm width. Afterword's samples are kept under observation for 28 days. It is observed that the crack is totally healed by extraction of bacteria that is calcium carbonate.

Now these samples are again loaded till the failure occurs and the compressive strength is recorded.


BEFORE HEALING


AFTER HEALING

Table 4.11 result of compressive strength of optimum combination after healing the cracks

Sr. No.	Material Mix With % of (Bacteria, Flyash)	No. of Cube	C/S Area of Cube (mm2)	Load (KN)	Compressive Strength @ 28 Days (N/mm2)	Average strength(N/mm^2)
1	MIX 4 (10%, 10%)	1	22500	619.4	27.53	27.81
		2	22500	625.3	27.79	
		3	22500	632.5	28.11	
2	MIX 3 (7.5%, 12.5%)	1	22500	710.6	31.58	31.41
		2	22500	703.1	31.25	
		3	22500	706.5	31.40	

Table 4.12 Comparison of compressive strength of uncracked cube and cube with healed crack

Sr. No.	Material Mix With % of (Bacteria, Fly ash)	Average strength(N/mm²)	after healing the cracks Average strength(N/mm²)	Percent reduction in strength
1	MIX 4 (10%, 10%)	31.97	27.81	13.02
2	MIX 3 (7.5%, 12.5%)	32.72	31.41	4.01

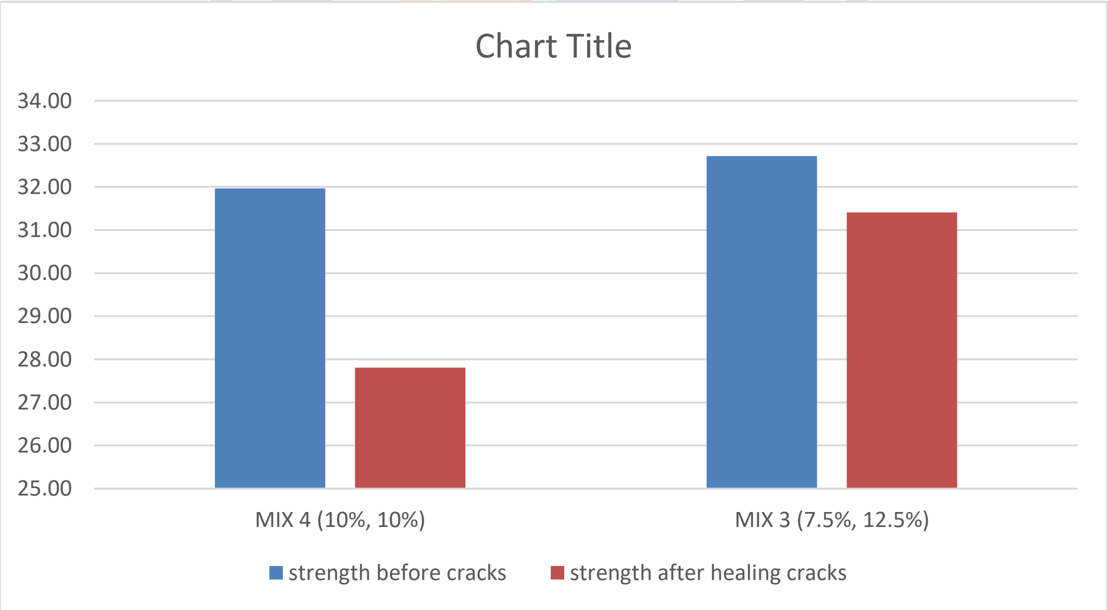
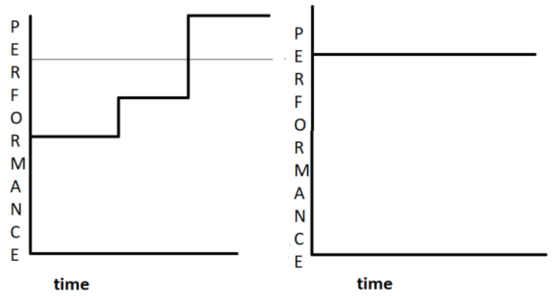


Fig No 4.6 comparison of compressive strength of uncracked cube And cube with healed crack

4.4 Effect on cost of construction

As we have discussed earlier use of bacteria will increase the initial construction cost so to compensate it we have used fly ash. The following graph for conventional concrete initial cost is low but as can see overall cost of structure throughout its life is probably equal to self-healing bacterial concrete.



Cost v/s time graph of Conventional concrete

Cost v/s time graph of bacterial concrete

CONCLUSION

Bacterial concrete is turning into a pattern during a unique concrete. It's a lot more useful because of the self-healing capacity of its compared to the traditional concrete with break fixing. Bio concrete is a novel as well as earth friendly approach. Calcium carbonate precipitate of the bacteria greatly gets better the sturdiness of concrete by filling the voids. By utilizing bacterial concrete the fix as well as rehabilitation expense of concrete framework could be lowered. By the literatures it's expected the longevity of the germs is a lot more compared to the lifetime on the construction. This's an extremely handy technique. This particular development is going to provide longevity on the concrete framework by lessening the permeability because of the precipitation of calcite by the germs via bio mineralization operation. Though the specifics associated with the financial issue of bacterial concrete need to be nevertheless to discover away. The optimum results are recorded by the substitution of bacteria & Fly ash with combination of MIX (10%, 10%) and MIX (7.5%, 12.5%) respectively. The Compressive Strength increases with the use of Bacteria material. The maximum strength achieved in concrete having 10% Bacteria, 10% Fly ash i.e., Mix 4.the strength increased 1.16% and The maximum strength achieved in concrete having 7.5% Bacteria, 12.5% Fly ash i.e., Mix 3 the strength increased 1.21% as compared to Conventional Concrete. Hence from an above experimental research has concluded that cement with Bacteria 7.5% & Fly ash 12.5% replacement gives an optimum result and also helps in the strength & durability improvement properties of concrete. From cracked sample it is conclude that there is negligible change in strength and It is observed that the crack is totally healed by extraction of bacteria that is calcium carbonate. It is also observed that early crack and void are effectively plugged by calcium carbonate deposit. It has better application to the hydraulic environment. Because bacteria react with moisture and then start filling cracks so there is no negative effect of water entering into cracks. It also increases life of structure. There will be increase in initial cost but this can compensate with maintenance cost of structure. In this research M25 concrete is used there is negligible reduction in compressive strength of self-healed concrete cube but this can be overcome by using different types of admixtures to increase strength.

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