STUDY ON STRENGTH EVALUATION CALCITE OF PRECIPITATING BACTERIA

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ABSTRACT

Cracks in concrete are a common problem. Cracks are the reason for ingress of water and other deleterious substances. Cracks if not treated, would lead to corrosion of reinforcement due to the entry of water and deleterious substances. This would result in loss of strength and durability of concrete. Hence there is a need to heal the cracksautomatically and increase the strength anddurability of concrete. A self healing mechanism by using calcite precipitating bacteria in concrete has been proposed in this study which will increase the strength of concrete. The aim of this paper is to find bacteria suitable for use in concretewhich will increase its strength. A bacterial strain *Bacillus Megaterium* BSKAU was selected for use in concrete, based on its high urease activity, ability to form endospores and ability to precipitate calciumcarbonate. Bacterial concrete specimens were cast with bacterial cell concentration of 10^5cells/ml of mixing water. Controlconcrete specimens were cast using potable water. Concrete mix was designed to develop strength of 25MPa at 28days.From the results, it was found that bacterial concrete specimens exhibited considerable increase in compressive strength, split tensile strength and flexural strength when compared to control concrete specimens.

Keywords: Bacteria, Compressive strength, Split tensile strength, Flexural strength.

1. INTRODUCTION

Bacteria have wide applications for the betterment in human life. In concrete they can be used for self healing of cracks which results in improvement of strength and durability of concrete. Bacteria are single celled microbes. The cell structure is simpler than that of other organisms as there is no nucleus or membrane bound organelles. Instead their control centre containing the genetic information is contained in a single loop of DNA. Some bacteria have an extra circle of genetic material called a plasmid. Bacterial concrete is the concrete that has been cast with the inclusion of bacterial cells. The bacterial cellswill be converted into bacterial endospores during mixing.Whencracks occur, the water and air would enter through the crack .This revives the dormant endospores and the endospores gets converted to live cells. The bacterial cells will multiply and start producing calcite (Calcium Carbonate). This calcite will seal the cracks before the water can do any harm. Bacteria in concrete offer a double layer of protection in preventing steel corrosion. The use of pure and mixed cultures of ureolytic bacteria will able to improve the durability of concrete. Bacteria are able to influence the precipitation of calcium carbonate by the production of a urease enzyme. This enzyme catalyses the hydrolysis of urea to carbon dioxide and ammonia. The carbon dioxide will combine with calcium ions attracted by bacterial cells and precipitated as calcite.

Mainly micro cracks widths typically in the range of 0.05 to 0.1mm have been observed to become completely sealed particularly under repetitive dry/wet cycles. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophilic spore forming bacteria which may be able to survive in this environment and increase the strength and durability of cement concrete.

Mangulkar (2007) recorded the benefits of microbial concrete which includes the enhancement of compressive strength, reduction in permeability and reinforced corrosion in construction materials. The use of microbial concrete in Civil Engineering has become increasingly popular. Microbial concrete technology has proved to be better than many conventional technologies because of its eco-friendly nature, self-healing abilities and convenience for usage.

Jonkers (2009) found that the crack healing in bacterial concrete is much more efficient than in concrete of the same composition but without added bio –chemical healing agent. On the crack surface of control concrete some calcium carbonate will be formed due to the reaction of carbon dioxide present in the crack ingress water with Portlandite (calcium hydroxide) present in the concrete matrix.

2. MATERIALSUSED

- Cement
- Fine Aggregate
- Coarse aggregate
- Water

2.1 CEMENT

Ordinary Portland cement of 53 grade conforming IS: 12269- 1987 was used. Table 2.1 gives the properties of cement.

Table 2.1 Properties of Cement

Particulars	Values
Grade of cement	OPC 53
Specific gravity of cement	3.15

2.2 FINE AGGREGATE

The fine aggregate was obtained from a nearby river source. The fine aggregate conforming to ZoneII according to IS: 383-1970 was used.Table 2.2 gives the properties of fine aggregate.

Table 2.2 Properties of Fine Aggregate

S. No	Properties	Values
1	Specific Gravity	2.64
2	Zone	II

2.3 COARSE AGGREGATE

Crushed granite was used as coarse aggregate. The coarse aggregate used was conforming to IS: 383-1970. Maximum coarse aggregate size used is 20 mm. Table 2.3 gives the properties of coarse aggregate.

Table 2.3 Properties of Coarse Aggregate

S. No	Properties	Values
1	Specific Gravity	2.60
2	Size of Aggregates(max)	20 mm

2.4 WATER

Locally available potable water was used. The pH value of water was between 6.0 and 8.0 and was conforming to IS456-2000.

3. MIX PROPORTION

The various ingredients in concrete were proportioned to develop the compressive strength of 25 MPa at 28 days. The mix proportion is given in Table 3.

Table 3 Mix Proportion for M25 Grade

Water	Cement	Fine Aggregate	Coarse Aggregate
197kg	492kg	628.884 kg	1134.57kg
0.4	1	1.27	2.3

4. METHODS OF TESTING

All concrete mixes were prepared by mixing the concrete in laboratory mixer along with water. Concrete cube specimens of size 150 mm x 150 mm x 150 mm were cast to compute the compressive strength after 7, 14 and 28 days of curing. Concrete cylinder specimens of 300 mm height and 150 mm diameter and beam specimens of size 500mm x 500mm x 100 mm were cast for determining the split tensile strength and flexural strength respectively.Bacterial concrete specimens were cast with bacterial cell concentration of 10^5cells/ml of mixing water. Control concrete specimens were cast using potable water.

4.1 PREPARATION OF CONCRETE SPECIMENS

- The cube, cylinder and beam moulds were cleaned and oil was applied to them. The concrete was filled in themoulds in layers approximately 5cmthick. Each layer was compacted with not less than 25 strokes per layer using a tamping rod. The top surface was levelled and smoothen it with a trowel.

4.1. COMPRESSIVE STRENGTH

The cube specimens were tested on a compression testing machine of capacity 3000kN as per IS 516-1959. To find the compressive strength the maximum load applied on specimen was recorded. The compressive strength was found by the following relation:

$$fc = P/A,$$

Where P = load at failure,
A = cross-sectional area of specimen

4.2. SPLIT TENSILE STRENGTH

The cylinder specimenswere also tested on compression testing machine of capacity 3000KN to find the split tensile strengthas per IS 5816-1999.

The maximum load applied on specimen was recorded.The split tensile strength was found by the following relation:

$$\text{Split tensile strength} = 2\,P/\pi DL,$$

Where P=load at failure, D=diameter of cylinder, L=length of the cylinder.

4.3 FLEXURAL STRENGTH TEST

Flexural strength is one measure to indirectly measure the tensile strength of concrete. The test was conducted on a Universal Testing Machine as perIS 516-1959.

The maximum load applied on specimen recorded.The flexural strength (f_b) was found by the following relation:

$$f_b = pl/bd^2,$$

Where b = width of specimen, d = depth of specimen, l = supported length, p = load at failure.

5. RESULTS AND DISCUSSIONS

5.1HARDENED CONCRETE PROPERTIES

5.1.1COMPRESSIVE SRENGTH TEST (ON CONCRETECUBES)

The compressive test results are given in table 5.1 .1 and represented graphically in figure 5.1.1

Table 5.1.1 Compressive Strength Test Results

S.no	Description	7^{th} day (N/mm^2)	14^{th} day ((N/mm^2)	28^{th}day (N/mm^2)
1	Control concrete	29.5	33.51	35.53
2	Bacterial concrete	31.67	35.16	36.53

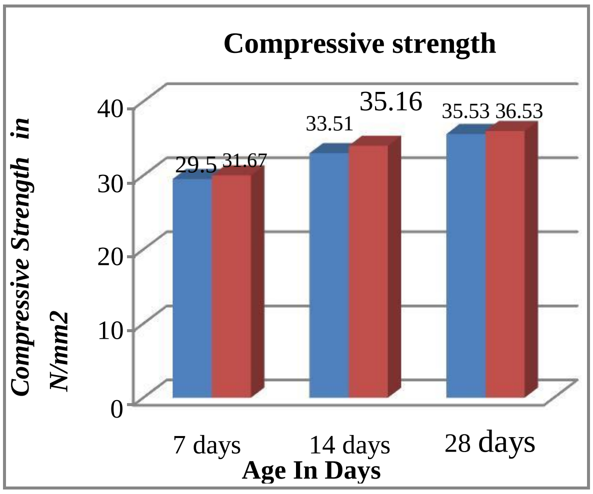

Figure 5.1.1 Compressive Strength Test Results

From the table 5.1.1 and figure 5.1.1, it can see that the compressive strength of bacterial concrete specimens was increased when compared to control concrete specimens. After 7 days of curing the increase in compressive strength was 6% with respect to control concrete specimens. For 14 and 28 days of curing, the increase in compressive strengthsobtained was 3.38% and 2.81% respectively.

5.1.2SPLIT TENSILE STRENGTH (FOR CYLINDER)

The split tensile strength test results are given in table 5.1.2 and represented graphically in figure 5.1.2

Table 5.1.2 Split Tensile Strength Test Results

S.no	Description	7^{th} day (N/mm^2)	14^{th} day (N/mm^2)	28^{th} day (N/mm^2)
1	Control concrete	2.23	2.27	2.5
2	Bacterial concrete	2.6	2.7	2.9

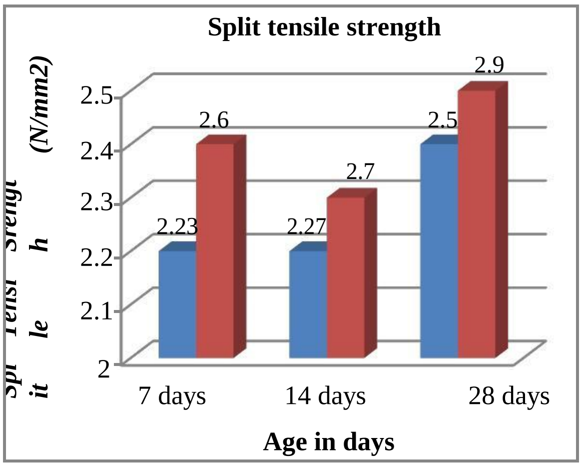

Figure 5.1.2 Split Tensile Strength Test Results

From the table 5.1.2 and figure5.1.2, it can seen that the split tensile strength of bacterial concrete specimens was increased when compared to control concrete specimens. After 7 days of curing the increase in compressive strength was 18.9% with respect to control concrete specimens. For 14 and 28 days of curing the increase in split tensile strengths obtained were18.9 %and 16 % respectively.

5.1.3 FLEXURAL STRENGTH TEST

The flexural strength test results are given in table 5.1.3 and represented graphically in figure 5.1.3

Table 5.1.3 Flexural Strength Test Results

S.no	Description	7^{th} day (N/mm^2)	14^{th} day (N/mm^2)	28^{th} day (N/mm^2)
1	Control concrete	5.3	5.4	5.9
2	Bacterial concrete	5.5	5.3	5.6

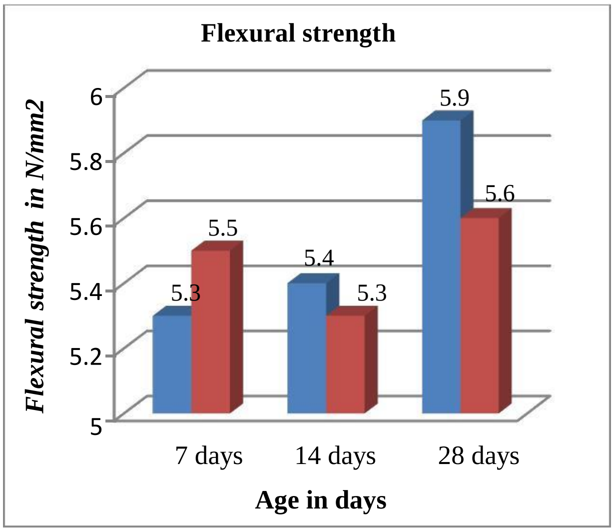

Figure 5.1.3 Flexural Strength Test results

From the table 5.1.3 and figure 5.1.3,it can seen that the flexural strength of bacterial concrete specimens was increased when compared to controlled concrete specimens. After 7 days of curing the increase in flexural strength was 1.88 % with respect to control concrete specimens. For 14 and 28 days of curing the increase in flexural strengths obtained were 1.88 %and 5.35%respectively.

DISCUSSION OF RESULTS

The increase in strength of bacterial concrete specimens was due to the filling of micro cracks and pores in concrete with calcite precipitated by bacteria. Bacterial cells added to concrete during casting will be converted into endospores.When crack occurs; water and air will enter through them. Thus endospores will convert tolive cells and start precipitating calcite. The calcite will plug the microcracks and hence the strength of concrete will be increased.

6. CONCLUSION

- The compressive, split tensile, flexural was increased for bacterial concrete specimens when compared to control concrete specimens.
- The compressive strength of bacterial concrete specimens was increased when compared to controlled concrete specimens. After 7 days of curing the increase in compressive strength was 6% with respect to control concrete specimens. For 14 and 28 days of curing, the increase in compressive strengths obtained were 3.38% and 2.81% respectively

- The Split tensile strength of bacterial concrete specimens was increased when compared to controlled concrete specimens. After 7 days of curing the increase in compressive strength was 18.9% with respect to control concrete specimens. For 14 and 28 days of curing the increase in split tensile strengths obtained were 18.9 % and 16 % respectively.

- The flexural strength of bacterial concrete specimens was increased when compared to controlled concrete specimens. After 7 days of curing the increase in flexural strength was 1.88 % with respect to control concrete specimens. For 14 and 28 days of curing the increase in flexural strengths obtained were 1.88 % and 5.35% respectively.

- Calcite precipitation by bacteria can be used to increase the strength of concrete.

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