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Role of Bacillus Subtilis in Self-Healing Mechanism of Concrete

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Abstract
This study includes various demonstrations regarding the role of Bacillus Subtilis in self-healing mechanism of concrete, As use of Bacillus Subtilis in concrete is important for development for strong concrete section by controlling and repairing the cracking mechanism which may occurs due to a number of reasons/ Here, MICP (Microbiologically Induced Calcite Precipitation)system is considered for the study by utilizing Bacillus Subtilis and its nutrients which later acts as the food for the micro-organisms or bacteria's such as Sodium Bi-Carbonate (NaHCO3), Ammonium Carbonate (NH4CL), Calcium Chloride Dehydrate (CaCl2). Generally, they are mixed in a proportion of 1:2.5:5, Liquid form of Bacillus Subtilis is also added to the proportion (35 ml approx.) with the cell concentration of approximately 100cells/ml. The tests are performed on a cubical concrete section of 150mmx150mmx150mm for calculating and testing the compressive and tensile strength. As a result, it is found that there is a considerable increase in the strength and quality of concrete with added bacteria's/ Bacillus Subtilis. Bacillus subtilis JC3 is a typical soil bacterium which can also instigate the precipitation of calcite (Kadian & pannu, Durability Performance of Bacterial Concrete, 2018).
Keywords: *Bacillus Subtilis, Bacterial Concrete, MICP (Microbiologically Induced Calcite Precipitation).*

Introduction

Cement concrete is the most widely used construction material in the world because of its special qualities such as it is recyclable, strong, versatile, durable and most importantly its easy availability. Generally, cement concrete is a mixture of fine aggregates, coarse aggregates, cement and water but it also very prone to cracking over time, as concrete structures also develops cracks leading the water to enter the concrete resulting in reduced overall strength of concrete, water later needs very expensive maintenance works. To overcome such problems, bacterial concrete becomes a new hope which is expected to do miracles in the construction industries. As, bacterial concrete is formed by adding micro-organisms or we can say bacteria's in the blend of cement, fine aggregates, coarse aggregates, cement and water. These bacteria's also helps in improving the overall strength and compressive strength of concrete. These bacteria's usually remains in the concrete for decades doing their job of sealing the cracks, such micro-organisms or bacteria's when come in contact with water/moisture, starts germinating limestone which acts as the sealing material. In general, time taken by bacteria's to seal the cracks is 3 to 4 weeks. This bacteria based system uses ureolytic bacteria's of genus bacillus to form calcium carbonate crystals. This production of calcium carbonate repairs the concrete by filing the voids and splits. This self-healing mechanism of concrete is an example of connecting the Mother Nature to the construction business.

Literature Review

For enhancing the strength of cement sand mortar with microbial actuated mineral precipitation, the expansion in the compressive strength of concrete mortar (25 %) at 28th day was seen with the expansion of thermo philic and anaerobic microscopic organisms. By the examination on examination of the impacts of Bacillus sp. CT-5 confined from cement for deciding the water retention test and compressive strength. The outcome demonstrated that the compressive strength of concrete mortar expanded with the expansion of organisms and the treated 3D shapes were found to ingest water six times lesser when contrasted with the control blocks because of the affidavit of microbial calcite. This show by utilizing Bacillus sp. for the generation of "microbial solid" it can improve the durability of development materials. Bacteria consolidated solid show protection towards the soluble base, solidify defrost and sulfate attack and drying shrinkage. By the consider for the appraisal of durability change in a few high strength bacterial auxiliary solid evaluations by utilizing diverse kind of acid, the trial comes about demonstrated that natural solid when contrasted with the standard Portland concrete without bacteria has lost less weight and strength. It was additionally discovered that greatest weight reduction and compressive strength happened amid the sulphuric acid drenching when contrasted with hydrochloric acid inundation. It was observable that lesser measure of chloride and sulfur were found in the bacterial cement inundated in sulphuric acid and hydrochloric acid. The aftereffects of this investigation obviously demonstrate that utilizing appropriate microscopic organisms in cement can build its durability and protection even within the sight of solid acids, for specimen, sulphuric acid and hydrochloric acid.

Jagadeesha Kumar B G, R Prabhakara and Pushpa H, distributed a paper on Impact of Bacterial Calcite Precipitation on Compressive Strength of Mortar Solid shapes. This paper depicts about the exploratory examinations did on mortar 3D squares which were subjected to bacterial precipitation by various bacterial strains and impact of bacterial calcite precipitation on the compressive strength of mortar block on 7, 14 and 28 days of bacterial treatment. Three bacterial strains Bacillus flexus, confined from solid condition, Bacillus pasturii and Bacillus sphaericus were utilized. The 3D shapes were submerged in bacterial and culture medium for previously mentioned days with control solid shapes drenched in water and was tried for compressive strength. The outcome demonstrated that there was a change in the compressive strength in the early strength of 3D squares which were decreased with time. Among the three strains of microbes, Solid shapes treated with Bacillus flexus, which isn't accounted for as microscopic organisms for calcite precipitation has indicated most extreme compressive strength than the other two bacterial strains and control 3D shapes. It was contemplated that the expansion in compressive qualities is for the most part because of solidification of the pores inside the cement mortar 3D shapes with miniaturized scale organically initiated Calcium Carbonate precipitation. The urease action was resolved for every one of the microscopic organisms in Urease media by estimating the measure of smelling salts discharged from urea as per the phenol-hypochlorite test strategy. All the three strains of bacterias were tried for urease movement. The difference in the shade of the media from yellow to pink demonstrated that it is urease positive. All the three strains were urease positive. X-beam Diffraction examination was likewise done to decide compound organization of the precipitation that happened because of bacterial mineralization.

Sub-Culturing of Bacteria

Sub-Culturing or preparation of bacteria is done by exchanging the cells from earlier prepared cultures to crisp the development medium for the additional growth in the quantity of cells of bacteria's such as Bacillus subtilis, sodium bi-carbonate, ammonium carbonate, calcium chloride dehydrate and urea, As these are the most important nutrients which acts as the food for the bacteria's to survive I the concrete. In the process of sub-culturing, the culture is formed by using the above discussed nutrients of the bacteria's which later are sterilized in the machine called as Autoclave at 125℃ and at an approx. pressure of 150ps. The nutrients are diluted later in 1 liter of water in their respected quantities such as 2gms. Of nutrient broth, 1.5gms. sodium bi-carbonate, 6gms. Ammonium carbonate and 4.5gms.of calcium chloride dehydrate in a sterilized apparatus to prevent contamination and when studies deeply at microscopic level after sub-culturing of bacteria various changes are observed in the electrical and acoustical properties of the concrete. (Singh & Kadian, 2018)

Sealing Process

In the process of sealing cracks, Bacillus Subtilis precipitates the calcium carbonates, as phenomenon of MICP(Microbiologically Induced Calcite Precipitation) is related to enzymes of urea and the nutrient broth mixed in the bacteria's to create circumstances for the bacteria's to seal the crack. Microbiologically induced calcite precipitation (MICP) is comprised of a series of complex biochemical reactions, including concomitant participations of Bacillus pasteurii, urease (urea amidohydrolase), and high pH. In this process, an alkalophilic soil microorganism, Bacillus pasteurii, plays a key role by producing urease that hydrolyzes urea to ammonia and carbon dioxide. The ammonia increases the pH in surroundings, which in turn induces precipitation of $CaCO_3$ mainly as a form of calcite. (Kadian, 2018) This process of self-healing is very similar to organic remediation processes. Calcite precipitation also limits the movement of the moisture The microscopic organisms and its hastens adjust the microstructure of cement in this manner the impermeability of cement increases. (Kadian & Pannu, A Study of Durability Properties of Bacterial Concrete, 2018)

The following are some observations from the test:

• The rate of moisture absorption of bacterial concrete is comparatively less then that of the conventional concrete, due to the formation of limestone crystals into the crack resulting in lesser permeability.

• It is safe to produce bacillus subtilis artificially in the laboratories because of its level 01 as per the bio-safety standards as compared to usage of epoxy resins in repairing purposes which indeed are extremely harmful for both human health as well as the environment. (Kadian A. , Bio-Concrete: The Future of Concrete Science , 2018)

• The observed increase in the compressive strength of bacterial concrete ranges between 24% to 30%.

• There is an average increase of 16.25% is noted in the overall flexural strength.

• Moisture absorption rate of bacteria based concrete or bacterial concrete reduced with time i.e. rate of absorption noted on 7th day was more then that of the rate of absorption noted on the 28th day.

Figure 1: Sealing of Cracks with calcium carbonate crystals

Suggestions

1. Microencapsulation system can also be used for adding bacteria's to the concrete.

2. The test should also be performed using other bacteria's such as Sporosarcina pasteurii, Psuedoformic, E-Colii etc. from the ureolytic bacteria family

3. Using cements of different grades and brands may give different results in terms of strength and durability.

4. Properties such as porosity and acidic resistance should be studies and tested for the betterment of results.

5. Detailed study on different types of paint application should also be studied regarding the various effects of paints on the self-healing mechanisms.

6. More trials and tests with different concentrations of bacteria's and their behavior in different weather conditions should be done and in cases where quality examples fails to give appropriate results, additional testing of concrete setup is required (Kadian A. , 2018)

Conclusions

This study demonstrated the changes in properties of concrete on addition of bacterial solution Bacillus Subtilis with respect to the conventional concrete. As per the test, an overall improvement in terms of strength and durability is observed in the studied concrete section. Elaborating the results, an improvement ranging from 24% to 30% in multiple tests is noted in terms of compressive strength, with an average increase of 16% in flexural strength. The rate of moisture absorption of concrete with added bacteria's is also found lesser then hat of the regular concrete. The bacteria's or the micro organisms used in the study have a very basic threat level as per the bio-safety standards, so it is completely safe to undergo these tests without any special protection gear, hence, using bacillus subtilis for self-healing mechanism in concrete can make strong, durable and cost-effective structures.

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