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Studies on Strength Charecterstics of Bacillus Subtilus Induced Self Healing Bacterial Concrete

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ABSTRACT

In spite of many precautions cracks in concrete are inevitable, cracks may be due to many reasons. Microbiologically induced calcite precipitation (MICP) has been shown to prolong concrete service life due to calcium carbonate precipitation. The calcium carbonate heals the concrete by solidifying on the cracked concrete surface mimicking the process by which bone fractures in human body are healed by osteoblast cells that mineralize to reform the bone. Two methods are currently being studied: injection of calcium carbonate precipitating bacteria and by applying bacteria and nutrients as a surface treatment. In the present study attempt is made to fill the cracks with the help of bacteria which has a self-healing property. The potential bacteria 'bacillus subtilus' is isolated and cultured. The optimum parameter will be considered and the bacterial liquid of 105 per ml of water of concentration is being coated on cracked surface of concrete and the variation in the strength characteristics was studied. Calcite formation of isolated bacteria which can produce calcite precipitates on suitable media supplemented with a calcium source. It is observed that there is an increase of 12.83% in compressive strength of bacterial concrete when compared with controlled concrete.

KEYWORDS : Self healing concrete, bacillus subtilus, Compressive, Split tensile and Compressive Strength

1. Introduction:

When the concrete is mixed with bacteria (bacillus subtilus), the bacteria go into a dormant state, a lot like seeds. All the bacteria need is exposure to the air to activate their functions. Any cracks that should occur provide the necessary exposure. When the cracks form, bacteria very close proximity to the crack, starts precipitating calcite crystals. When a concrete structure is damaged and water starts 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 feed on the calcium lactate nutrient. Such spores have extremely thick cell walls that enable them to remain intact for up to 200 years while waiting for a better environment to germinate. As the bacteria feeds oxygen is consumed and the soluble calcium lactate is converted to insoluble limestone. The limestone solidifies on the cracked surface, thereby sealing it up. Oxygen is an essential element in the process of corrosion of steel and when the bacterial activity has consumed it all it increases the durability of steel reinforced concrete constructions. Tests all show that bacteria embedded concrete has lower water and chloride permeability and higher strength regain than the surface application of bacteria. The last, but certainly not least, key component of the self-healing concrete formula is the bacteria themselves. The most promising bacteria to use for self-healing purposes are alkaliphilic (alkali- resistant) spore-forming bacteria. The bacteria, from the genus Bacillus, subtilus is adopted for present study. It is of great concern to the construction industry whether or not these bacteria are "smart" enough to know when their task is complete because of safety concerns. Bacillus Subtilus which is a soil bacterium is harmless to humans as it is non-pathogenic microorganism.

2. Literature Review:

Crack is commonly observed failure in the case of concrete. Crack may develop due to addition of excess of water during mixing of concrete, or may be due to shrinkage and creep. In the present study, crack healing and improvement of physical properties of cement paste, mortar and concrete were studied. It is done by the addition of bacterial strains namely Bacillus Sphaericus and Sporosarcina Pastuerii. It is found that these bacteria when added at 106 concentration of cells/ml of water to cement composites increased by about 39.8% and 33.07% in paste. There is an increment of 50% and 28.2% in mortar for two bacterial strains. The strength increment is found to be 18.3% and 12.2% for Bacillus Sphaericus and Sporosarcina Pastuerii respectively for concrete. Ultrasonic pulse velocity of the bacterial concrete was in line with conventional concrete (3).

Studies investigates the effect of Bacillus Subtilis JC3 on the compressive strength of Laterized concrete. Taguchi method of experimental design which involved the use of orthogonal tables with three levels and three factors was employed. In all, 108 samples of 150mm×150mm×150mm concrete cubes cured in two media (water and nutrient broth) with a mix ratio of 1:2:4 were tested for compressive strength at 7, 14 and 28 days. The factors used were water/cement ratio, percentage laterite replacement for fine aggregate and concentration level of bacterial medium (added in different proportions as liquid for mixing the composite material). The results showed that Bacillus Subtilis JC3 generally enhanced the compressive strength and durability of the conventional concrete studied. The observed optimum values for water/cement ratio and bacterial medium for the constitution of concrete were found to be 0.50 and 20% respectively, however a negative trend was observed for laterite replacement for sand. At 20% replacement for sand, laterite can be used in structural concrete as compressive strengths as high as 24 N/mm2 were attained in 28 days (1).

Some experimental studies carried out on cement mortar using Bacillus cereus and Bacillus pasteurii in different cell concentrations. Test results showed that the addition of bacterial cultures of both species enhanced the compressive strength of cement mortar due to the bio-mineralization of calcium carbonate in the cement mortar matrix. The test results revealed 38% increase in compressive strength using B. cereus and 29% increase in the case of B. pasteurii over the control cement mortar. The chloride ingress capacity of Bacillus cereus incorporated concrete found through rapid chloride permeability test confirms the reduction of chloride penetration compared to control sample. Characterization studies have been performed to confirm the calcite precipitation through different experimental techniques, viz. X-ray diffraction, scanning electron microscope, thermo gravimetric analysis and Fourier transform-infrared spectroscopy (2).

One such thought lead to the development of a very special concrete known as Bacterial Concrete where bacteria is induced in the mortars and concrete to heal up the faults. Researchers with different bacteria have proposed different bacterial concrete's. Here an attempt was made by using the bacteria "Bacillus subtilis" According to them Calcite formation by Bacillus subtilisis a model laboratory bacterium, which can produce calcite precipitates on suitable media supplemented with a calcium source. Cement mortar cubes with four different cell concentrations were cast and control specimen was also cast. This study showed a significant increase in the compressive strength due to the addition of bacteria for a cell concentration of 105 cells per ml of mixing water with a percentage increase of 16.15% in cement mortar. With the addition of bacteria the compressive strength of concrete showed significant increase by 14.92% at 28 days. There was a significant increase in Split Tensile Strength. With the addition of bacteria it is observed that there is less percentage of loss in weight and compressive strength. From Scanning Electron Micro graphic analysis, it is noted that pores were partially filled up by material growth with the addition of the bacteria. Reduction in pore due to such material growth will obviously increase the material strength (4).

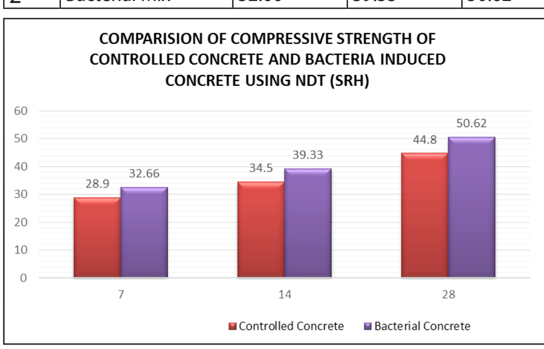
3. Present Investigation

The experimental work was carried out in three stages. In the first stage preliminary investigations such as consistency, specific gravity, initial and final setting time of cement and sieve analysis of fine aggregates and coarse aggregates were carried out on materials used. In the second stage isolation and culture of bacillus subtilus was done and in the third stage concrete mix proportioning was done as per the draft code (IS: 10262-2009) for M-40 grade Concrete and cubes, beams and cylinders were cast and tested. In the same way bacteria induced concrete specimens were cast and tested. The cubes beams and cylinders were tested properly in uniaxial compressive testing machine, Rebound Hammer Value, flexural testing machine and split tensile testing machine at the age of 7, 14 and 28days.

The cured concrete blocks were taken out of curing tank 24hrs priors to treatment. A small raised edges around the crack was created using M-seal in order to provide sufficient nutrients for precipitation of calcite. Then after 24hrs the centrifuged bacterial cells of Bacillus Subtilis were injected into the crack, and then calcite precipitation media was flooded over the crack. The precipitation of calcite in visible amount started to appear after 3 days. The precipitate was not confined within the crack but observed all over the edges and surface of ponded area as the bacteria we freely moving in the media. Bacillus subtilis started to show precipitate after 2 days in Calcium Chloride and Calcium Nitrate.

Table No.1 Compressive strength results using Schmidt Rebound Hammer

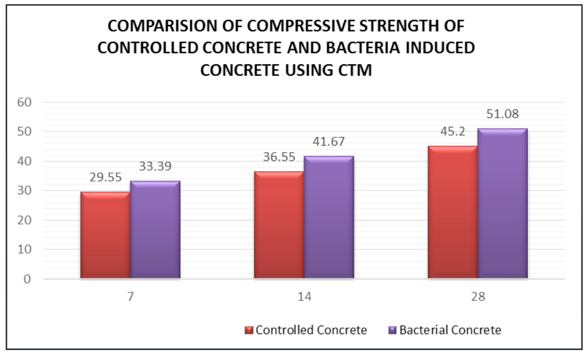
Sl No	Type of Concrete	Average Compressive Strength NDT Value (SRH)		
		7 days	14 days	28 days
1	M 40 Mix	28.90	34.50	44.80
2	Bacterial Mix	32.66	39.33	50.62



Graph No.1 Compressive strength results using SRH

Table No.2 Compressive strength Results using Compression Testing Machine

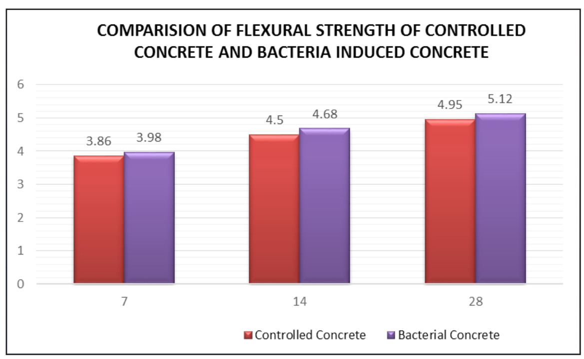
Sl No	Water type	Average Compressive Strength fck, Nmm^{-2}		
		7 days	14 days	28 days
1	M 40 Mix	29.55	36.55	45.20
2	Bacterial Mix	33.39	41.67	51.08



Graph No.2 Compressive strength results using CTM

Table No.3 Flexural strength Test Results

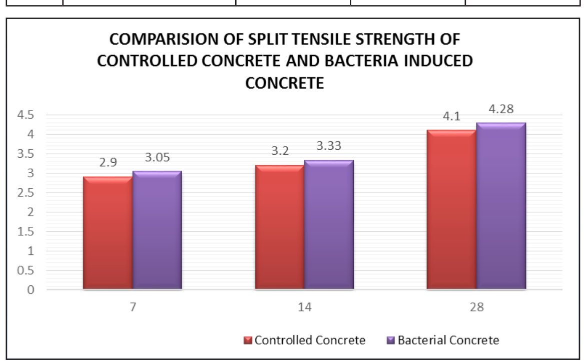
Sl No	Water type	Average Flexural Strength fcr, Nmm^{-2}		
		7 days	14 days	28 days
1	M 40 Mix	3.86	4.50	4.95
2	Bacterial Mix	3.98	4.68	5.12



Graph No.3 Flexural strength test results

Table No.3 Split Tensile strength Results

Sl No	Water type	Average Split Tensile Strength fck, Nmm^{-2}		
		7 days	14 days	28 days
1	M 40 Mix	2.90	3.20	4.10
2	Bacterial Mix	3.05	3.33	4.28



Graph No.4 Split Tensile strength test results

5. Discussions and Conclusions

Discussions

1. There is an increase of 12.83% in Compressive strength of bacterial concrete when compared to Controlled cubes
2. There is an increase of 4.47% in Split tensile Strength of bacterial concrete when compared to controlled beams
3. There is an increase of 3.51% in Flexural Strength of bacterial concrete when compared to controlled cylinders.

Conclusions

Based on experimental investigation carried out, following conclusion is drawn

1. Bacillus Subtilus can be produced from the lab which is proved to be safe and cost economic.
2. To conclude we can state that the bacterial approach has potential to contribute to self-healing capacity of concrete. We have shown that the bacteria incorporated in 105 per ml has considerably filled the cracks present in the concrete and it is also found that there is an increase of 12.38 % in compressive strength when compared to controlled cubes.
3. The use of this biological repair technique is highly desirable because the mineral precipitation induced has a result of microbial activities is pollution free and natural, however further experiments have to be done to examine the durability of this crack technique.

6. References

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