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Influence of Bacteria on The Strength and Durability Properties of Concrete Incorporating GGBS

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Abstract

The main aim of this experiment is to study the effect of bacteria on the strength and durability properties of normal and GGBS concrete. Cement was replaced with 40% of GGBS by weight. Tests were performed for flexural, shear strength, water absorption, and water sorptivity. Flexural strength and Shear strength of GGBS bacterial concrete was found to be higher when compared to normal concrete and reduction in water absorption and water sorptivity was observed with concentration 105cells/ml of bacteria. The bacteria used in concrete is Pseudomonas Putida which improves the strength and durability of concrete through self-healing effect.

Keywords: *- Pseudomonas Putida, Calcium carbonate formation, Durability, GGBS, Self-Healing*

INTRODUCTION

Concrete is the most important material used widely in construction all around the world. Concrete is very weak in tension and very strong in compression. Since, concrete is weak in tension, steel bars are embedded into the concrete to contour the tensile forces. The steel reinforcement bars are provided with suitable cover to avoid corrosion of the bars. There may be some cracks due to the steel reinforcement which will affect the durability of concrete structures.

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Self-healing concrete acts as watertight due to the filling of cracks. In self-healing concrete the cracks are automatically sealed and there will be no chance for the water to pass through the concrete. This self-healing technique is mostly used in abroad countries for important structures like bridges, retaining walls and aqueducts. Because the life span of the structures is more so they should survive for a long period with low maintenance cost.

Durability of the structure is also very important factor. The durability of structure is related to the pores present in the concrete. The structure cracks under heavy load if the pores are more in concrete. So, the basic idea is to minimize the pores in concrete. Repairing the cracks in the later part is done by resin, injecting epoxy or any other methods, these methods are uneconomical and time consuming for all the structures. So, nowadays many researchers have found a convenient method for filling these pores known as self-healing concrete.

MATERIALS

Cement (43 Grade OPC)

Fine aggregate

Coarse aggregate

Water

GGBS (JSW)

Bacteria (Pseudomonas Putida)

METHODOLOGY

Reference Concrete Mix

Mix design was done as per IS10262-2007(Reference). M25 grade of concrete was designed by this method.

Table 1: Mix proportion

W/C Ratio	Cement	Fine Aggregate	Coarse Aggregate
0.45	1	1.7	2.66

Casting of specimens

Cement, Fine aggregate and Coarse aggregate were weighed and mixed according to mix proportion for M 25 grade of concrete i.e. 1: 1.7: 2.66. Cement was partially replaced by GGBS for 40%. For this dry mix required number of microorganisms with media (w/c=0.45) are added and thoroughly mixed in a machine mixture. This concrete was poured into moulds required for strength and durability assessment. Then the mould was placed on vibrator and enough vibrations were given so that the entrapped air was expelled out. After 24 hours the specimens were demoulded and transferred to curing tank wherein they were allowed to cure for 28 days.

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GROWTH CURVE

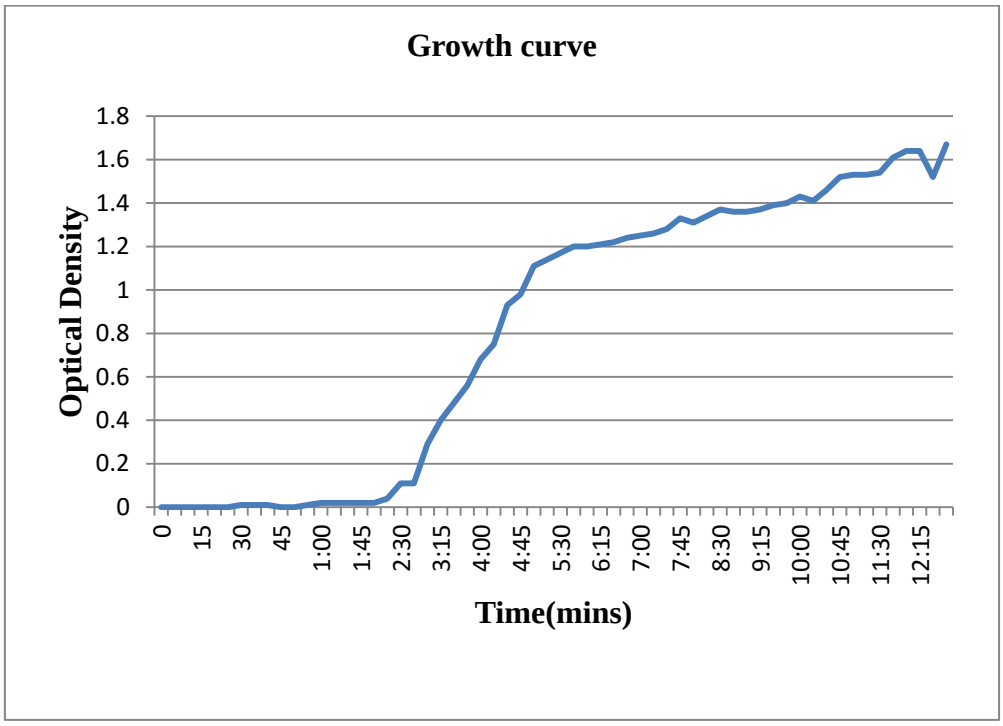


Figure 1 Growth curve graph

Inference made by observing the growth phase:

Bacterial growth follows three phases.

1. The first phase of increase is the lag segment, slow growth of cells is observed in this segment because they need to adapt to the high-nutrient surroundings and prepare for immediate growth. The lag section has excessive rate of biosynthesis, as proteins critical for rapid growth are produced.

2. The second phase of growth is the logarithmic section (log phase), additionally known as the exponential phase. The rate at which cells expand sooner or later of this phase is referred to as the increase rate, and the time taken for the cells to double is known as the technology time. During log section, proteins are metabolized at maximum speed until one of the nutrients is depleted and starts off evolved boom.

3. The final phase of growth is the stationary section and is due to depleted proteins. The cells lessen their metabolic activity and consume non-essential cellular proteins.

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STRENGTH TESTS ON BACTERIAL CONCRETE

Flexural strength test results

Table2. Test results of Flexural Strength

Description of concrete	Bacteria concentration (cell/ml)	Average flexural strength (MPa)	% increase in flexural strength w.r.t conventional concrete
Concrete with 40% GGBS as replacement of cement	10^0	3.13	-
	10^3	3.32	6.07%
	10^5	3.56	13.73%
	10^7	3.28	4.79%

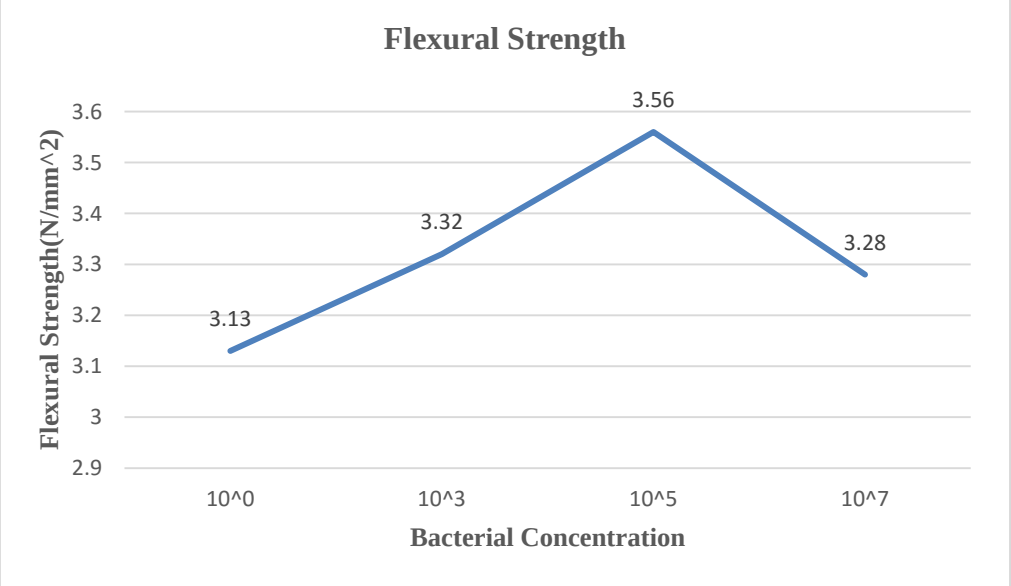


Figure 2 Variation of Flexural strength

It was observed from the Table no:2 and Fig no:2 that the flexural strength of conventional concrete and GGBS bacterial concrete increased with increasing bacterial cell concentration up to 105 cells / ml. There was a 13.73% improvement in the flexural strength of concrete with the inclusion of 105 cells / ml of bacterial cells. The improvement in the flexural strength is probably due to the deposition of CaCO3 on the cell surfaces of the microorganisms and in the pores of, which clog the pores in the binder matrix. The results of the study showed that because of the inclusion of Pseudomonas putida bacteria in GGBS bacterial concrete, flexural strength was improved, which in turn increased the overall durability performance of the concrete.

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SHEAR STRENGTH TEST

Table3. Test results of Shear Strength

Description of concrete	Bacteria concentration (cell/ml)	Average shear strength (MPa)	% increase in shear strength w.r.t conventional concrete
Concrete with 40% GGBS as replacement Of cement	10^0	3.44	-
	10^3	3.70	7.55%
	10^5	4.05	17.73%
	10^7	3.53	2.61%

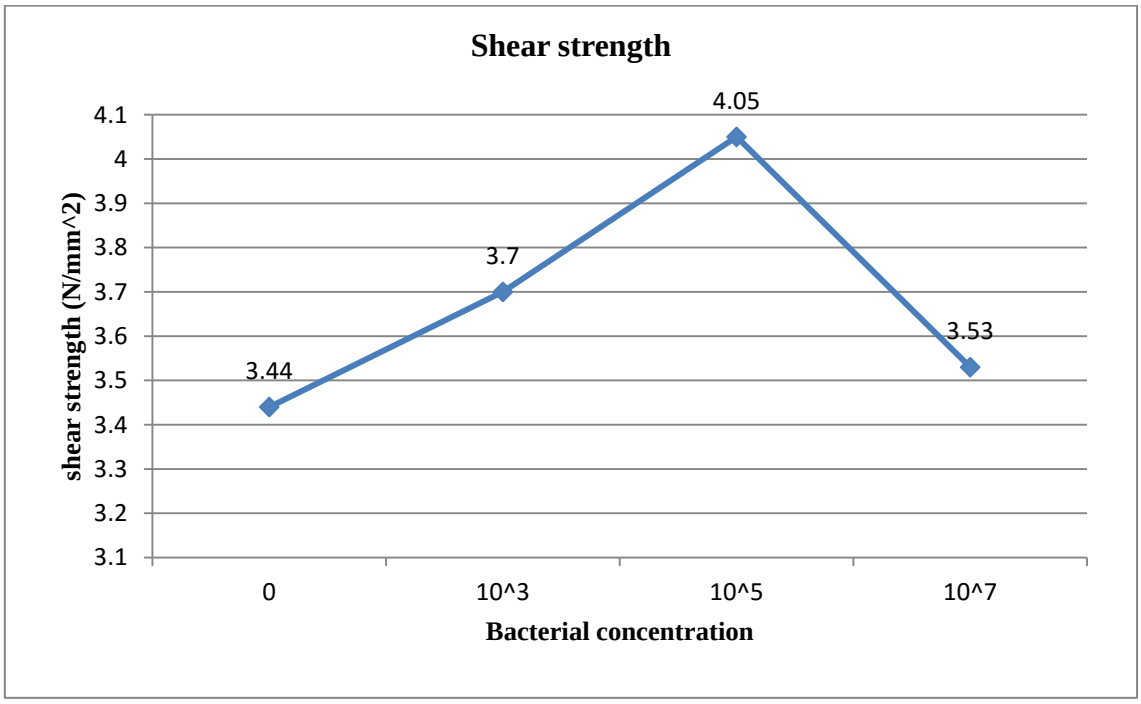


Figure 3 Variation of shear strength

It is observed that shear strength of conventional and GGBS bacterial concrete increased with increase in bacteria cell concentration up to 105cells/ml. In GGBS bacterial concretes, there was 17.73% .The improvement in shear strength of bacterial concrete is probably due to deposition of CaCO3 on the microorganism cell surfaces and within the pores of, which plug the pores within the binder matrix. The results from the study showed that due to inclusion of bacteria in conventional and GGBS bacterial concrete, shear strength was improved which would in-turn increase the overall durability performance of the concrete.

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DURABILITY TESTS ON BACTERIAL CONCRETE

Water absorption

Table 4: Test results of Water Absorption

Bacterial concentration (cells/ml)	Average Water Absorption (%)	% decrease of water absorption w.r.t normal concrete(%)
10^0	4.09	-
10^3	3.88	5.13
10^5	3.45	18.55
10^7	3.60	11.98

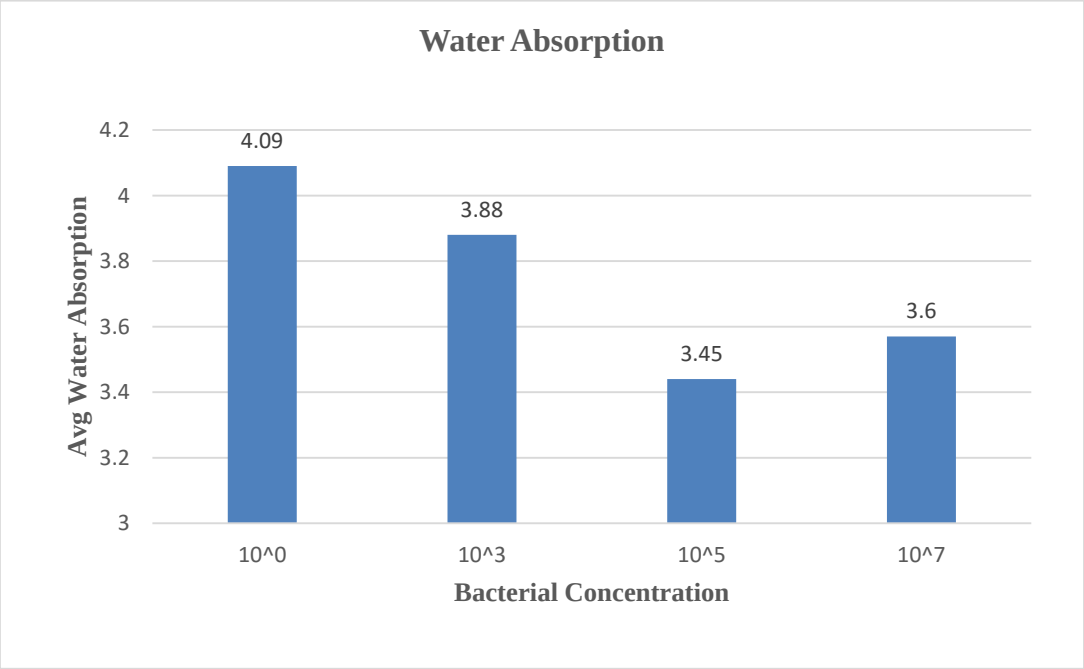


Figure 4 Variation of water absorption

It can be seen from the Table no: 4 and Fig no: 4 that with the inclusion of bacteria, water absorption capacity of normal and GGBS concretes decreased with the increase in bacteria concentration. Maximum reduction in water absorption was observed with 105cells/ml for all normal and GGBS concretes. The presence of bacteria resulted in a significant decrease in the water uptake compared to normal concrete. The deposition of a layer of calcium carbonate on the surface and inside pores of the concrete specimens resulted in a decrease of water absorption and permeability.

Water sorptivity

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Table 5: Test results of water sorptivity

Cell concentration (Cells/ml)	Water sorptivity	% decrease of water sorptivity w.r.t normal concrete(%)
10^0	4.36	-
10^3	3.86	12.95
10^5	3.54	18.80
10^7	3.70	15.13

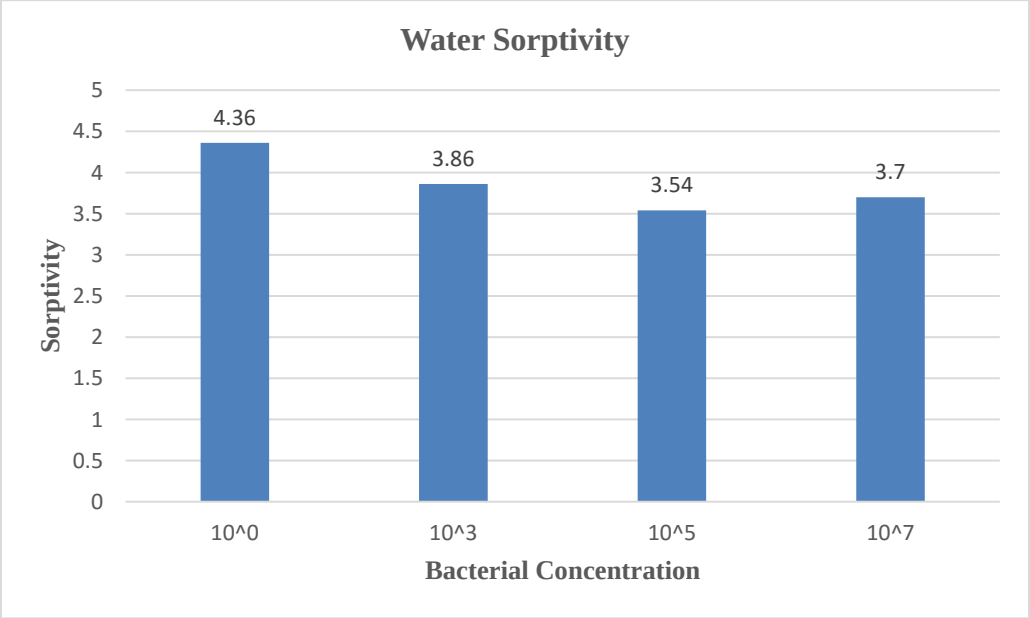


Figure 5 Variation of water Sorptivity

It can be seen from the Table no: 5 and Fig no: 5 that with the inclusion of bacteria, sorptivity capacity of GGBS concretes decreased with the increase in bacteria concentration. Maximum reduction in sorptivity was observed with 105cells/ml for GGBS bacterial concretes. The presence of bacteria resulted in a significant decrease in the water uptake compared to normal specimens.

CONCLUSION

Introducing the bacteria into the concrete makes it very beneficial. It improves the property of the concrete which is more than the conventional concrete. Bacteria repair the cracks in concrete by producing the calcium carbonate crystal which block the cracks and repair it. Flexural strength was increased by 13.73% in 28 days w.r.t conventional concrete at 105 (cells/ml) cell concentrations with 40% replacement of GGBS. Shear strength was increased by 17.73% in 28 days w.r.t conventional

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concrete at 105 (cells/ml) cell concentrations with 40% replacement of GGBS. Bacterial concrete exhibited lower rate of water absorption than conventional concrete. This is due to the bacteria induced formation of Calcium Carbonate in the pores present in concrete, leading to a lesser void and hence a lesser permeability. Maximum reduction in sorptivity was observed with 105cells/ml for all normal and GGBS bacterial concrete. Hence, from this experiment, the presence of a layer of carbonate crystals on the surface by bacterial cells has the ability to improve the resistance of cementitious materials towards degradation.

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