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Experimental Investigation on M20 Bacterial Concrete

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ABSTRACT-

Conventional Cement Concrete (CCC) is the most commonly used construction material in the world, under moderate and aggressive environments. This is due to the fact that it can occupy any size and shape when mixed with water. It is cheaper and more easily available in the field. Hence, there is an urgent need to pay more attention for improving the properties of concrete with respect to strength and durability, especially in aggressive environments. In this dissertation, investigations are carried out on strength-related properties such as compressive strength, splitting tensile strength, flexural strength, is carried out to assess the quality of concrete. The use of bacteria is to precipitate CaCO3 micro environment. It is concluded that BM, BS and PA bacteria can safely be used for improving the performance of strength and durability characteristics of concrete. However, all the three bacteria increase the strength of concrete to a certain level only. BM bacteria is found to be more effective than BS and PA in strength and durability properties. The details of the investigations along with the results are presented in this thesis.

Keyword: Bacteria, Durability Test, Bacterial Concrete, BM, PA, BS.

I. Introduction

Concrete, is very vital and essential element which is invariably used for construction of infrastructural facilities. In recent times, efforts are being taken for enhancing the properties of concrete such as strength and durability under various environments. In future, it appears that there is no substitute to concrete as a construction material. Remarkable developments are taking place during the last century in the field of concrete technology. During the last two decades, it has been observed that durability and corrosion are considered as vital criteria for analyzing the behaviour of concrete in addition to strength. Therefore, for improving the service life of customary 40 - 50 years to 150 years of concrete, research activities are undertaken to find suitable potential material to provide reliable performance under different environments. The major shortcoming of Conventional Cement Concrete (CCC) is that it develops cracks under tension. Small cracks formed on the surface of the concrete make the entire structure to lose strength due to permeation of water in the concrete. Therefore, it leads to corrosion of steel and reduction of life span of the structure. It may not be possible to visualize the cracks but they may tend to propagate into fissures in due course and affect the reinforcement of the structure. The deterioration of reinforced concrete results in high maintenance costs. Micro-cracks are therefore precursors to structural failure.

II. Objective

The objectives of the present work are summarized as follows:

• To produce bacterial concrete by adding bacteria into M20 grade conventional concrete.

• To obtain the optimum dosage of cell concentration of various types of bacteria like Bacillus Megaterium (BM), Bacillus Subtilis (BS) and Pseudomonas Aeruginosa (PA) to be added into concrete for better strength and durability characteristics of bacterial concrete.

• To increase the mechanical properties of concrete using bacteria.

III. Experimental work

Materials:

Cement: In this experimental study, ordinary Portland cement (OPC) 53 grade, used which satisfies the requirements of IS: 12269-2013.The specific gravity of cement was found to 3.15.

Bacteria: Bacillus Megaterium (BM), Bacillus Subtilis (BS) and Pseudomonas Aeruginosa (PA) were found to thrive in this high-alkaline environment under conditions of high pH value up to 13 of the cement-water mixer.

Fine aggregates: Locally available river sand was used as fine aggregates. Sand used confirmed to grading zone – II as per IS: 383-1970 specification. Standard tests have been performed on fine aggregate to characterized physical properties.

Natural coarse aggregates: Aggregate are the essential constituents in concrete. They give bulk to the concrete, decrease shrinkage and affect economy.

Water: The standard drinking water was used for concrete mixes.

Mix Designation: The mix proportion was arrived for M20 grade concrete as per IS: 10262 – 2009 and is 1: 1.59 : 2.96 with water cement ration of 0.45. In that proportion, three types of bacteria namely BM, BS and PA were added in three concentrations of 10^4, 10^5 and 10^6 cells/ml each and the specimens were designated as BM1, BM2, BM3, BS1, BS2, BS3, PA1, PA2 and PA3 respectively. The water-cement ratio was similar for all the proposed mix proportions. Totally, ten different mixes (one control mix and nine bacterial concrete mixes) were prepared.

Sl. No	Type of test	Properties studied	Specimen size	No. of Specimens tested
1	Cube compressive strength	Cube compressive strength at 7, 14, 28 days	150 x 150 x 150 mm cube	150
2	Splitting tensile strength	Splitting tensile strength at 7 days and 28 days	150 mm x 300 mm cylinder	60
3	Flexural strength	Flexural tensile strength (Modulus of rupture) at 28 days	150 x150 x 750 mm Prism	30

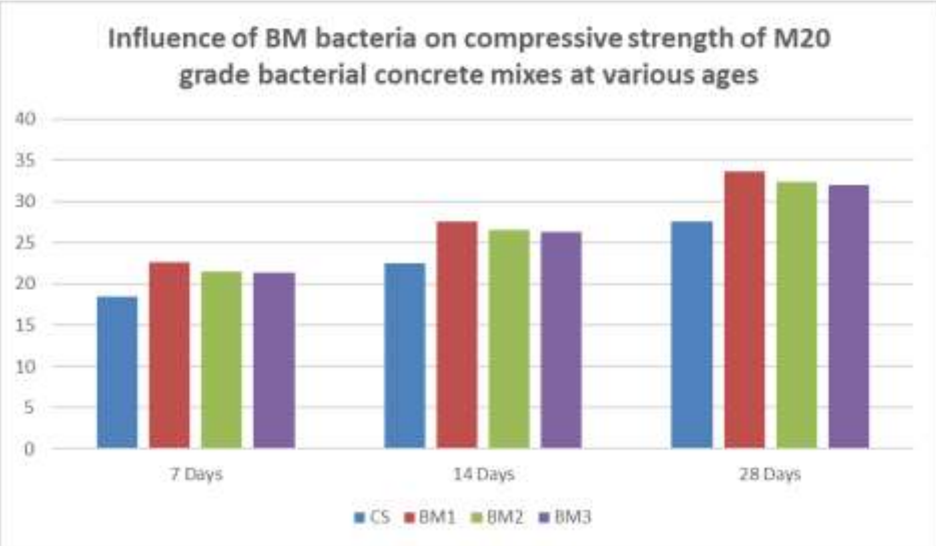
IV. Results & Discussion

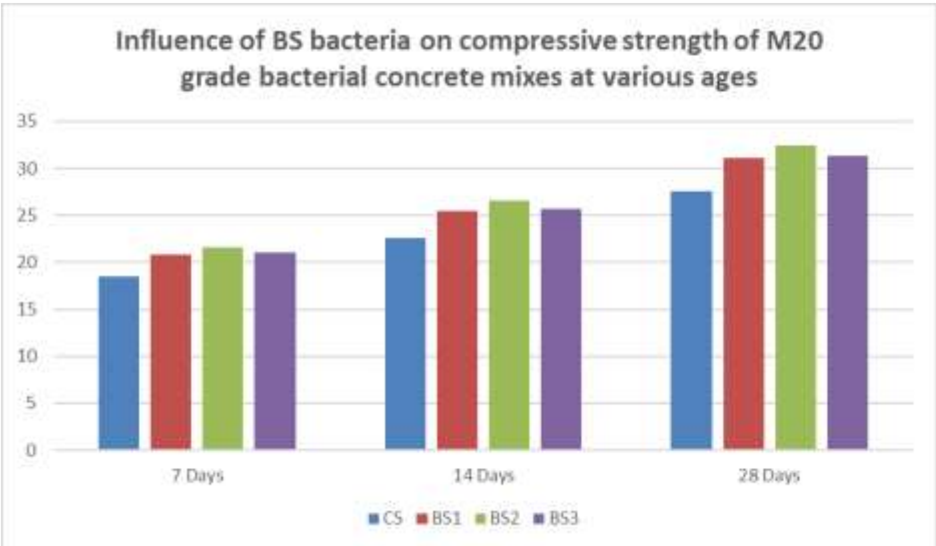
Workability:

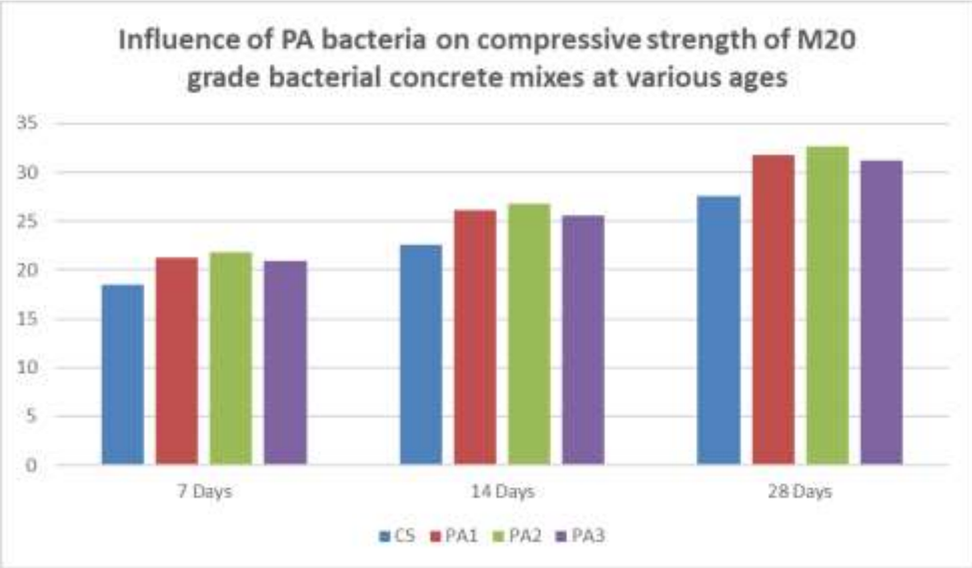
Mix designation	Type of bacteria	Cell concentration (cells / ml)	Slump in 'mm'
CS	Control Specimen	-	95
BM1	Bacillus Megaterium	10^4	98
BM2		10^5	102
BM3		10^6	105
BS1	Bacillus Subtilis	10^4	95
BS2		10^5	102
BS3		10^6	106
PA1	Pseudomonas Aeruginosa	10^4	97
PA2		10^5	104
PA3		10^6	108

Compressive Strength:

Mix designation	Type of bacteria	Cell concentration(cells / ml)	Average cube compressive strength in MPa		
			7 days	14 days	28 days
CS	Control Specimen	-	18.48	22.56	27.54
BM1	Bacillus Megaterium	10^4	22.63	27.56	33.62
BM2		10^5	21.47	26.58	32.45
BM3		10^6	21.42	26.33	31.98
BS1	Bacillus Subtilis	10^4	20.87	25.52	31.12
BS2		10^5	21.63	26.56	32.48
BS3		10^6	21.02	25.65	31.28
PA1	Pseudomonas Aeruginosa	10^4	21.28	26.10	31.80
PA2		10^5	21.77	26.78	32.64
PA3		10^6	20.96	25.60	31.20

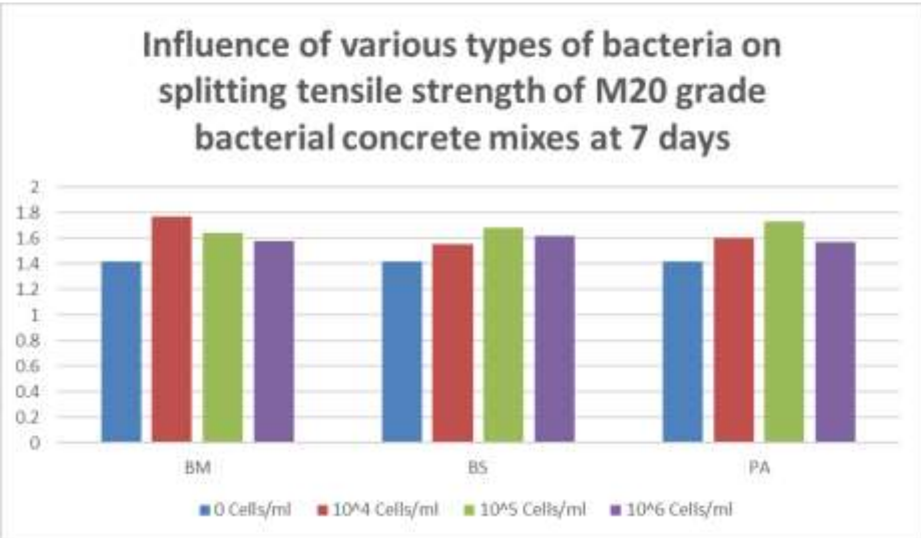


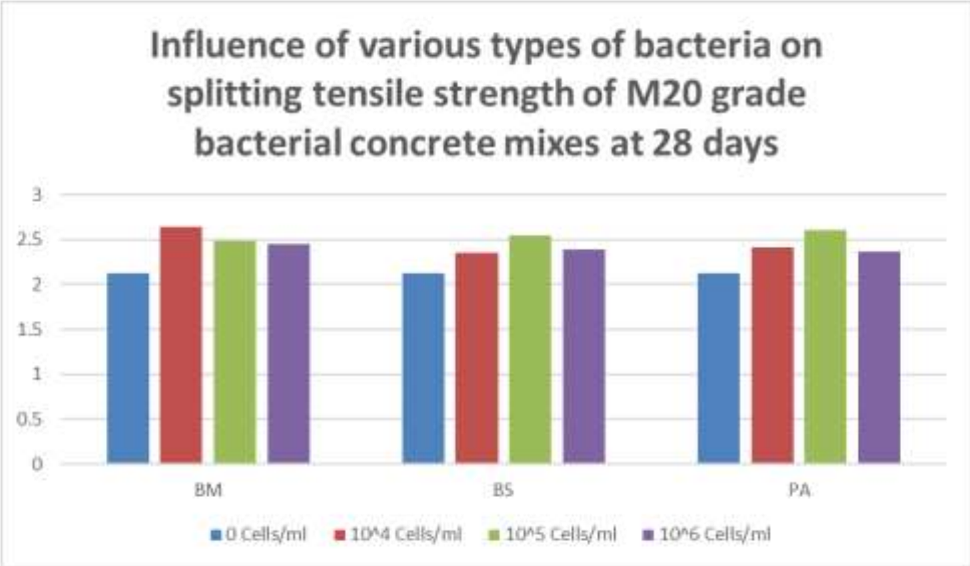




Split Tensile Strength:

Mix designation	Type of bacteria	Cell concentration (cells / ml)	Average splitting tensile strength at 7 days (MPa)	Average splitting tensile strength at 28 days (MPa)
CS	Control Specimen	-	1.42	2.12
BM1	Bacillus Megaterium	10^4	1.77	2.64
BM2		10^5	1.64	2.49
BM3		10^6	1.58	2.45
BS1	Bacillus Subtilis	10^4	1.55	2.35
BS2		10^5	1.68	2.54
BS3		10^6	1.62	2.39
PA1	Pseudomonas Aeruginosa	10^4	1.60	2.41
PA2		10^5	1.73	2.60
PA3		10^6	1.57	2.37

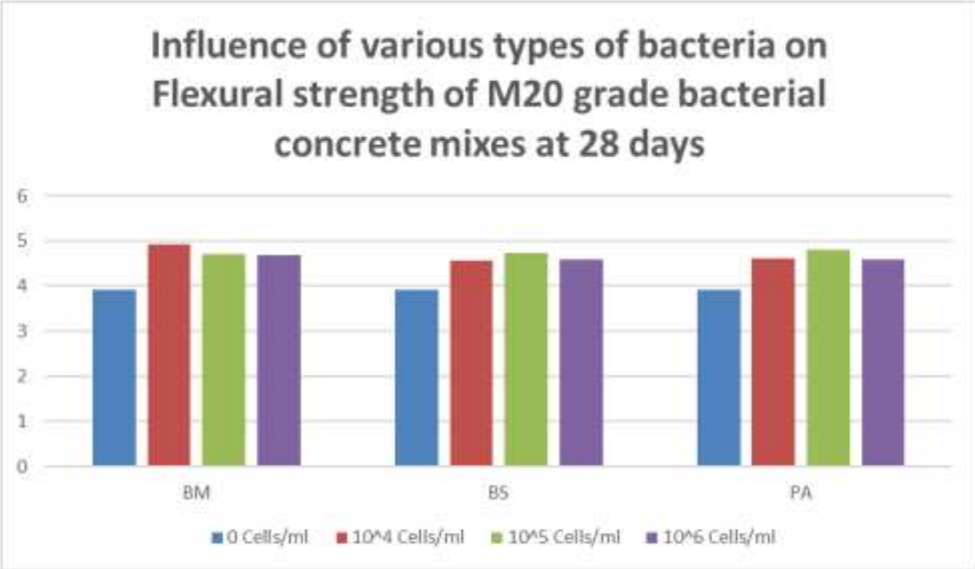




Split Tensile Strength:

Mix designation	Type of bacteria	Cell concentration (cells / ml)	Average flexural strength at 28 days (MPa)
CS	Control Specimen	-	3.92
BM1	Bacillus Megaterium	10^4	4.93
BM2		10^5	4.70
BM3		10^6	4.67
BS1	Bacillus Subtilis	10^4	4.55
BS2		10^5	4.74
BS3		10^6	4.59
PA1	Pseudomonas Aeruginosa	10^4	4.62
PA2		10^5	4.80
PA3		10^6	4.58

Mix designation	Type of bacteria	Cell concentration (cells / ml)	Average flexural strength at 28 days (MPa)
CS	Control Specimen	-	3.92
BM1	Bacillus Megaterium	10^4	4.93
BM2		10^5	4.70
BM3		10^6	4.67
BS1	Bacillus Subtilis	10^4	4.55
BS2		10^5	4.74
BS3		10^6	4.59
PA1	Pseudomonas Aeruginosa	10^4	4.62
PA2		10^5	4.80
PA3		10^6	4.58



V. Conclusion

The following conclusions are made based on the experimental investigations carried out on concrete mixes with and without bacteria.

Workability

• The workability of bacterial concrete is not affected with the induction of bacteria into concrete.

Cube compressive strength

At the ages of 7, 14, 28 days, the compressive strengths of bacterial concrete mixes were more than those of concrete mix without bacteria. This indicates that addition of bacteria into concrete causes an increase in compressive strength.

• The bacterial concrete mixes showed higher values of cube compressive strength than control concrete mix. The increase in compressive strength was mainly due to plugging of the pores inside the bacterial concrete induced by calcium carbonate (calcite) precipitation.

• The 7 - day compressive strength of the bacterial concrete mixes was 66 to 67 percent of 28 days compressive strength. This indicates that addition of bacteria does not cause early strength.

• There was an increase of only 7 to 10 MPa in the compressive strength between 28 days for concrete mixes without bacteria while this increase was in the range of 10 to 16 MPa for bacterial concrete mixes. This could be advantageously used for design of structures such as bridge piers, abutment walls and other mass concrete structural elements where early strength is not a criterion.

• The optimum dosage of cell concentration for BM, BS and PA bacteria are found to be 104, 105 and 105 cells /ml respectively for achieving the maximum value of cube compressive strength.

• The maximum increase in compressive strength of 22.08 percent is obtained for BM bacterial concrete for 104 cells/ml concentration.

• The bacteria used in this investigation exhibits good results. Therefore, it is strongly recommended for the production and use of bacterial concrete.

Splitting tensile strength

• The splitting tensile strengths of all bacterial concrete specimens were found to be greater than those of the control concrete specimen. The maximum splitting tensile strengths were obtained for bacterial concrete specimens BM1, BS2 and PA2 as 2.64 MPa, 2.54 MPa and 2.60 MPa respectively at the age of 28 days.

• The splitting tensile strength increases along with increase in compressive strength. The splitting tensile strength of bacterial concrete is about 7 to 8 percent of cube compressive strength. The maximum increase in splitting tensile strength of 24.53 percent is obtained for BM bacterial concrete.

Flexural strength

• The flexural strengths of all bacterial concrete specimens were found to be greater than those of the control concrete specimen. The maximum flexural strengths were obtained for bacterial concrete specimens BM1, BS2 and PA2 as 4.93 MPa, 4.74 MPa and 4.80 MPa respectively at the age of 28 days.

• The flexural strength increases along with increase in compressive strength. The flexural strength of bacterial concrete is about 15 percent of cube compressive strength. The maximum increase in flexural strength of 25.76 percent is obtained for BM bacterial concrete.

• The optimum dosage of cell concentration for BM, BS and PA bacteria are found to be 104, 105 and 105 cells /ml respectively for achieving the maximum value of flexural strength.

• The flexural strength of concrete at the age of 28 days is higher than the value calculated by the expression 0.7 √fck as specified in IS : 456 - 2000. The code IS : 456 - 2000 underestimates the value of flexural strength of bacterial concrete.

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