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Bacteria Impregnated Concrete - Effects on Strength Parameters

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Abstract

This study describes a method of strength improvement of concrete by microbiologically induced mineral precipitation. A gram-positive, anaerobic microorganism known as ***Bacillus Subtilis*** *is incorporated at different cell concentrations with the mixing water. Concrete cubes, concrete cylinders and concrete prisms with three different cell concentrations were cast and control specimen were also cast to check for improvement or deterioration in strength parameters. It was observed that there was an increase in strength of the specimens with addition of bacteria. The strength improvement is due to growth of filler materials within the pores of the cement-sand-aggregate matrix. Reduction in pore due to such material growth will obviously increase the material strength.*

Keywords: Micro-organisms, bacteria, Bacillus Subtilis, compressive strength, split tensile strength, flexural strength, cube, cylinder, beam, gram-positive

1. INTRODUCTION:

Concrete is the most commonly used man-made material, because of its great construction qualities (It can be given almost any shape). It is a combination of Cementious binding material, such as cement, fly ash, mud etc., some ballast, usually gravel, sand and stone-chips (coarse aggregate), water (activating reagent) and sometimes, some additive minerals in proper quantity. With the exception of cement all other constituents are naturally and easily available. Cement is an easily available factory made material. Hence, at almost any place concrete may be easily available or producible in adequate quantity.

After concrete paste is produced, plastic/green concrete paste is left to harden in suitable formwork, under appropriate curing conditions. After hardening, concrete develops a strength resembling to that of stone, taking almost any shape that may be required of it.

Need for modification in Concrete mix preparation:

Concrete, as we know, has a weak resistance against tensile loads. That is why steel reinforcing bars are embedded in concrete to be able to build structures. The steel bars take over the load when the concrete cracks in tension. The concrete on the other hand protects the steel bars from corrosion and attacks of various chemical and environmental factors. But when cracks are developed, ingression of moisture and different chemical ions takes place. Thereby longevity of the steel bars is reduced, and hence durability of the structure is reduced.

To increase durability of the structure either the cracks that form are repaired later or in the design phase extra reinforcements are placed in the structure to ensure that the crack width stays within a certain limit.

Crack repairing requires use of costly chemicals and experienced workmanship. Even the most skilled workers may face very difficult problems during crack repairing. Most common of these problems may be the presence of these cracks in unreachable corners. In such a case even the most skilled and experienced worker will have to accept defeat.

Use of extra reinforcing bars to negotiate crack development will result in increased cost of construction. But that may not always arrest crack development entirely.

Crack development depends on a lot of factors. Some of these factors may be due to some structural fault. But most of the times it is the effect of poor workmanship and bad ethics. In such case use of extra reinforcing bars may be of little help.

There may be some unforeseen environmental effect that may result in crack development. In such a case, use of extra steel or use of crack repairing techniques may be of little help, as the environmental effect may repeat itself causing further development of cracks.

So a relatively new and novel technique may be applied to stop the ingression of moisture and harmful chemicals into the concrete. This technique tries to replicate the repairing of bones naturally. In this technique, we try to imbibe the concrete with some micro-organisms that may infuse the concrete with an inherent property of self-healing. This is where "**Bacterial Concrete"** may be introduced, not only to protect the reinforcing bars and concrete from effect of harmful chemicals, and subsequently the structure, but also to lessen the extra reinforcing bars to negotiate crack development and subsequently bringing down the cost of the entire project.

2. RESEARCH AIM AND OBJECTIVE:

The aim of this study was to obtain the role of ureolytic bacteria such as Bacillus Subtitlis in modification of properties of normal Portland Cement Concrete (PCC) by experimental procedures. The following objectives are used to achieve the research aim.

i. To ascertain whether or not the bacteria has any harmful effects on people and their health
ii. Comparison between the compressive strength characteristics, split tensile strength characteristics and flexural strength characteristics of normal concrete and concrete embedded with bacteria after 7 days and 28 days of casting.
iii. To ascertain whether there was any change in strength properties when concentration of the bacteria used was varied.
iv. To ascertain whether or not the bacteria can perform satisfactorily in normal site conditions without any type of temperature or climate control.
v. To ascertain whether the bacteria under consideration can contribute to the strength of concrete when used in combination with normal tap water as the case may be in normal construction site conditions.
vi. To ascertain whether or not the micro-organisms can perform satisfactorily without immobilisation.
vii. To evaluate the results obtained.

3. METHODOLOGY:

The research investigation of this work was supported by experimental work which consists of three stages:

i. Culture of the microbial organism under consideration and preparation of solution where the cell concentration would be known.
ii. Preparation of the concrete mixes where the microbe would be introduced and simultaneous preparation of control mixes.
iii. Testing of the specimens prepared after 7 & 28 days of casting.

4. EXPERIMENTAL PROCEDURE:

i. Culture of Bacillus Subtilis was prepared on Mueller Hinton Agar base. And sub-culturing was carried out to prepare a number of samples. Cell concentration was determined by McFarland process.

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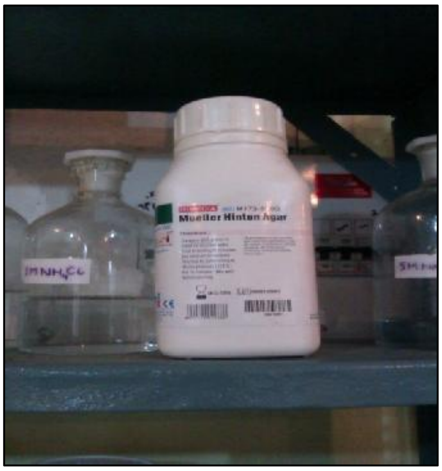

Fiture 1.1: Nutrient media

Fiture 1.2: During the culture preparation

Figure 1.3: Culture preparation

ii. Mix proportions chosen for the concrete mix preparation are:

Water : cement : sand : coarse aggregate = 0.4 : 1 : 1 : : 2.5

iii. Bacterial concentrations chosen were $10^5 c\ \ /m$, $1.5 \times 10^5 c\ \ /m$ and $2 \times 10^5 c\ \ /m$ and another sample was cast incorporating only the nutrient media for the bacterial strain.

iv. The mix was prepared for each concentration seperately and filled into 6 moulds of standard 150×150×150 mm cubes, 4 moulds of standard cylinders of 300 mm height and 150 mm dia and 6 moulds of standard beam of dimensions 500×100×100 mm.

v. Control specimens were mixed alongside and filled into same number of similar moulds

Figure 1.4 – Preparation of concrete mix with bacteria

Figure 1.5 – Filling of moulds with concrete mixed with bacteria

5. RESULTS AND DISCUSSIONS:

The results of various experiments are tabulated below.

5.1.1. Compressive strength

Table 1.1: Compressive strength test results of bacterial concrete of $10^5 c\ \ /m$ bacterial concentration and control specimens

Controlled Concrete				Bacterial Concrete			
Compressive strength (Mpa or $N/m\ ^2$)							
7 days		28 days		7 days		28 days	
Specimen 1	11.55	Specimen 4	27.77	Specimen 1	21	Specimen 4	31.78
Specimen 2	18.88	Specimen 5	28.89	Specimen 2	27	Specimen 5	36.22
Specimen 3	20.11	Specimen 6	28.22	Specimen 3	26.66	Specimen 6	36.67

Table 1.2: Compressive strength test results of bacterial concrete of $1.5 \times 10^5 c\ \ /m$ bacterial concentration and control specimens.

Controlled Concrete				Bacterial Concrete			
Compressive strength (Mpa or $N/m\ ^2$)							
7 days		28 days		7 days		28 days	
Specimen 1	20	Specimen 4	31.11	Specimen 1	20.44	Specimen 4	40.44
Specimen 2	21	Specimen 5	30.22	Specimen 2	27.11	Specimen 5	41.56
Specimen 3	22.22	Specimen 6	30	Specimen 3	27	Specimen 6	39.56

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Table 1.3: Compressive strength test results of bacterial concrete of $2 \times 10^5 c\ \ /m$ bacterial concentration and control specimens

Controlled Concrete				Bacterial Concrete			
Compressive strength (Mpa or N/m^2)							
7 days		28 days		7 days		28 days	
Specimen 1	17.78	Specimen 4	30.22	Specimen 1	28.9	Specimen 4	42.22
Specimen 2	16	Specimen 5	26.67	Specimen 2	26	Specimen 5	36.44
Specimen 3	21.33	Specimen 6	27.11	Specimen 3	26.7	Specimen 6	37.78

Table 1.4: Compressive strength test results of concrete with nutrient media (urea & calcium acetate) for bacteria and control specimens

Controlled Concrete				Bacterial Concrete			
Compressive strength (Mpa or N/m^2)							
7 days		28 days		7 days		28 days	
Specimen 1	21.11	Specimen 4	23.56	Specimen 1	19.56	Specimen 4	27.56
Specimen 2	19	Specimen 5	26.67	Specimen 2	20.44	Specimen 5	30
Specimen 3	21.33	Specimen 6	30.22	Specimen 3	21.33	Specimen 6	30.44

5.1.2. Split tensile strength

Table 1.5: Split tensile strength test results of bacterial concrete of $10^5 c\ \ /m$ bacterial concentration and control specimens

Controlled Concrete				Bacterial Concrete			
Split tensile strength (in Mpa or N/mm^2)							
7 days		28 days		7 days		28 days	
Sample 1	1.42	Sample 2	2.26	Sample 1	1.84	Sample 2	2.97

Table 1.6: Split tensile strength test results of bacterial concrete of $1.5 \times 10^5 c\ \ /m$ bacterial concentration and control specimens

Controlled Concrete				Bacterial Concrete			
Split tensile strength (in Mpa or N/mm^2)							
7 days		28 days		7 days		28 days	
Sample 1	1.91	Sample 2	2.97	Sample 1	2.48	Sample 2	4.10

Table 1.7: Split tensile strength test results of bacterial concrete of $2 \times 10^5 c\ \ /m$ bacterial concentration and control specimens

Controlled Concrete				Bacterial Concrete			
Split tensile strength (in Mpa or N/mm^2)							
7 days		28 days		7 days		28 days	
Sample 1	1.6	Sample 2	2.83	Sample 1	2.83	Sample 2	3.82

Table 1.8: Split tensile strength test results of concrete with nutrient media (urea & calcium acetate) for bacteria and control specimens

Controlled Concrete				Concrete with nutrient media			
Cyllindrical samples: Split tensile strength (in Mpa or N/mm^2)							
7 days		28 days		7 days		28 days	
Sample 1	1.6	Sample 2	2.83	Sample 1	1.77	Sample 2	2.97

5.1.3. Flexural strength

Table 1.9: Flexural strength test results of bacterial concrete of $10^5 c\ /m$ bacterial concentration and control specimens

Controlled Concrete		Bacterial Concrete	
Flexural strength (in Mpa or N/mm^2)			
28 days		28 days	
Specimen 1	5.6	Specimen 1	6.8
Specimen 2	6	Specimen 2	8.4
Specimen 3	5.2	Specimen 3	8
Specimen 4	5.6	Specimen 4	7.6

Table 1.10: Flexural strength test results of bacterial concrete of $1.5 \times 10^5 c\ /m$ bacterial concentration and control specimens

.Controlled Concrete		Bacterial Concrete	
Flexural strength (in Mpa or N/mm^2)			
28 days		28 days	
Specimen 1	6.4	Specimen 1	7.2
Specimen 2	5.6	Specimen 2	8.8
Specimen 3	5.8	Specimen 3	8.8
Specimen 4	6	Specimen 4	8

Table 1.11: Flexural strength test results of bacterial concrete of $2 \times 10^5 c\ /m$ bacterial concentration and control specimens

Controlled Concrete		Bacterial Concrete	
Flexural strength (in Mpa or N/mm^2)			
28 days		28 days	
Specimen 1	6.4	Specimen 1	6.4
Specimen 2	6	Specimen 2	8.8
Specimen 3	6.8	Specimen 3	8
Specimen 4	6.4	Specimen 4	8.4

Table 1.12: Flexural strength test results of concrete with nutrient media(urea & calcium acetate) for bacteria and control specimens

Controlled Concrete		**Bacterial Concrete**	
Flexural strength (in Mpa or N/mm^2)			
28 days		28 days	
Specimen 1	6	Specimen 1	7.6
Specimen 2	5.6	Specimen 2	8
Specimen 3	6.4	Specimen 3	6.8
Specimen 4	6.2	Specimen 4	7.6

5.2. DISSCUSSIONS

There was a definite increase in compressive strength as well as tensile strength. The bacteria as theorised precipitated calcium carbonate crystals in the mix, thereby filling the voids and sealing the micro-pores in the concrete matrix. If the voids and micro-pores and cracks are somewhat filled, there will be a definite increase in compressive strength and tensile strength. So there was an increase in 7 day compressive strength. For the same reason the split tensile strength observed were also high. If the nutrient media added played any role in increase of compressive strength there would have been a notable increase in compressive strength and split tensile strength in case of the samples prepared with introduction of only the nutrient media. There was no notable incrase in the strength values in case of the samples prepared with only nutrient media. So it is concluded that microbial precipitation of calcite crystal led to increase of the strength values of the samples. Also with the change of bacterial concentration there was a slight increase in the strength values of the mixes.

6. CONCLUSIONS:

With the test results of 7 days and 28 days strength tests it can be concluded that the introduction of bacteria in the concrete mix along with right nutrients can give promising results. Keeping in view the objectives of this studey the conclusions that can be drawn are discussed below.

- **i.** The bacteria has no notable effect on the health of human beings
- **ii.** There was a definite increase in compressive strength , split tensile strength and flexural strength due to the introduction of the bacteria.
- **iii.** Since increase in strength was observed it can be concluded that the bacteria can perform satisfactorily in normal temperature variation without any kind of temperature or climate control.
- **iv.** It can be concluded that the bacteria can perform satisfactorily when used in combination with normal tap water.
- **v.** The bacteria can sustain and contribute to the strength of the concrete without immobilisation.
- **vi.** Calcium acetate, in no way, hampered or interfered with strength development of concrete.
- **vii.** Contrary to the findings of Jonkers, H.M., Thijssen, A., Muyzer, G., Copuroglu, O., and Schlangen, E (2010) in their their research paper titled **"Applicaton of bacteria as self-healing agent for the development of sustainable concrete"** Ecological Engineering 36(2): 230-235, and as used by H. M. Jonkers for his research paper titled **"Bacteria-based self-healing concrete"** HERON 56(2011) no 1/2, Calcium Acetate was found to have no effect (positive or negative) on the strength of concrete.
- **viii.** The bacteria used in this study were not immobilised. So the functionality of the bacteria used may have varied and with it the strength obtained of the concrete mix.
- **ix.** Also without immobilisation the life expectancy of the bacteria will be less than the bacteria which have been immobilised.

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