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An experimental study on compressive strength of bacteria induced concrete

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Abstract —
Micro cracks in concrete are frequent and leads to the degradation of concrete. Calcium carbonate precipitation caused by bacteria is a sustainable solution for crack refill technique. This paper elaborates the compressive strength of concrete with fly ash having varying dosage of addition of bacteria. Furthermore, the addition of Bacillus Subtilis to the fly ash concrete leads to higher compressive strength.

Keywords — ***Self healing concrete, Compressive strength, Bacillus Subtilis, X-ray diffraction, Bacterial concrete.***

1. INTRODUCTION

Cement is most commonly used binding material. Concrete exhibits strong compressive resistance but weak in tensile resistance. Also the formation of cracks in concrete is a common problem leading to degradation of structures, causing reduced lifespan of structures.

Cracks enhances the degradation of reinforcement due to increase contact with water, chlorine attack etc.[1] Recently bio mineralisation helps to heal cracks and stabilize the structures . When concrete is being mixed, specific strains of the bacterium genus Bacillus, nutrients like calcium lactate, nitrogen are induced in fresh state of concrete. The filling of cracks is by the precipitation of calcium carbonate by-product of bacteria and water reaction inside the cracks called as bacterial concrete.[2] Some species of bacteria are used in preparation of bacterial concrete. Bacillus Subtilis is used in the present study.

Utilization of flyash in concrete leads to a sustainable growth reducing the amount of ash waste of different industries. Numerous studies are actively investigating the characteristics of these concrete that contains bacteria.

Self-healing concrete would be alternative of conventional concrete. Application of bacteria in the concrete directly is now modified by adding nutrients to the concrete mixes. Results of tests conducted on concrete with calcium nitrate, calcium lactate, and urea helps to gain initial strength of concrete at early age.[3] K. Vijay et. al. [4] worked on different types of bacteria for healing of cracks in concrete. Sandip Mondal et al. [5] found that Bacillus Subtilis is more effective for increasing compressive strength of Ordinary Portland cement that Bacillus Cereus. A. A. Akindahunsi et al. [6] found out the optimum dosage of bacteria concentration (10^5 cells/ml) which increased the average compressive strength by 19% and 14% at 7 and 28 days testing.[6] B. Naveen and S. Sivakamasundari [7] used silica gel to shield the bacteria from pH value of concrete and it proved to be successful because. Water became

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impermeable as a result of crack sealing. As $CaCO_3$ crystals formed inside the matrix, the durability of materials is increased. Ultrasonic pulse velocity test and visual measurements were used to assess the effectiveness of the biological treatment C.i Karthik and R. M. Rao. [8] studied the characteristics of Bacillus subtilis which precipitates $CaCO_3$ in a highly alkaline environment by converting ammonium and carbonate. Using a scanning electronic microscope, calcium carbonate precipitation was observed. The benefits of adopting bio-based cement composites initially decrease maintenance and repair expenses. C. C. Gavimath et al. [9] have used bacteria S. pasteurii for examination and observed that up to 30% fly ash replacement revealed better strength and durability properties than normal concrete. All materials, data, computation details, protocols associated with the study/design etc should be made available for readers. Please disclose restrictions (if any) to the availability of information.

2.EXPERIMENTAL STUDY

A. Martials used

PPC having 2.9 gravity (SG), fly ash having 3 gravity (SG), collected from Durgapur Projects Limited (DPL), river sand used as fine aggregate having 2.57 gravity (SG) tallying with IS383. Crushed stones of 20mm used as coarse aggregate having 2.8 gravity (SG). B. subtilis (bacteria induced in fresh concrete). Bacteria cell concentration in this case is 10^5 cells/ml. Table.1 and 2 shoes the properties of ingredients used.

Table 1- Property of Cement

Property	**value**
Consistency	30%
Setting time(Initial)	140 m
Setting time(Final)	427 m
Fineness	2.7 %
Specific gravity	2.9
Compressive strength (28days)	34 MPa

Table 2 - Physical property of Filler Materials

Property	**value**	
	Finer Filler	**Coarser Filler**
S.G.	2.56	2.8
F.M.	2.71	
Water absorption		

B. Method and Preparation of specimens

An attempt has been made to carry our experimental investigation for determination of strength parameter of concrete with fly ash and bacteria. Control concrete mix was prepared following IS 10262-2009 for M25 Grade. Flyash subsituated cement by 0 and 10% in this study. Bacterial culture B. Subtilis 0 and 10% is added to the concrete at fresh state. Fig. 1 shows the testing of casted specimens.

The steps involved in this method are

- IS code reference and Mix design
- Testing of materials
- workability test
- Mix proportion
- Preparation of bacteria
- Mixing and compaction
- Curing

- Testing Results.

The cubes used in this study are made of conventional concrete both with and without bacteria. For each batch, a total of 12 cubes were tested after 7 and 28 days. The size of cube is 150mm×150mm×150mm.

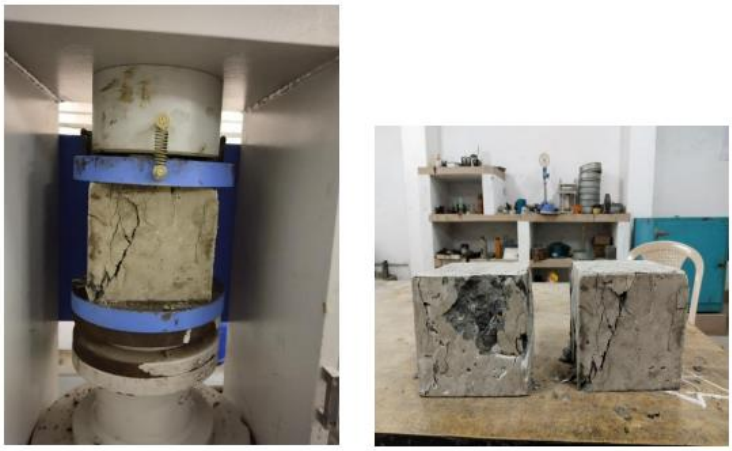

Fig. 1 – Testing of Specimens.

Table 3- Concrete mix potions with and without fly ash (FA).

Concrete Cube name	**Number of cube specimens (150×150×150 mm) for compressive strength**		**Mix proportion**					**Bacteria (%)**	**Fly ash replacement (%)**
	7days	**28days**	**Cement (kg/c-m)**	**FA (kg/c-m)**	**CA (kg/c-m)**	**Fly ash (kg/c-m)**	**Water**		
M0	6	6	394	615.25	1191.68	-	197	0	0
M1	6	6	354.6	614.33	1189.88	39.4	197	0	10
M2	6	6	394	615.25	1191.68	-	197	10%	0
M3	6	6	354.6	614.33	1189.88	39.4	197	10%	10
M4	6	6	394	615.25	1191.68	-	197	20%	0
M5	6	6	354.6	614.33	1189.88	39.4	197	20%	10

C. Results with Discussion

Influence of bacteria on the compressive behaviour of specimens for 7 and 28-day is illustrated in Table 4 and exhibited in Fig.2. The findings are obtained for Bacteria solution to water ratio 0.1 & 0.2 for both plain and fly ash induced concrete. From test results it is evident that at 7 days as well as at 28 days age strength with increase in bacteria solution with plain cement & fly ash-based concrete has been slightly increasing. From Fig 3. It is observed that increase in compressive resistance for plain mix are 5.78% and 6.22 % at 7 days for bacteria solution mixing 10% and 20% respectively and for fly ash concrete are 9.23 & 11.23% for the same. In case of 28 days strength percentage increase in compressive resistance is increased for both type of concrete i.e. 6.92 %, 7.62 % for plain concrete and 10.02%, 12.74% for fly ash concrete.

Hence the positive effect of bacteria on compressive resistance is evident from the results.

Table 4 – Bacterial effect on compressive resistance to normal and fly-ash based concrete.

Identification	Average compressive strength (N/mm^2)		Slump (mm)
	7days	28days	
M0	20	29.06	90
M1	17.26	26.55	80
M2	21.21	31.07	80
M3	18.9	29.21	80
M4	2130	31.27	75
M5	19.30	29.93	75

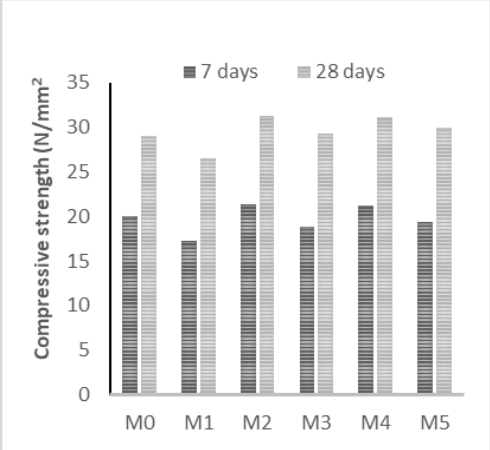

Fig. 2 - Compressive strength test results

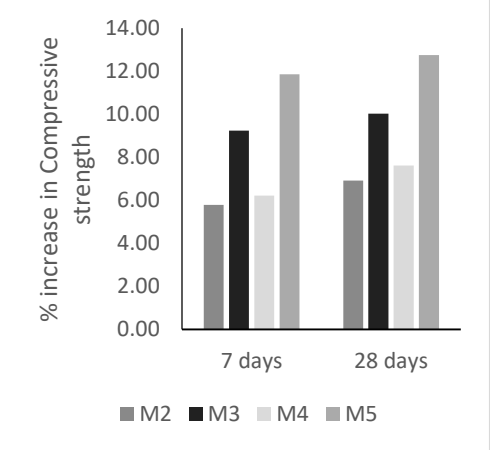

Fig. 3 - Percentage increase in compressive strength

4. CONCLUSION

The outcome of this study emphasises the following points:

- Bacteria induced concrete specimens show better compressive resistance than control concrete at 7 and 28 day of testing for normal as well as fly-ash based concrete
- Early age compressive resistance is less as compared to 28 days for bacteria induced concrete.
- Bacteria incorporation is more effective for fly ash concrete as it improves 3-7% more strength than plain cement concrete.

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