A Comparative Review –Elucidation about Longevity of Bio-Concrete

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Abstract - *At present, for the time being, Bio-concrete is extensively blooming in the world of construction, which incorporates some admixture and effective micro-organisms concentration. Effective micro-organisms are used to partial replacement of water or cement in concrete. Microbial intensity used in various mixtures may differ concerning mixes proportions and grade of concrete. Bacteria are the most effective micro-organisms for self-healing concrete. Some calcite precipitating bacteria are bacillus megaterium, bacillus subtillies and Effective micro-organisms etc. These micro-organisms can produce calcite precipitate when it comes to contact with oxygen, which is used to heal the micro-cracks produced in concrete due to the involvement of effective micro-organisms used to make better strength and serviceability, compared to the conventional concrete mixture. And it will be the major consideration for longevity properties against an aggressive environment. This study involves better strength and durability of concrete, optimum effective microorganisms concentration were manipulated. Consequences of incorporating effective micro-organisms, concrete should possess less permeability of water, gas, and Chloride permeation than the control Mix. Efficiency and Service years of specimen increase while adding micro-organisms in construction industries.*

***Key Words*: Micro-organism, Bio-concrete, Durability, Calcite precipitation, Microcracks.**

1.INTRODUCTION

Concrete can crack, allowing chemicals to enter and potentially reducing the mechanical and durability qualities of concrete constructions. The application of various surface coating agents, sealants, binding agents, and adhesives has been a widespread technique to maintain, repair, and restore concrete buildings. While these methods have their uses because of their built-in mechanism, there are other options for sealing cracks because of problems such delamination and low cost. Concrete mixtures containing bacteria that promote calcite precipitation can be used as one of the unique self-healing processes to repair concrete cracks. By breaking down urea and calcium to create calcium carbonate ($CaCO_3$), which can fill cracks, this method of bacterial mineralization is carried out. This essay attempts to examine the mechanisms governing this precipitation.

Contemporarily utilization of cement widely enlarging. Production of cement will also increase tremendously to overcome the demand in construction industries. Recent researchers are inducing to reduce the utilization of cement in the future and start practicing with cementitious materials produced as waste from various industries. While producing cement, raw materials are exploited from the ground, which will cause a tremendous increase in the amount of carbon emission in the outside environment.

To better this situation, utilize other pozzolanic materials such as fly ash, Micro silica, silica fume, GGBS, Rice husk ash, and Micronized biomass silica. It's better to reduce the utilization of cement in construction, and rehabilitation works will safeguard the environment. The use of various pozzolanic materials will result in a major improvement in the strength and longevity of concrete structures. The effectiveness of those pozzolanic materials will impart bonding between granules and reduce the heat of hydration generated by the hydration process.

In recent days emerging smart constructions like self-healing concrete incorporating micro-organisms. Micro-organisms are abundantly accessible in the natural environment. Micro-organisms are mainly categorized as Bacteria, fungi, and viruses. In such a way that very few bacteria groups can produce calcite precipitation used to heal the micro-cracks formation on the surface of the concrete.

The usefulness of this study involves comparing various bacterial species used in the literature and suggesting the better species among them. Distinguishing the numerous pozzolanic substances in numerous research and Manipulated the most reliable utilization and its effectiveness.

2. DISCUSSION

2.1 Ghasan Fahim Huseien, Zahraa Hussein Joudah et al.,

As a control mix, the scientists looked at both regular Portland cement concrete and customized concrete made with cement, which alternates various pozzolanic materials and powerful microorganisms with cement. Fly ash is used as a supplementary cementitious substance in this analysis. Additionally, efficient microorganisms were used in accordance with ASTM C150 standards.

Ordinary Portland cement of Type-1 was used in this study. Fly ash's specific gravity is 2.20. Modified concrete mixture incorporated with fly ash of 10%, 20%,30%, and 40% were replaced for cement. Effective micro-organisms of Type-1 were used. Chemical composition in effective micro-organisms was analyzed using XRF analysis. As per the analysis, effective micro-organisms contain Aluminum, Magnesium silica, Calcium, Potassium, Phosphorus, Rhodium, Ruthenium, Zirconium, and Promethium; this will result in concrete strength development. Effective micro-organisms replaced water by 5%, 10%, 15%, and 20% water, as per ASTM C1602, was used to mix and cure the concrete.

As per Marsh's (2007) Guide, the mixing proportion for the concrete was followed. As per the guidance mentioned in the code book, OPC 450 kg/m3, water 250 kg/m3, 875 kg/m3, and gravel kg/m3 were used in the control concrete mix. From the mix proportion, cement was replaced by fly ash for 10%, 20%, 30%, and 40% of the amount of cement. Effective micro-organisms replaced water for 5%,10%,15%, and 20% of the total amount of water mentioned.

Results for 7 days and 28 days were studied for mechanical qualities such compressive strength. In accordance with the test results, typical concrete had a compressive strength of 33.9 MPa and 40.6 MPa at 7 days and 28 days, respectively. By adding 10% fly ash, the concrete's compressive strength will rise by 7 days and 28 days, representing 35 MPa and 45.4 MPa, respectively. At the same time, increasing the fly ash content by20%,30%, and 40% simultaneously decreases the strength at 7 days and 28 days. Also, this will delay the final setting time of the concrete mix. Fly ash will enrage the degree of hydration due to the presence of Tri-calcium Aluminates content. Incorporating 5% and 10% of effective micro-organisms was used to gradually increase the compressive strength of specimens compared to the conventional mix. Because of the higher degree of hydration, concrete pores were filled by C-(A)-S-H gel, which increased the concrete's compressive strength. It will cause the structure to be denser.

Further use of Effective micro-organisms will lower the strength of the concrete. As per this detailed investigation, 10% of fly ash will impart a better result. Use of 10 % fly ash is optimum while comparing the other results. Simultaneously Optimum use of Effective micro-organisms can be determined as 10% from the comparison. Including 10% of fly ash and 10% of Effective micro-organisms in the concrete mix will enhance the compressive strength from 3, 7, 28, and 56 days up to 55MPa.

The modified concrete mixture will improve the compressive strength of the concrete; definitely, it shows betterment in the serviceability properties. Water absorption of conventional concrete was observed as 7.4%. While adding 10% of Fly ash and 10%, Effective Microorganisms decrease water absorption by 7.2% and 6.9% against conventional mixes. The test specimens with conventional concrete and modified concrete were exposed to sulfuric acid for 180 and 365 days. Finally, the strength loss was determined 81.3% for conventional concrete, 69.8%, 67.6% for fly ash, and effective micro-organisms incorporated in concrete at 180 days. Similar results were obtained for 365 days. Simultaneously percentage weight loss will also be shown to decrease than conventional concrete.

On the other hand, the concrete specimens' strength diminished after 180 and 365 days of being bombarded with 10% magnesium sulfate. In line with the findings, ordinary concrete lost 22.8% of its strength. Concrete with fly ash as well as effective microorganisms lowered strength by 8.9% and 8.2%, correspondingly. It will be less than the typical concrete's strength loss.

Finally, the inclusion of fly ash and effective micro-organisms will play a major part in strength and serviceability performance to enhance the quality of concrete. And also, it will reduce the heat of hydration and enhance early age strength attainment by up to 30%. From the microstructure evaluation Fly ash and Effective micro-organisms integrated mixes have low calcium hydroxide levels. The use of micro-organisms in concrete is an environmentally effective and sustainable material.

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The research was used to mitigate the utilization of cement and enhance the use of cementitious materials. Implementing the use of additional pozzolanic materials is more economical than cement. It will help us protect our environment from extracting underground raw material and emission of CO_2 during the production process.

Majorly strength of concrete is based on the type of cement and pozzolanic material used in the particular mix. In this study, the OPC 53-grade cement was used per the requirement of IS12269-1987. Locally available clay was used as a fine aggregate. Clay must be free from silt and organic matter. The concrete mix contains river sand followed by the codal provision of IS 383-1970. Crushed granite aggregate is used as coarse aggregate. 60 % passed over 20mm sieve and retained 12.5mm. 40 % passed over 12.5mm sieve and retained 4.75mm sieve. The total weight of coarse aggregate used in this mix is 60 %, and fine aggregate is 40 % of the total weight of aggregate. Water shall be used to satisfy the standards mentioned in the code of IS 456-2000. Bacillus pasteurii and Bacillus megaterium were used in different concentrations. Bacillus pasteurii can produce calcite precipitation when it comes to contact with oxygen. These calcite precipitation spores are more effective in improving the density of concrete. Bacillus megaterium bacteria are gram-positive bacterium and aerobic. The cell diameter lies 4 to 11 micrometers. The bacterial concentration varies like 10^3cells/ml, 10^5cells/ml, and 10^7cells/ml for various mixes.

This study's mix designs have been developed for the M_{30} grade. Using the results of trial mixes, these proportions for the mix were established. The experimental mixes called for 387.5kg/m^3 of OPC to be utilized. Sand was used as the fine aggregate and crushed granite weighing 1261.89 kg/m^3 was used as the coarse aggregate. Bacillus bacteria are added to each mix according to its bacterial concentration, with the water to binder ratio set at 0.48.

For the compressive strength test, specimens were cast in accordance with Indian Standards. After 7, 28, and 56 days of cure, a compression test was performed. Results from compression strength tests on the addition of bacterial concentration can vary. According to these findings, the ideal bacterial concentrations for both types of bacillus species are 10^5 cells/ml. When efficient microorganisms are added, concrete's ability to absorb water likewise declines. Similar to compressive strength, bacterial concentrations of 10^5 cells/ml absorbed less water than any mix.

Compression and water absorption tests conclude that mixes with 10^5 cells/ml bacterial concentrations can produce better results and cost-effectiveness. These mixes are named B2 and C2 mixes. These B2 and C2 mixes were a little more costly than conventional concrete. Further, the study was extended to enhance the durability of concrete with Bacillus species

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In the evolution of concrete enlarging, sustainable materials are like effective Micro-organisms and other pozzolanic materials. The use of other pozzolanic materials will help reduce the use of cement. It will be cost-effective and safeguard the environment from the co2 emission. And also, pozzolanic materials like Micronized Biomass Silica help to induce the strength properties of concrete mixes.

Normally Ordinary Portland cement of 43 grade was used based on IS 8112-1989, which also satisfied the requirement of ASTM-Type-1. River sand is used as a Fine aggregate for passing a 4.75mm sieve. Coarse aggregate with a nominal size of 12.5mm was used. The water to binder ratio was the most important factor in inducing the strength properties of concrete. Using a super plasticizer will improve the workability and flow ability of concrete In case of a low water binder ratio. Conplast SP430 was used in this concrete mix and granulated rice husk ash with a particle size of 48 Micro metres. Pozzolanic action of the material increases concerning increasing the surface area. Due to this, Micronized Biomass Silica showed high pozzolanic action enhancing CSH gel formation. Bacillus sphearicus were used as the self-healing agent. It's a gram-positive, aerobic, spore-forming bacteria. The nutrient broth was added as powder form during the concrete mix production.

Mix proportions of concrete derived based on ACI 211.4R-08 for M60 grade concrete. On account of the mix design, one part of Binding or pozzolanic material, 1.23 part of fine aggregate, 2.17 parts of coarse aggregate, and 0.32 water to binder ratio were used to produce the concrete mix. Two types of concrete mixes were used to study. One was made with bacteria alone, and the other was made with bacteria and micronized biomass silica. Bacillus sphearicus were added to the concrete vary for each mix as 10ml, 20ml, and 30ml in the form of liquid. Similarly, the amount of micronized biomass silica used in various mixes differed from 4%, 8%, and 12%. During casting, nutrient broth and bacteria culture in liquid form was also included to improve the performance of spores forming bacteria.

The compressive strength of concrete mixes gradually improved concerning the amount of bacteria up to 20ml. It was observed that the concentration of bacteria increased by more than 20ml compressive strength of concrete should be decreased. The incorporation of bacteria enhances attaining early age strength. After the analyzing outcome of the compressive strength test, 20ml of bacteria concentration with 8% of micronized biomass silica will be effective for concrete. Similar to that tensile strength test was conducted with cylinder specimens. Analysis of tensile strength test conveys that concrete mix with 20ml bacteria and 8% micronized biomass silica impart better strength for concrete. The durability of concrete mixed with and without bacteria has its optical density of 1, and micronized biomass silica was performed. The concrete mix with 20ml bacterial solution and 8% micronized biomass silica became better than conventional concrete by 15.5% at 28 days of curing age. XRD analysis was carried out for the conventional and modified concrete mixes. XRD spectra intensity of concrete mix with micronized biomass silica and bacteria was stronger than conventional mix XRD spectra. Performance of spore-forming bacteria was induced in the concrete mix with micronized biomass silica than in the control mix. Water absorption of modified concrete mix will be decreased than conventional mix due to enhancement of calcite precipitation. The formation of CSH gel improves the durability of concrete. The addition of bacteria and micronized biomass silica improves CSH gel formation, leading to reduced water absorption of concrete mix. The self-healing activity of bacteria was examined with artificially induced cracks. After 7 days, the cracks had been completely healed and will increase the provider existence of the concrete.

2.4 Jaydeep chavda, Kishor Vaghela and Jayeshkumar Pitroda

Innovative solutions are routinely created to improve concrete's performance. One of the emerging solutions nowadays is self-healing concrete using bacteria. It will lengthen the concrete's useful life. This is the process to enhance the concrete's mechanical properties. To evaluate the physical characteristics of concrete, M_{70} grade concrete with bacterial species was used. Here, several concentrations of Bacillus megaterium were utilized. This could be 10^3, 10^5, or 10^7 cells per milliliter. Due to its self-healing properties, it will aid in lowering the permeation rate of concrete, improving durability, and resistance to the freeze and thaw impact.

As per the requirement of codal provision, IS12269:1987 locally available ordinary Portland cement 53 grade was used as a binding material. Coarse aggregate of retained 10mm sieve and coarse aggregate of retained 20mm sieve. Normal river sand of passing 4.75mm sieve was used as fine aggregate. Mineral admixtures such as Fly ash and silica fume were used in this study. Mineral admixtures help improve the pozzolanic activity in concrete Super plasticizer was used as a chemical admixture to reduce water to binder ratio and maintain the workability of concrete. Super plasticizer named FOSROC Conplast SP-430 was used in this work. The bacterial strain used in this study was bacillus megaterium. It will not be harmful to the surrounding environment compared to other bacterial species. Bacillus megaterium can be able to survive a pH level up to 12. Various bacterial concentration liquids were added to the concrete for various mixes like 10^3 cells/ml, 10^5 cells/ml, and 10^7 cells/ml.

Mineral admixtures and chemical admixtures from the IS 10262:2019 specifications were chosen and used in this work. In a way that the total amount of cement was substituted with 15% fly ash and 5% silica fume. 10% of the water is used in mixed amounts with the bacterial liquid. The super plasticizer intake was 0.5% of the total amount of pozzolanic material employed in the mixture, and the water to binder ratio was restricted at 0.26. The addition of the nutrient broth helps bacteria survive in watery environments.

Compressive strength of high strength bacterial concrete was conducted after 7days and 28 days of curing age. It can be inferred that bacteria-incorporated concrete showed better compressive strength. The mix containing 10^5 cells/ml bacterial concentration shows peak compressive strength compared to other mixes. Early age strength is also good when compared to conventional mix. Conventional concrete mix shows 56.7N/mm2 at the age of 7 days, concrete mix with 10^5cells/ml bacterial concentration showed 77.36N/mm2. Similarly, at 28 days, conventional and bacterial concentration mix with 10^5cells/ml showed 73.79N/mm2 and 98.06N/mm2, respectively.

From the compression test result, the bacterial concentration of 10^5cells/ml shows better results than other concrete mixes. So that 10^5 cells/ml bacterial concentration was taken as optimum bacterial concentration. Bacillus megaterium is a non-pathogenic bacterium that is not harmful to human health. Bacillus megaterium is a spore-forming bacteria that will occupy the micropores formed in the concrete; due to this porosity of the concrete will be reduced enormously. It helps to achieve a better cross-section of concrete.

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3. VARIOUS BACTERIAL NUTRIENTS

Better properties and durability are provided by bio-concrete compared to ordinary concrete. Nevertheless, the amount of calcium present in cement limits the spontaneous formation of $CaCO3$. Thus, in order to supply additional calcium for use as a calcium source in bio-concrete, additional nutrients must be added. Bacillus sp. and Enterococcus faecalis have been employed with calcium lactate in bio-concrete. This study showed that bacteria and calcium lactate might be added to concrete to increase its strength and longevity. (Alwan and Irwan, 2016). AK13 uses calcium ions from oyster shells to precipitate CaCO3 (Hong et al., 2021). The results of the investigation showed that these ions enhanced the survival of bacteria and the precipitation of CaCO3 in mortar cracks when combined with soybean meal solution. CaCl2, calcium acetate, and Ca(NO3)2 were evaluated on bio-cement by Xiang et al. (2022). When compared to the other two nutrients, calcium acetate was the most effective source of bio cement. Compared to CaCl2 and Ca(NO3), the ammonia emission decreased by 54.2% and 51.4%, respectively.2.In order to create a multi nutrient system that works well and increases the effectiveness of bacterial precipitation, more research on nutrients is necessary. The overall cost of bio-concrete could be decreased by combining inexpensive fertilizers.

4. MORPHOLOGY OF MICP

It is necessary to carry out an analysis and determine the chemical structure of bacterial CaCO3 precipitates in order to determine whether or not they are suitable for use in building activities. A significant characteristic of CaCO3 precipitation is its form. Vaterite, aragonite, and calcite are the three distinct morphologies of dehydrated crystalline materials. Calcite is the smallest soluble and most thermodynamically inert substance in the group. Whereas vaterite has the opposite qualities, the aragonite appears in the middle of the solubility and stability of heat charts. The elements that affect the morphology are the species of bacteria, the composition of the solution, and the excretion process of microbes (Zhang J L et al., 2016; Qian C et al., 2019Both the atomic force microscope and a scanning electron microscope are used to investigate the microstructure of CaCO3. The amount of organic calcium ion template in the simulated solution is influenced by its pH value, which changes the crystals' advancement pace and morphological characteristics. The ratio of ellipsoidal to spherical fragments is directly proportional to the calcium ion concentration in calcite. Relative contact area rises with increasing spherical/ellipsoidal particle a fraction. The degree of heat at which CaCO3 crystals disintegrate directly affects particle adhesion. Because of the structure of its crystals, calcite is regarded as the most ideal form of CaCO3 for concrete applications.

5. COMPARISON SUMMARY

Effective micro-organisms can be classified into basic groups. They are bacteria, viruses, and fungi. Some bacterium is capable of producing calcite precipitation. Calcite precipitation heals the micro-cracks and can improve the mechanical properties of concrete. EM is non-toxic and cost-effective. As a possibility, EM is good for human health. It is used to produce healthy drinking water. It can resist corrosion. The element called rhodium present in EM is helpful to protect the concrete from corrosion. The viscosity of Diluted EM is slightly higher than water, which leads to improving workability and reduced segregation and bleeding. Bacillus pasturii is also known as sporosarcina pasturii. Bacillus pasturii is a gram-positive, rod-shaped bacterium that can produce calcite precipitate and solidify sand. It contains calcium and urea. It will help to fill the micropores in concrete. It leads to reducing the permeability and water of concrete specimens. It could have the ability to triumph over the outcomes of concrete in competitive environment.

A Gram-positive, rod-shaped, spore-forming bacterium is called Bacillus megaterium. It can be found in disintegrating waste from plants and root soil. It can withstand up to a pH of 12. Give up attempting to cultivate that specific variety of bacteria at the desired concentration. The concentrations of 10^3, 10^5, and 10^7cells/ml were used in the present research. When there is oxygen present, Bacillus megaterium begins to actively produce calcite precipitation. The tiny pores in the concrete structure are filled with calcite deposition. A number of microorganisms have been recognized and given important characteristics after being examined in concrete. The aragonite the substance, rhombohedral calcite, and amorphous calcite are among the several forms of CaCO3. The limited longevity of bacteria throughout the direct addition process increases concrete strength but decreases self-healing efficacy

A few studies investigated the potential of directly misting the bacterial solution over the cracking, with favorable outcomes. Numerous encapsulating strategies have been proposed for extending the lifespan of bacteria; polymer-based encapsulation is the most commonly utilized self-healing substitute. Beyond bacterial concrete, concrete that has had additional nourishment added to it is also gaining popularity as a disruptive self-healing method. Microbial CaCO3 precipitation is one biogeochemical process that results in deposition in concrete. Spores are shielded from injury during the procedure of hydrating by the encapsulation of bacteria, as they are larger than the pores in concrete. By looking at micronutrients in more detail and developing an arrangement with multiple nutrients, it is possible to enhance the performance of bacterial precipitation. The total cost of bio-concrete could be decreased through mixing low-cost fertilizer products. Monetizing this technique will demand an integrated strategy and a thorough comprehension of the bacterial precipitation of calcium carbonate mechanism.

6. RECOMMENDATION FOR FUTURE WORK

A unique technique with possible applications in specific structural sections is called "bacterial concrete," which refers to the use of bacteria as a supplement for healing or as a partial replacement material for the binding agent (such as Portland cement). However, this material has environmental implications and a variable cost of production, in spite of its numerous benefits. Since the addition of alive microbes to concrete mixtures and their continued survival necessitates the achievement of significant conditional criteria, including the existence of an appropriate temperature and all other environmental conditions, it is advised to overcome those difficulties and should be anticipated that they will be remedied.

7. CONCLUSION

1. From the comparison of each study can be inferred that 10% of bacterial incorporation gives the optimum result for various mix proportions with various pozzolanic materials.
2. Comparatively Effective micro-organisms (EM-1) are economical
3. It can survive along with a high pH range of 12.
4. It shows better performance in against Sulphate attack, Acid attack, Chloride ions movement, and water absorption examinations. Also, it is capable of resisting corrosion in concrete. It can be used in RCC structures in aggressive environments.
5. Bacillus pasturii considerably performs better in the mechanical properties of concrete.
6. Bacillus sphearicus can heal crack width up to 0.45mm to be used for repair purposes.

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