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A Study on Properties of Bacteria Based Blended Concrete

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Abstract
Concrete is certainly the most widely used building material. Because concrete is prone to environmental changes, cracks easily. Even with the best grade materials and skilled labor, surface cracks in concrete are often inevitable. Concrete's strength and durability may deteriorate as a result of the cracks. The maintenance required to fix these cracks will be expensive. In order to eliminate these defects, the technique of self-healing is applied to the concrete. Hence, the present study is to determine the performance of the concrete by using GGBS, Metakaolin, Bacteria and river sand as a fine aggregate. The present study focuses on optimal usage of GGBS and Metakaolin (5, 10, 15, 20, 25, 30) percent by weight of the cement in concrete and their effect on microbial concrete made of Bacillus Subtilis of concentration 10^5 *cells/ml. The mechanical and durability properties of concrete for different mixes i.e., with bacteria and without bacteria in blended concrete determined by casting concrete cubes, cylinders and prisms respectively. The Results reveal promising improvements in strength and durability, highlighting the potential of incorporating bacterial agents as a sustainable solution in concrete technology.*

Keywords: *GGBS, Metakaolin, Bacteria, Blended Concrete & River Sand.*

1. Introduction

Cement serves as the fundamental binding agent in concrete and advances in technology have influenced its properties over time. Cement production is associated with significant carbon emissions. Eventually this will lead to global warming and several effects on environment. Small surface fissures in the concrete allow water to seep in and destroy the concrete and steel reinforcing, significantly shortening the structure's life. The fractures require expensive, maybe unaffordable, human maintenance on a frequent basis. To improve the various aspects of concrete, several varieties have been developed. In addition to providing strength, pozzolanic materials are essential primarily for environmental and economic reasons. Over the various aspects from the past few years, bacterial concrete has been the focus of several studies. A common approach for repairing fractures in building materials is the bio mineralization of calcium carbonate, as cracks compromise the structural safety of the structure in addition to affecting its service durability [1]. The specimens' capillary intake of water and permeability decreased as a result of bacteria depositing a coating of calcite on their surface [2]. T. Shanmuga Priya et al.,[3] concluded that the most effective microbial mineral technique for enhancing the qualities of concrete is the employment of Bacillus family bacteria, which produce calcite precipitation to fill in the holes, in concrete. T Divya et al.,[4] have demonstrated that the addition of a bacterium at, concentration of 106 cells/ml improves the characteristics of fly ash and GGBS-based concrete. Patil et al.,[5] conducted an analysis of the flexural and compressive strengths of concrete produced in different concentrations from 0% to 40% utilizing ground granulated blast furnace slag and Portland cement. In the course of the study, it is discovered that the percentage of cement

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substituted with slag has an inverse relationship with the strength of concrete. Anupama et al.,[6] discussed about the SCMs needed to reduce concrete's permeability and improve its resistance against sulphate assault. Mineral admixtures in concrete can help achieve this. Addition of admixture in concrete reduces the volume of pores by filling effect and also due to pozzolanic reaction more secondary binding materials are formed by consuming Ca $(OH)_2$. In general terms, sulphate attack is the result of sulphates reacting with calcium hydroxide that is created during hydration. The quantity of portlandite generated reduces when this kind of additive is added to the mixture. Kanamarlapudi et al.,[7] examined the different characteristics of concrete that were impacted by partial replace of cement with different admixtures, such as fly ash, GGBS and rice husk. It was found that the addition of metakaolin can increase concrete's strength by up to 15 percentage, However, it may also adversely affect the concrete's workability. Venkat et al.,[8] outlined in his study on increasing the strength of concrete by substituting M-Sand for river sand entirely and pozzolanic materials such silica fume, GGBS & metakaolin for some of the weight of cement at (5,10, & 15). This article's preliminary research focuses on analyzing the split tensile strength, and non-destructive testing at ages of seven to 28 days. The results indicate that 10% of the cement's weight may be replaced with silica fume, metakaolin, and GGBS using M-sand to increase compressive and tensile strength. Anjaneya Babu et.al,[9] focused on how an M30 grade ternary mixed concrete mix performed. In order to evaluate the qualities, 180 specimens were produced. In order to produce the blended concrete mix, different proportions replacements of cement by SF (5%, 7.5%, &10%) and FA (20%, 30%, as well as 40%) were used. The compressive, tensile, and strength, flexural strengths were determined by a ternary mix which included 62% cement, 30% FA, and 7.5% silica fume.Ofuyatan et al.,[10] the assessment of the SCC with two additional cementitious materials GGBS and metakaolin was accomplished. Three different types of mixes were made: a Controlled mix, which was created without the addition of any additional cementitious material; a 2nd Mix, that was prepared with GGBS; and a 3rd Mix, which were produced with MK at 5, 10, 15, 20, and 25 percent. In comparison to the controlled mix, they noticed that substitution of five percent of the admixtures MK and GGBS improved the compressive strength. Navneet Chahal et.al,[11] presented the results of a study showing that the bacteria Sporoscarcina pasteurii affects the compressive strength and rapid chloride permeability of concrete mixed with and without fly ash. In substitute of cement, three weight percentages (10%, 20%, and 30%) of fly ash were utilized. To create the concrete mixes, three different microbial cell concentrations (103, 105, and 107 cells/ml) were utilized. According to test results, adding S. pasteurii to fly ash concrete decreased its porosity and permeability while improving its compressive strength. A significant compressive strength improvement (22%) and were noted when 105 bacteria cells/ml was used. The calcite deposition in fly ash concrete led to a decrease in chloride permeability approximately eight times. S Sri Durga et al.,[12] The purpose of the durability and physical testing is to determine how rapidly concrete recovers itself. In accordance with the research, bio concrete mixes enhanced 22% in compressive strength, 11% in split tensile strength, and 11 percent in flexural strength after 28 days of curing when compared to conventional concrete. Both normal and bacterial concrete samples were evaluated for life expectancy using tests of porosity, the bacteria enhanced the durability parameters of the bacterially based concrete specimens.The present research investigates at how bacillus subtills bacteria and admixtures like GGBS and metakaolin affect the mechanical qualities and longevity of concrete made using river sand. In the current study, the bacterial concentration of 105 cells/ml has been taken into consideration.

2. Method

2.1.Cement

Grade 43 Portland cement, commonly referred to as Zuari cement and easily found in the local general store, is utilized. The same batch of cement is used for each test. The cement was found to satisfy IS: 12269-1987 criteria after being assessed for a number of qualities in accordance with IS 4031-1988. Table 1 provides an illustration of the physical attributes.

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Table 1 Physical Properties of Cement

Sl No	Property	Results
1	Normal Consistency	31%
2	Specific Gravity	3.01
3	Initial setting time	65 min
4	Final setting time	230 min
5	Soundness of cement	1.5 mm
6	Fineness of Cement	3.5%

2.2.Fine Aggregate

River sand that is easily found locally and conforms to IS 383-1970 zone II. Table 2 lists fine aggregate parameters. River sand is less than 4.75 mm size.

. **Table 2 Qualities of Fine Aggregate**

Sl No	Property	Fine aggregate
1	Specific gravity	2.51
2	Fineness modulus	2.31
3	Loose Density	1440 kg/m^3
4	Rodded density	1633kg/ m^3

2.3.Coarse Aggregate

Here are two maximum percentages of coarse aggregate that are used: 12.5 mm and 20 mm. The parameters of the coarse aggregate, as shown in Table 3, in compliance with IS 2386-1983 and IS 383-1970.

2.4.GGBS

Quenching is the method used to create GGBS. The byproduct of the iron industry, is added to concrete for improving its strength, durability, and workability. The GGBS employed in the current research has a specific gravity of 2.8.

Figure 1 Nutrient Media Kept in Shaking Incubator

Table 3 Properties of Coarse Aggregate

Sl No	Property	Coarse aggregate
1	Specific gravity	2.61
2	Fineness modulus	7.71
3	Loose Density	1410 kg/m^3
4	Rodded density	1583kg/ m^3

2.5.Metakaolin

The clay mineral kaolinite can be found in its hydrous calcined state called metakaolin. Metakaolin, also known as High Reactivity Metakaolin (HRM), is a fine, natural white clay with a high silica concentration. The specific gravity of metakaolin, which was used in this research, is 2.46.

2.6.Water

For casting and curing, potable water that met IS: 456-2000 criteria were used (laboratory tap water). When mixing concrete, the necessary amount of water was measured using a graduated jar and poured to the dry mixture.

2.7.Bacteria

Bacillus subtilis of 105 cells/ml, a laboratory grown bacterium, is used in this study. The nutrient media kept in the shaking incubator and the bacteria cultured are shown in Fig 1 & 2. A nutritional supplement called calcium lactate is added to the mixture at a fixed ratio of around 0.5. Bacteria is cultivated in BMS College of Engineering Bengaluru.

2.8.Mix Design and Details of Mixes

M25-grade mixes were designed in accordance with IS 456-2000 and IS 10262-2019. In this investigation, GGBS and Metakaolin are used to partially substitute cement. Firstly, the GGBS concrete cubes are cast to get the optimum percentage. Then GGBS is maintained constant through the casting of concrete specimens. The optimal proportion of GGBS and different metakaolin percentages are then cast into concrete cubes to determine the ideal combination of ternary concrete. In order to determine how blended concrete's qualities change, the study also involves adding bacteria to the optimum blend of blended concrete. Table 4 & 5 illustrates the quantities of materials required for one cube and notations of mixes.

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Figure 2 Cultured Bacteria

Table 4 M25 Design Mix Ratio

Sl No	Material	Quantity(kg/m^3)
Design Mix Ratio: 1:2.00:3.54 & W/c is 0.45		
1	Cement	340
2	Fine Aggregate	681.66
3	Coarse aggregate	1206.9

Table 5 Notations for the Mixes

No	Mix	C	G (%)	M (%)	BS	CL
1	M0	100	-	0	0	0
2	M1	95	5	0	0	0
3	M2	90	10	0	0	0
4	M3	85	15	0	0	0
5	M4	80	20	0	0	0
6	M5	75	25	0	0	0
7	M6	70	30	0	0	0
8	M7	85	10	5	0	0
9	M8	80	10	10	0	0
10	M9	75	10	15	0	0
11	M10	70	10	20	0	0
12	M11	65	10	25	0	0
13	M12	60	10	30	0	0
14	M13	80	10	10	10^5	0.5

* C-Cement; *G- GGBS; *M-Metakaolin
*BS-Bacillus Subtilis; *CL- Calcium Lactate

3. Results and Discussion

3.1.Results

3.1.1. Compressive Strength

Cube of 150 mm by 150 mm x 150 mm size and assessed in a Compression Testing Machine (CTM) for different concrete mix proportions, such as the ideal percentages of GGBS and Metakaolin mixes, after 7, 14, 28, and 56 days of curing. Table 6 displays the average of three specimens for each proportion.

Table 6 Compressive Strength Test Outcomes

	Compressive strength (MPa)			
	7 Days	**14 Days**	**28Days**	**56 Days**
M0	23.7	28.48	31.26	34.18
M1	24	28.68	33.68	35.05
M2	**26.55**	**32.10**	**38.52**	**40.08**
M3	20.55	26.40	32.18	36.32
M4	21.55	23.23	30.00	32.16
M5	19.55	27.51	29.04	30.78
M6	16.20	20.76	24.53	27.89
M7	25.32	33.99	35.10	39.17
M8	**27.84**	**36.21**	**39.77**	**42.92**
M9	24.81	26.72	27.99	30.16
M10	18.73	22.66	20.21	24.62
M11	18.06	21.32	23.33	24.38
M12	17.38	19.66	20.94	21.79
M13	**30.68**	**36.92**	**40.95**	**44.53**

As illustrated in table 5, the mix, ternary concrete (10% GGBS + 10% Metakaolin) with bacillus subtilis shown maximum strength about at 56 days compared to other mixes.

3.1.2. Split Tensile Strength

The test was performed on a variety of cylindrical specimens (150 mm in Dia by 300 mm height) for 28 & 56 days. In Figure 3, the split tensile strength is illustrated. Split Tensile Strength = 2P/LDπ

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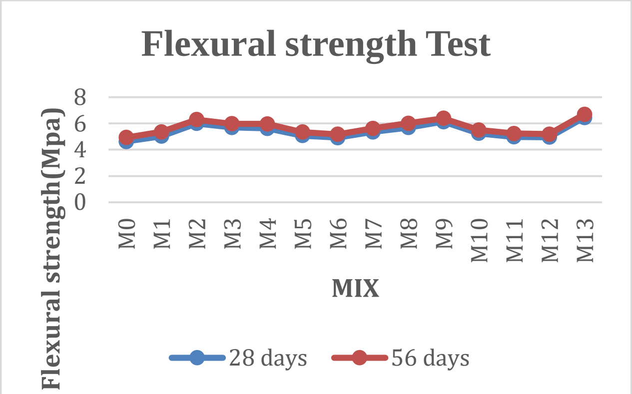

Figure 3 Test Graph

3.1.3. Flexural Strength

For prisms (100x100x500mm) at ages 28 and 56days, the flexural behavior of the concrete was tested.

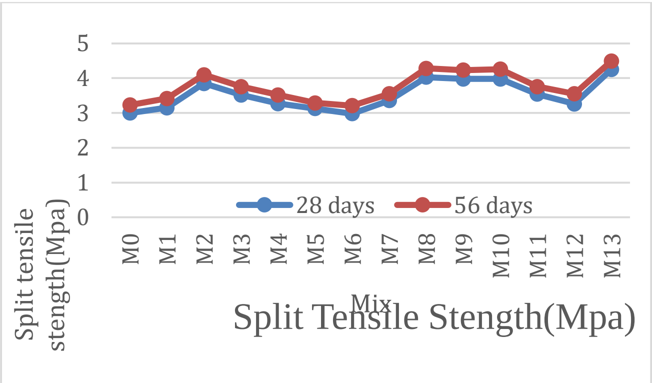

Figure 4 Test Results

3.1.4. Water Absorption

Low permeability is a crucial attribute of good quality concrete, especially when it comes to its resistance to freezing and thawing. The water absorption test at 28 days of age is carried out in accordance with the standard protocol described in BS 1881: Part122: 1983. A minimum of 72 + 2 hours is spent drying Standard cubes in an oven at 100 °C for the water absorption. After the specimens are removed from oven, allow them to cool for 24 +/-0.5 hours in an airtight container. Finally, weigh it (W1). After submerging the specimens in the water for 30 + 0.5 minutes, remove them from the water immediately. Weigh the specimen (W2). Water absorption is expressed as a percentage. Percentage of Water Absorption = (W1 – W2)/W2 x 100

Table 7 Water Absorption Test

MIX	% Water Absorption
M0	0.986
M2	1.49fi
M8	1.25
M13	1.24

3.1.5. Chlorine Penetration Depth Test

Calorimetric chlorination is one method used for evaluating the degree of chlorine penetration in concrete cube specimens. For this investigation, specimens of 150x150 x 150 mm were casted using river sand, both with and without admixtures and bacteria. Following a 28-day water curing period, which begins from the casting date, the cubes are taken out and submerged in water that has around 3.5% sodium chloride (NaCl). Samples are taken out after 28 days. After ten minutes, the specimens are cut into two equal pieces. Silver nitrate (AgNO3) in a 0.1M solution is sprayed on the specimens (broken part) immediately. A white precipitate forms on the specimens as shown in fig 4, because of the chemical interaction between sodium chloride and silver nitrate, and the depth is measured and tabulated in table 8.

Table 8 Chlorine Penetration Depth

MIX	Chlorination Depth(cm)
M0	1.20
M2	0.95
M8	0.82
M13	0.50

Conclusion

1. The optimal percentages of GGBS and metakaolin were crucial factors in the present study's outcomes.
2. The findings suggest that a blended combination such as 10% GGBS and 10% Metakaolin resulted in the most favorable mechanical properties in blended concrete.
3. The inclusion of bacteria (Bacillus Subtills 10 cells/ml) in the concrete mix demonstrated improvements in increased compressive strength and enhanced durability.

4. The Bacterial activity contributed to the formation of CaCo3, aiding in the healing of micro fractures and enhancing, overall resilience on the concrete.
5. The compression strength tests indicated the concrete's ability to self-heal micro cracks. Bacillus subtills, in collaboration with GGBS and metakaolin, facilitated biomineralization, contributed to the closure of cracks and the enhancement of overall compressive strength.
6. Extended durability tests emphasized the performance of the bacteria -based blended concrete. According to the study, this innovative approach may increase concrete structures' lasting resilience as well as their capacity to last longer, which would eventually increase their sustainability.

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