Variation of Strength Parameters of Bacterial Concrete with Different Cell Concentration

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Abstract— Generally concrete is a prime material of construction for many of infrastructures like hydraulic structures, highways, and buildings. Cracks I n concrete are inevitable as the phenomenon of formation of micro cracks in concrete is common. This causes degradation of strength properties of concrete and also causes corrosion of reinforced members and subsequently decreases the ability of structure. Self - healing technique should be adopted to overcome such situations. It is simple to seal micro cracks with bio-mineralization technique. Freshly formed micro pores can be sealed up with help of calcium carbonate precipitation of bacteria. In this study, the calcifying bacteria E.coli is induced in concrete as self - repairing agent in different cell concentrations. The bacteria are introduced in concrete along with liquid media of nutrient broth. The strength parameters of bacterial concrete with variation in cell concentration of bacteria along with 40% M-Sand substitution by weight to natural sand are determined and results are compared with strength parameters of normal concrete.

Key words: Self-Healing, Micro-Cracks, Calcite Precipitation, Bacteria, Bio-Mineralization, Escherichia Coli

I. Introduction

Now a day's microorganisms are practiced in concrete to recover the strength and durability characteristic of concrete. The study deals with bio-mineralization field which comes under broader category of MICP (Microbiological Induced Calcite Precipitation) technique. Microbes which precipitate calcite by absorbing oxygen from concrete are emended in concrete to make itself healable. Calcite precipitation from microbial activity is pollution free method of remediation of concrete structures and historical monuments.

Microbes of bacillus species are commonly used for bacterial concrete. In this study, an anaerobic, contamination free and harmless strains of E.coli culture which is collected from K.L.E. Pharmacy College, Belagavi is used. From life cycle study and characteristics study of the species it is proved that E.coli precipitates calcium carbonate and hence can be adoptable for research work. The favorable conditions for bacteria in concrete do not exist directly but have to be accomplished so that the bacteria should produce calcite as much as needed to repair.

The bacteria are introduced in concrete with different cell concentrations along with nutrient broth solution as food in liquid form. While functioning with bacteria, proper care should be taken to avoid flaw. A common bacteria E.coli with concentration 10^5 and 10^7 cells/ml are chosen in this study with 40% replacement of M-Sand with natural sand. Water content in concrete is replaced by nutrient broth up to 25%.

II. Objectives and Methodology

A. General

The main objective of the project is based on upgrading of strength parameters by appliance of calcite precipitating implement from biological origin in concrete as self-repairable and strength recovering agent. Following are the broader objectives of the dissertation work.

1) Application of risk-free and laboratory sample bacteria E.coli as self-healing agent in concrete effectively.
2) Examination on result of variation of bacterial concentration on strength parameters of concrete.
3) Examination on cause of bacterial concrete along with 40% replacement of M-Sand on strength parameters of concrete.
4) Exploration of calcite precipitation in bacterial concrete through SEM (Scanning Electron Microscopy) technology.

III. Methodology

Bacteria have been habitually reported that are able to precipitate calcite in typical and optimum conditions. The experiments are set in accordance with objectives of study. The grade of concrete used in this study is M25 as it is commonly adopted in day today applications. Mix design carried out as per IS 10262-2009. The additional materials used for concrete are procured locally. Natural sand is replaced by M-Sand in trial mix of concrete with 40% by weight. The growth curve of bacteria E.coli is determined using colorimeter to set the bacterial concentration. Bacteria were introduced into reference mix of concrete in different cell concentrations along with and without M-Sand. The material properties are tested below and satisfied for the further study.

W/C Ratio	Water Content (kg/m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
-	180	375	700	1256
0.48	0.48	1	1.86	3.35

Table 1: Mix proportion table

IV. Experimentation and Discussion

The main aim of the study is to improve the strength parameters of concrete after 28 days of curing with the help of MICP technique. The strength tests like Compressive strength of concrete, Split tensile strength of concrete, Flexure strength of concrete and Shear strength of concrete as per Indian standards are performed on specimens casted as per methodology and discussions are made on results. And also the SEM test results are analyzed with the crushed sample.

A. Compression Test

Concrete cubes of size 150 x 150 x 150 mm are casted and are tested in compression testing machine as per IS 516:1959. Compressive strength can be calculated by using relation of stress given below.

F = P/A

Where

F = Compressive strength in N/mm^2.

P = Maximum load applied in N.

A = Area of cube in mm^2.

1) Average Compressive Strength Results

Results of average compressive test conducted on normal concrete and bacterial concrete with different cell concentrations with addition of 40% M-Sand replacement are mentioned in below table.

Cell Concentration (cells/ml)	Compressive Strength of normal Concrete (MPa)	% Increase or decrease in compressive strength	Compressive Strength with M-Sand (40%) (MPa)	% Increase or decrease in compressive strength
0	32.89 (Ref)	-	33.18 (Ref)	-
10^5	37.22	+13.16	37.84	+14.00
10^7	35.51	+7.96	37.15	+11.90

Table 2: Overall compressive strength results

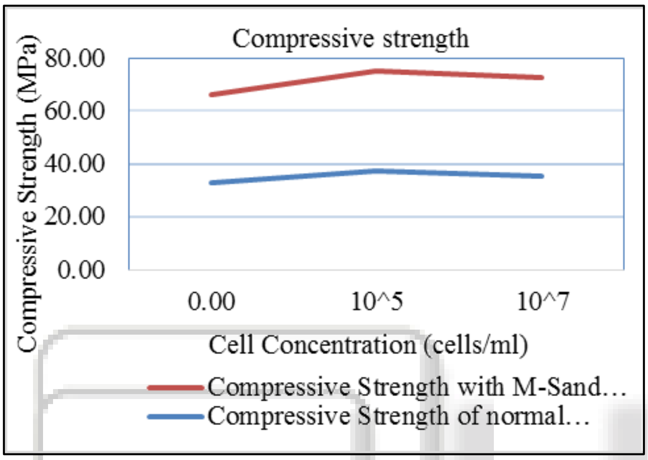

Fig. 1: Shows the variations of average compressive strength with different cell concentrations along with 40% M-Sand substitution.

B. Split Tensile Test

Cylindrical specimens of diameter 150mm and 300mm height was casted and tested in compression testing machine according to IS 5816:1999.Tensile strength of concrete is obtained from relation given below.

$$F = 2.P/\pi DL$$

Where,

F = Split tensile strength of concrete in N/mm^2.

P = Load at failure of specimen in N.

L = Length of specimen in mm.

D = Diameter of specimen in mm.

C. Average Split Tensile Strength Results

Results of tensile strength test conducted on normal concrete and bacterial concrete with different cell concentrations with addition of M-Sand replacement are mentioned in below tables.

Cell Concentration (cells/ml)	Split Tensile Strength (MPa)	% increase or decrease in Split tensile Strength	Split tensile Strength with M-Sand (40%) (MPa)	% increase or decrease in Split tensile Strength
0	3.46 (Ref)	-	3.55 (Ref)	-
10^5	3.96	+14.45	4.10	+15.49
10^7	3.61	+4.33	4.03	+13.52

Table 3: Overall split tensile strength results.

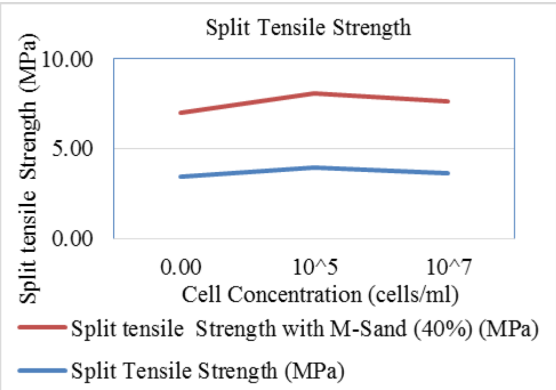

Fig. 2: Shows the variations of average split tensile strength with different cell concentrations along with 40% M-Sand substitution

D. Flexural Strength Test

A rectangular specimen of 100 X 100 X 500 mm were casted likewise a beam. Two point loadings were placed at a distance of 133mm and bottom was placed at an effective span of 400mm as per IS 516:1959. The load should be functional with increasing continuously at rate of 1800 N/min. The load at which specimen fails should be noted as failure load. The flexure strength of concrete is intended by relation given below.

$$F = PL/BD^2$$

Where,

F= Flexure strength of specimen in N/mm^2.

P = Failure load in N.

L = Length of sample in mm.

B = Width of sample in mm.

D = Depth of sample in mm.

1) Average Flexural Strength Results

Results of flexure strength test conducted on normal concrete and bacterial concrete with different cell concentrations with addition of 40% M-Sand replacement are mentioned below.

Graph no.3 shows the variations of average flexural strength with different cell concentrations along with 40% M-Sand substitution

E. Shear Strength Test

L shaped specimens are casted to find shear strength of concrete. The specimen is tested in compression testing machine of capacity 2000 kN. A loading arrangement should be done in such a way that direct shearing force should be applied on the shorter arm of specimen of area 150 x 60 mm. The maximum load before the specimen fails is noted. The failure load due to shear force is calculated by equation given below.

$$F = P\ L_{1} / L_{1} + L_{2}$$

Where,
P = Highest applied load to the specimen in kN
l1 = 25mm
l2 = 25mm
The shear strength is given by the relative
Shear strength = F/A
Where,
F= Failure load
A = Shear force applied area = 150mm x 60mm.

1) Average Flexural Strength Results

Results of flexure strength test conducted on normal concrete and bacterial concrete with different cell concentrations with addition of 40% M-Sand replacement are mentioned below.

Graph no.4 shows the variations of average shear strength with different cell concentrations along with 40% M-Sand substitution

F. Scanning Electron Microscopy

Calcite precipitation in concrete was inspected by SEM analysis. The specimens casted with bacteria did not develop any pores in concrete when compared to normal concrete. Precipitated calcite deposit are in contact with spherical immersion of bacteria E.coli. These microscopic observations made from SEM results confirm the mechanism of microbial calcite deposition.

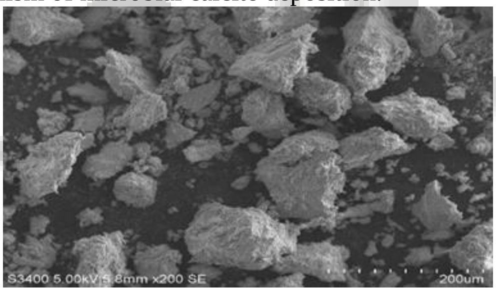

Fig. 3: SEM picture of normal concrete.

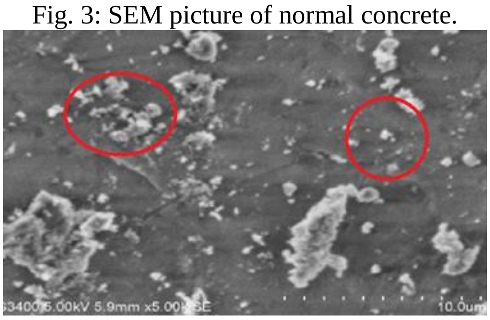

Fig. 4: SEM picture of bacterial concrete with deposited calcite crystals in contact with bacteria.

V. DISCUSSION

The strength tests like Compressive strength of concrete, Split tensile strength of concrete, Flexure strength of concrete and Shear strength of concrete as per Indian standards are performed on specimens casted as per methodology and discussions are made.

1) The compressive strength of bacterial concrete of cell concentration 105 cell/ml with 40% M-Sand contributes more to the strength due to sufficient precipitation of calcium carbonate and better meshing of M-Sand with aggregates when compared to normal concrete or bacterial concrete of cell concentration 107 cell/ml with 40% M-Sand.
2) the tensile strength of bacterial concrete of cell concentration 105 cell/ml with 40% M-Sand also contributes to tensile strength by chemical activity and calcification of bacteria in concrete when compared to normal concrete and bacterial concrete of cell concentration 107cell/ml with 40% M-Sand.
3) the flexural strength results of bacterial concrete are not so altered when compared with conventional concrete. It is noted that flexural strength of bacterial concrete can be improved with bacterial concentration of 105cells/ml along with 40% substitution of M-Sand as the bacteria are more active with concentration 105cells/ml when compared to 107cells/ml.
4) slight variations are seen in bacterial concrete at 105cells/ml with 40% M-Sand alternative when compared to 107cells/ml and normal concrete with 40% M-Sand replacement which indicates that the calcite precipitation of bacteria of cell concentration 105 cells/ml is worthy when compared to the bacteria of cell concentration 107 cells/ml.

SEM picture of normal concrete is shown in figure no. 1 where the pores in concrete are seen inside. Figure no. 2 shows the presence of precipitated calcium carbonate in contact with bacteria. The deposition of calcite acts as pores filling agent in concrete and thus contributes to strength properties.

VI. CONCLUSIONS

After carrying out the investigation over the specimens casted as per methodology of E.coli emended bacterial concrete of cell concentrations of 105 and 107 cells/ml with substitution of M-Sand 40%, the following conclusions are prepared.

1) The compressive strength of bacterial concrete of cell concentration 105 cells/ml with 40% M-Sand replacement contributes significantly to the concrete when compared to bacterial concrete of cell concentration 107 cells/ml and normal concrete with 40% M-Sand substitution.
2) The split tensile strength of bacterial concrete of cell concentration 105cells/ml with 40% M-Sand substitution offers more tensile strength when related with bacterial concrete of107cells/ml and normal concrete with 40% M-Sand substitution.
3) There bacterial concrete of 105cells/ml with 40% M-Sand replacement offers substantial flexural strength when correlated with bacterial concrete of 107cells/ml and normal concrete with 40% M-Sand substitution.
4) There is not much improvement in shear strength of normal and bacterial concrete. The bacterial concrete of cell concentration 105cells/ml with 40% M-Sand substitution shows slight increase in shear strength when compared to bacterial concrete of cell concentration 107cells/ml and normal concrete with 40% M-Sand substitution.
5) Small variations can be realized when E.coli induced bacterial concrete with cell concentration of 105

cells/ml with 40% M-Sand compared with bacterial concrete of concentration 107 cells/ml and normal concrete along with 40% M-Sand.

6) E.coli bacteria and their culturing is cost effective and easily available in biotechnological laboratories.
7) The harmless strain of E.coli bacteria is another way out as pollution free and self-healing agent in concrete and the method provides trouble-free way for cementation.

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