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A REVIEW OF BACTERIA-BASED SELF-HEALING CONCRETE

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ABSTRACT

This article examines the many kinds of bacteria found in concrete and how they may be utilized as healing agents. This article also includes a short explanation of the different characteristics of concrete that change when microorganisms are added. Concrete has micro-cracks by nature. This results in concrete degradation, which leads to the entrance of harmful chemicals into the concrete, causing structural damage. As a result, the concrete must be repaired. Self-healing methods are used to overcome these problems. Calcite precipitation in concrete is caused by the combination of urease-producing bacteria and a calcium supply. The use of bio-mineralization methods to seal micro cracks in concrete has shown to be effective. The continuous hydration process in concrete may cover up newly formed micro-cracks. The ureolytic bacteria Bacillus Pasteurii and Bacillus Subtilis, both of which may produce urea, are combined with the calcium source to seal the newly formed micro fissures with CaCO3 precipitation. The bacterial concentrations were adjusted for improved outcomes in improving pore structure in concrete. According to the literature, the encapsulation technique produces better results than the direct application method, and the employment of bacteria may improve the strength and durability of concrete.

KEYWORDS: *Bacteria, Caco3 Precipitation, Micro-Cracks, Micro-Organism, Self-Healing Concreate.*

1. INTRODUCTION

Concrete is one of the most frequently utilized building materials. Concrete is brittle in tension yet robust in compression, thus fractures are unavoidable. When fractures appear in concrete, it may shorten the life of the building[1]. The fractures may be repaired using a variety of methods, but they are all very costly and time-consuming. Self-healing concrete is a modest method for repairing fractures in concrete on its own. At the time of mixing, bacteria with a calcium nutrition source are introduced to the concrete. If there are any fractures in the concrete, bacteria will precipitate calcium carbonate[2]. The cracks will be sealed as a result of this. Bacterial concrete will have a higher strength than regular concrete. A biotechnological approach based on calcite precipitation may improve the strength and durability of structural concrete. Cracks larger than 0.8mm are more difficult to mend, although cracks may heal with the assistance of bacteria and calcite precipitation. When lightweight aggregates are used in lieu of fine aggregate, the strength of the bacteria-based mortar is reduced[3]. Bacterial lightweight mortar has a higher strength than regular lightweight mortar. Wherever low weight constructions are needed, this may be utilized.

These low weight aggregates serve as bacterium carriers, improving healing efficiency and structural durability. Due to calcite precipitation, the addition of bacteria to Rice husk ash concrete may improve the strength characteristics of the concrete at all ages[4]. With maximal calcium carbonate precipitation, the M50 grade concrete may be raised by up to 24 percent. Adding Sporoscarcina Pasteurii bacteria to fly ash concrete increases its strength while reducing porosity and permeability. This leads in a 22 percent improvement in compressive strength and a four-fold decrease in water absorption over regular concrete. Recently, self-healing methods have shown encouraging results in repairing fractures that are still in the early phases of development[5]. Calcite precipitation in concrete specimens through hydro gel encapsulation, capsules, and vascular systems, on the other hand, seems to be excellent at self-healing in building operations and research. By using cementitious elements in concrete, self-healing processes may be feasible. For the bacteria to precipitate calcite, a variety of calcium sources may be used. Recent advancements such as Biotechnology and Nanotechnology are utilized to improve the characteristics of concrete, such as durability[6].

The goal of this research is to look at how the characteristics of concrete change when microorganisms are added. And the microorganisms that cause calcium carbonate precipitation in concrete. Damage or fissures in a perfect self-healing system should trigger the release of the healing agent. Self-healing procedures are effective methods for repairing micro cracks in concrete. The autogenously healing methods have shown to be effective in the repair of micro-cracks on the concrete surface[7]. Bacteria will create a pervious layer on concrete fractures, which will control the precipitation of calcium carbonate. Because concrete is an alkaline substance, the bacteria introduced must be able to survive the alkali environment. Microbiologically induced calcium carbonate precipitation aids in the filling of micro fractures and the binding of other components in concrete such as sand and gravel.

The presence of microorganisms in calcite precipitation may improve concrete's durability. Bacillus Sphaericus may precipitate $CaCO_3$ in a high alkaline environment by converting urea to ammonium and carbonate. Concrete cracks of smaller than 0.2 mm may be filled by the concrete itself. However, if fractures are larger than 0.2 mm, concrete fails to repair, allowing harmful elements to enter. The development of any fractures in self-healing concrete causes microorganisms to awaken from their hibernating state. Calcium carbonate precipitates into the fractures during the self-healing process due to the metabolic activities of bacteria[8]. Bacteria enters a state of hibernation after the cracks are fully filled with calcium carbonate. If any fractures develop in the future, the bacterium becomes active and fills them. Microbiologically Induced Calcium Carbonate Precipitation is a method through which bacteria serve as a long-lasting therapeutic agent (MICP). According to their metabolic pathways, several microorganisms can mediate the production of calcium carbonate. Precipitated calcium carbonate has been shown to be more prevalent in heterotrophic processes than in autotrophic activities. Autotrophs are creatures that create complex organic molecules from simple components, often utilizing energy from light (photosynthesis) or chemical processes (chemosynthesis); heterotrophs, on the other hand, are organisms that cannot fix carbon and must rely on organic carbon sources for growth. Calcium carbonate is generated by the microbes and creates a mineral coating that protects the bacterial cells[9].

The breakdown of urea by bacteria with the help of the bacterial urease enzyme is perhaps the route that has been researched the most for engineering reasons. As part of their metabolism, bacteria produce urease, which catalyzes the conversion of urea to carbonate and ammonium, resulting in a rise in pH and carbonate concentration in the bacterial environment. These components then hydrolyze into ammonia and carbonic acid, resulting in calcium carbonate production. The capacity to precipitate calcium carbonate through urea lysis is possessed by a number of microorganisms. Bacterial applications have been discovered after a comprehensive study of the literature. With lightweight aggregate and graphite nanoplatelets, the Bacillus Subtilis bacterium may improve the concrete's strength. The presence of Bacillus Aerius bacteria in rice husk ash concrete was examined, and it was discovered that the concrete's durability had improved. The introduction of Bacillus Megaterium bacteria in concrete resulted in a 24 percent improvement in compressive strength[10]

2. DISCUSSION

Bacillus Sphaericus increases the durability of concrete by depositing calcium carbonate in it. Through a self-healing action, the Sporoscarcina Pasteurii bacteria employed in fly ash concrete has improved the strength and longevity of the concrete. Through the self-healing action of the Sporoscarcina Pasteurii bacteria employed in silica fume concrete, it was discovered that the strength and durability of the silica fume concrete improved. The surface treatment of concrete was tested using Bacillus Sphaericus bacteria, and the findings show that bacterial carbonate precipitation may be utilized as an alternative surface treatment for concrete. According to the literature, there are two ways to apply the healing agent to concrete: direct application and encapsulation. The application of a healing agent in concrete by direct, incorporation of bacteria in light weight aggregates (LWA), and graphite Nano platelets (GNP) has been revealed in previous literature; it has been revealed that GNP is a good carrier compound for bacteria and has given better results in crack healing.

The direct approach was utilized to determine the optimal concentration of bacteria for strength purposes, and the optimum concentration was found to be 30x105cfu/ml. Another technique for improving the self-healing overall performance of concrete is to impregnate lightweight particles with bacteria solution and then encapsulate them in a polymer-based coating layer. The use of a microencapsulation technique including a healing agent for self-healing of materials is a self-healing strategy. The healing agent is released into the fracture faces by capillary migration as soon as the crack ruptures the implanted microcapsules. The healing agent now forms a bond with the imbedded catalyst, triggering polymerization and ensuring the closure of nearby fractures. An illustration of a burst microcapsule. Encapsulation-based self-healing has the potential to offer high-quality self-healing, with a broader range of crack widths that can be repaired and a faster response to matrix breaking. The hydro gel encapsulation technique was also employed, and the specimens with hydro gel encapsulated bacterial spores showed better self-healing efficacy in terms of both precipitation and fracture repair.

The direct application of Shewanella bacteria species into concrete was investigated, and the results revealed a 25% increase in cement mortar compressive strength after 28 days. According to the literature, the encapsulation technique demonstrated excellent self-healing effectiveness in terms of crack closure and calcium carbonate precipitation, which is related to the uniform distribution and protection of bacteria in an alkaline environment. The technique for healing, as well as the breadth and depth of the cracked, were all mended utilizing this approach. Depending on the calcium source used, adding bacteria spore powder to concrete may either speed up or slow down the setting time. Calcium lactate, calcium nitrate, and calcium formate are used to provide nutrition to bacteria. Calcium lactate, calcium formate, and calcium nitrate may slow down the setting time of concrete, whereas calcium formate and calcium nitrate can speed it up.A biotechnological technique based on calcite precipitation has enhanced the structural concrete's strength. Because the cement mortar was porous, microbial cells received enough nutrition throughout the first curing phase.

However, these cells were adjusting to a new environment. Because of the high PH of cement, bacterial cells may develop slowly in the beginning and then adapt to high PH circumstances throughout the curing phase. Calcite precipitates on the cell surface and in the cement mortar matrix during cell development, which may be owing to the presence of different ions in the medium. As a consequence, the cement mortar has reduced porosity and permeability. If several of the holes in the matrix are blocked at the same time, the supply of nutrients and oxygen to the bacterial cells is halted. The cell either dies or transforms into endospores throughout time. As a result, the behavior of microbial cells with enhanced compressive strength may be described. When Bacillus megaterium bacteria at a concentration of 30 105 cfu/ml were added to concrete, the precipitation of calcite was greater in higher grade concrete than in lower grade concrete, indicating that higher grade concrete has more strength than lower grade concrete. The maximal strength development rate for the highest grade of 50 MPa concrete is as high as 24 percent. The cement was substituted with 10% fly ash, and 105 cells per milliliter of Sparciouspasteurii bacteria were added. The deposition of calcium carbonate on the cell surfaces of microorganisms resulted in a 20% increase in compressive strength of structural fly ash concrete.

Due to the precipitation of CaCO3, the compressive strength of bacteria added to silica fume concrete increased. The presence of calcium carbonate in the concrete was verified by microstructure investigation using XRD and SEM. Concrete containing Sparcinapasteurii and Bacillus subtilis bacteria had a 20 percent higher compressive strength than concrete without bacteria after 28 days of testing. When cement was substituted with various percentages of fly ash (10%, 20%, and 40%) in mortar, bacterial cells increased mortar compressive strength by 19%, 14%, and 10%, respectively, when compared to control specimens. GNP serves as an excellent carrier compound for bacteria, allowing for homogeneous dispersion and optimum crack healing effectiveness. Due to microbial precipitation of calcium carbonate, the compressive strength of concrete improved at all ages after the addition of Bacillus subtilis bacteria together with GNP. By adding the reactive spore powder in cement mortar, the 28-day compressive strength improved when compared to the control cement mortar.

CaCO3 deposited on cell surfaces and in the pores of the cement-sand matrix blocks the mortar pores. Permeability determines the penetration of aggressive chemicals that cause concrete to degrade under pressure gradients, and is therefore regarded as the most important characteristic in determining the durability of concrete. This is determined by the characteristics of the cementitious materials' pore network, which are measured by porosity, tortuosity, specific surface, size distribution, connectedness, and micro fractures. The water/cement (w/c) ratio, particle size distribution, the age of hardened cementitious materials, and the entrance of aggressive chemicals, among other things, influence these parameters. CaCO3 deposition in concrete decreased water absorption and permeability of concrete specimens. The addition of S.

Pastteurii bacteria to fly ash concrete reduced the porosity and permeability of the concrete, according to studies. With a concentration of 105cells/ml bacteria in concrete, water absorption was decreased fourfold. Bacteria fill the pores of bacterial concrete with calcium carbonate precipitated by the bacteria. Due to microbial calcite deposition, cubes cast with Bacillus Megaterium and its nutrients absorbed more than three times less water than control specimens. Due to calcite precipitation, the inclusion of Bacillus Aerius bacteria produces a decrease in water absorption and porosity, increasing the durability of concrete buildings.

Due to holes filled with calcium carbonate, all control cement bag house filter dust concrete specimens show high to moderate permeability after 28 days, while AKKR5 bacterial (105 cells/ml) concrete specimens exhibit high to low permeability after 28 days. Microbial precipitation enhanced the quality of the recycled aggregate, which will decrease water absorption of the recycled aggregate. Corrosion of reinforcing steel caused by chloride intrusion is one of the most common environmental assaults that causes concrete buildings to deteriorate. The rate of chloride ion penetration into concrete is largely determined by the concrete's interior pore structure. Other variables that affect pore structure include mix design, curing conditions, degree of hydration, use of additional cementitious ingredients, and building methods. The quantity of electrical current that flows through a sample is monitored during the rapid chloride permeability test. A qualitative assessment of the concrete's permeability is based on the charge that flows through the sample. By incorporating bacteria into concrete, the resistance of the concrete against chloride penetration may be improved. When comparing bacteria-containing concrete to bacteria-free concrete, it was discovered that the average number of coulombs was 11.7 percent lower. Sparcious Pasteurii and Bacillus Subtilis were also shown to decrease concrete chloride penetration and enhance the mass reduction trend of sulfate-exposed concrete. Bacillus Aerius bacterial cells added to concrete may lower the overall charge transmitted through control and RHA specimens. At all curing ages, bacterial concrete indicates the minimal charge passed. At the ages of 7, 28, and 56 days, the charge transmitted in bacterial concrete specimens dropped by 55.8%, 49.9%, and 48.4%, respectively, as compared to normal concrete. Sparcious Pasteurii was added to 10 percent silica fume concrete with an optimal bacterial concentration (105 cells/ml) and exhibited excellent resistance to fast chloride penetration 380 coulombs.

The greatest decrease in chloride ions was found for all fly ash concretes with Sporoscarcina Pasteurii bacteria concentrations of 105 cells/ml; nevertheless, concrete with 30% fly ash concrete only resulted in 762 coulombs penetration, which is extremely low. The capacity of concrete to withstand chloride ion penetration determines the service life of concrete buildings exposed to deicing salts or marine conditions. A large-scale demonstration is needed before this idea can be commercialized. The issue of nutritional media optimization must also be addressed. Concrete's shrinkage, corrosion, and carbonation characteristics have yet to be thoroughly investigated. The real-time behavior of microbial self-healing concrete will be revealed by a comprehensive examination of the aforementioned characteristics. Although this concept has shown encouraging results in the lab, it has to be evaluated further in the field under non-ideal temperature ranges, high salt concentrations, and at later ages of concrete components. Only an in-depth understanding of the self-healing efficiency and its variability allows for precise service life estimate, and this is the key to spreading this idea among contractors and owners.

3. CONCLUSION

The purpose of this study is to learn more about the utilization of urease-producing bacterium isolates such Bacillus subtilis and Bacillus pasteuri in the healing of concrete fractures. The research looked at a variety of microorganisms that may be utilized to repair fractures. Bacteria has a beneficial impact on the compressive strength of Portland cement mortar cubes and concrete, according to this research. The use of bacteria has the benefit of reducing water penetration and chloride ion permeability. According to the findings of this research, utilizing "microbial concrete" as an alternative and high-quality concrete sealer that is cost-effective, environmentally friendly, and improves the longevity of construction materials is a good idea.

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