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Performance Evaluation of Rice-husk Ash Based Bacterial Concrete

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Abstract

The performance evaluation of bacterial concrete made with Rice Husk Ash (RHA) is presented in this paper. Concrete is the most widely used construction material on the planet, and because of its longer service life than other building materials, it is sometimes viewed as indestructible. Continuous exposure to harsh weathering, on the other hand, causes an increase in concrete porosity and, as a result, a reduction in mechanical properties. The effect of concrete permeability on porosity and porosity connection. Microbial concrete, which uses microorganisms to increase the durability and life of the concrete, has been presented. These bacteria are employed to precipitate calcium carbonate in concrete, which is extremely desired because the calcite precipitation caused by microbial activity is pollution-free and natural. Rice husk is used to substitute fine aggregate in concrete mixes of 0, 5, 10 and 15.

Keywords: Bacteria, Bacterial concrete, Cement, Fine aggregates, Rice-husk ash, Self-healing.

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Introduction

Concrete is a widely utilized and significant building material in construction projects. It is primarily used in heavy construction because of its strength and longevity. Regardless matter how effectively the concrete is constructed or reinforced, it will eventually fail.[1] Many factors affect concrete's durability and strength, with crack formation being one of the most common stumbling obstacles.

Concrete is a widely utilized construction material in nearly all public facilities and most constructions. It is most effective when reinforced with steel bar since its tensile strength without reinforcement is substantially lower than its compressive strength.[2] It's also a highly brittle material with a poor strain tolerance, so it's likely to break over time. While these fractures do not jeopardize structural integrity right away, they expose the steel reinforcement to the environment, resulting in corrosion, increasing maintenance costs and jeopardizing structural integrity over time. Concrete is also a material that requires much upkeep.[3] Self-healing concrete, in general, seeks to remedy these flaws to extend the service life of any concrete structure.[4,5] This concrete is made of bacterial self-healing bacteria. Self-healing concrete consists of a mix that includes bacteria embedded in the concrete and calcium lactate food to maintain the bacteria once they become active. The bacteria, which feed on the supplied food supply, repair the damage and can even minimize the amount of damage to the concrete structure.[6]

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Rice Husk Ash

Rice is one of the most valuable and widely grown cereal species on the planet, ranking second only to wheat in terms of total planted area.[7] India and China are the world's top rice producers, accounting for about half of all rice harvested worldwide. Rice grains are embedded in a natural protective shell, called flower scales by botanical scientists, and are commonly known as Rice Husk (RiH).[8,9] The RiH accounts for almost 20% of the total grain weight. RiH is a rice plant agricultural by-product material that accounts for about one-fifth of the rice weight; its structure is made up of lignin (25–30%), cellulose (50%), moisture (10–15%), and silica (15–20%), which when burnt forms a new waste known as Rice Husk Ash (RHA).[10]

Self-healing Concrete

After a fault arises, self-healing is defined as restoring performance. The damage that bacteria-based self-healing

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concrete aims to repair is related to improved durability, leakage prevention, and the extension of the service life of concrete structures. Self-healing concrete, in general, seeks to remedy these flaws to extend the service life of any concrete structure. This concrete is made of bacterial self-healing bacteria.[11] Self-healing concrete consists of a mix that includes bacteria embedded in the concrete and calcium lactate food to maintain the bacteria once they become active. The bacteria, which feed on the supplied food supply, repair the damage and can even minimize the amount of damage to the concrete structure.[12]

Bacteria Used in Concrete

In suspension state, substantial blend is added with microscopic organisms. Concrete being very basic in nature, the microorganisms added should fit in some extraordinary standards. Additional microorganisms should be able to resist the harsh environmental conditions of cement. Concrete is a dry substance with a pH of up to 13 when combined with water, making it hostile because most organisms cannot exist in an environment with a pH of more than 10.[13,14]

Types of Bacteria

Bacteria may be found in a variety of forms in nature. They may be found not just on the surface of the planet, but also underneath it. The following microorganisms can be utilized in concrete:

1. Anaerobic Bacteria

When anaerobic bacteria, such as a closely related species of Shewanella, are added to concrete, its compressive strength increases by 25–30%.

2. Aerobic Bacteria

There are several different forms of aerobic bacteria that may be utilized in concrete:

- *Bacillus pasteurii*
- *Bacillus sphaericus*
- *Escherichia coli*
- *Bacillus subtilis*
- *Bacillus cohnii*
- *Bacillus pseudofirmus*
- *Bacillus halodurans*
- *Bacillus massiliensis*

After 7 days, the compressive strength of *Solimonas soli* and *Left Fusiform Gyrus* improved, but *Bariatricus massiliensis* and *Arthrobacter crystallopoietes* exhibited no change. After 28 days, *A. crystallopoietes* reached its full strength.[15]

Review of Litrature

B. R. Gautam:[1] the study aims to introduce bacteria-based self-healing concrete, currently under development in our lab. A completely working system exists on the lab scale. The concrete mixture contains a healing agent made up of two components trapped in expanding clay particles. Bacterial activity causes a calcium carbonate layer to develop on the fracture surface, sealing the fissure and preventing degrading chemicals from entering. More research and development are necessary to make the material ready for usage in practice. The self-healing material must be cost-effective and durable, since the potential benefits are primarily expected in the reduction of expenses for maintenance and repair and the extension of the service life of concrete buildings.

Jasira Bashir *et al*.:[2] Various microorganisms were employed in this study to examine how much strength was obtained due to filler material growing inside the pores of the cement sand matrix. The strength of a concrete mix is determined using compressive strength, split tensile strength, and flexural strength tests. Scanning Electron Microscopy (SEM)/X-Ray Diffraction (XRD) investigation is additionally done to demonstrate the association of the separated ureolytic microbes in calcium carbonate precipitation. The outcomes got from the investigation presume that when water enters in the substantial get-togethers arrangement of breaks enacts the lethargic microscopic organisms.

Rafat Siddique *et al*.:[3] The author of this study investigates the characteristics of concrete created from rice husk ash. Control concrete was developed to have a 28-d strength of 32.8 MPa for this purpose. Cement was partially substituted with RHA (0, 5, 10, 15, and 20% by weight) in the control concrete. The bacteria *Bacillus aerius* (105 cells/mL) was then introduced to the water during the concrete making process. Compressive strength, water absorption, porosity, chloride permeability, and abrasion resistance were evaluated on all concrete mixes with and without bacteria up to 56 days. As revealed by SEM and XRD studies, the development of ettringite in pores, calcium silicate hydrate (CSH), and calcite resulted in the concrete being denser. According to the findings of this study, the employment of RHA and bacteria in concrete improves its durability.

Asst. Prof. Saranya *et al*.:[4] because of its eco-friendly nature, self-healing powers, and increased durability of various construction components, bacterial concrete technology has proven superior to many traditional technologies. When comparing conventional concrete to bacterial concrete (which is made by directly adding bacteria (*B. subtilis*)), bacterial concrete has higher compression strength, with a compressive strength value of 10% higher than conventional concrete and the ability to self-heal.

Materials and Methodology

Materials

- *Cement:* Cement is binder information, Ordinary Portl, Cement (OPC) of fifty-three quality was utilized. Chemical, and physical qualities of cement are as per IS: 12269 (1987b).
- *Course aggregate:* River s, passing via 4.75 mm Is actually sieve and verifying to zone 1 of IS:383 (1987a) was utilized. Particular gravity was discovered to be 2.3.

- *Rough aggregates:* its crushed stones of optimum size 20 mm, n retained on 4.75 mm is actually sieves. Particular gravity was discovered to be 3.13.
- *Water:* For ordinary concrete, potable drinking water is required. Bacterial drinking water containing 105 B. magisterium cells or mL of drinking water.
- *RHA:* It is a waste product used on a small to huge basis. It can be used to make a watertight seal.
- *Metal sheet:* To reveal a syntic crack within an unhardened concrete sample material up to a level of 10 mm, a thin metallic sheet of thickness 0.3 mm was used.
- Bacterial-Cement, also liquid, have an extremely high pH of about 13, when it is mixed intimately. The majority of microorganisms stick up to bucket in a higher pH environment. Bacteria that must be loaded must meet certain criteria, such as being alkali resistant and having the capacity to withstand significant green concrete issues;

a) *Bacillus megaterium*
b) *Bacillus pasteurii*
c) *Bacillus* sp. CT-5
d) *Bacillus subtilis*

It has been observed that B. magisterium can precipitate the optimal level of calcite compared to other or urease good bacteria, resulting in a higher increase in compressive strength and fracture healing efficiency.

Figure 1: Compression Testing Equipment

Table 1: Result of mix design

W/C	*CEMENT*	*FINE AGG.*	*COARSE AGG.*
186.86	406.22	523.64	1244.40
0.46	1	1.289	3.06

Methodology For Preparing Bacterial Concrete

In this research project, the preparation of bacterial concrete is be done through three process

- By direct adding of bacteria (*B. subtilis*).
- By developing bacteria with the help of adding the chemicals.
- Extraction of bacteria and directly sprayed or injected in structure.

Results

Compressive Strength Study

Ordinary Portland cement was used to make the mortar samples. The cement-to-sand ratio is 1:3. (by weight) (Table 1). 150 mm x

Figure 2: Flexural test equipment

Table 2: Compressive strength of cube for 28 days

Sr. No.	*Grade*	*Notation for cube*	*Date of casting*	*Date of testing*	*Age (days)*	*Weight of cube at 28th day (kg)*	*Load on cube (kN)*	*Strength (N/mm^2)*	*Average*
1	M20	F1	01/12/2015	30/12/2015	28	8.57	520	23.11	22.44
		F2	01/12/2015	30/12/2015	28	8.84	490	21.77	
2	M20	G1	01/12/2015	30/12/2015	28	9.43	750	33.33	31.77
		G2	01/12/2015	30/12/2015	28	9.35	680	30.32	
3	M20	C1	01/12/2015	30/12/2015	28	8.76	720	32	28.88
		C2	01/12/2015	30/12/2015	28	6.62	580	25.77	
4	M20	GB1	01/12/2015	30/12/2015	28	8.81	530	23.55	22.88
		GB2	01/12/2015	30/12/2015	28	8.97	500	22.22	
5	M20	FB1	01/12/2015	30/12/2015	28	8.98	550	24.44	24.66
		FB2	01/12/2015	30/12/2015	28	8.79	560	24.88	
6	M20	CB1	01/12/2015	30/12/2015	28	9.29	650	28.88	35.99
		CB2	01/12/2015	30/12/2015	28	9.18	970	43.11	

Table 3: Compressive strength of cube for 56 days

Sr. No.	*Grade*	*Notation for cube*	*Date of casting*	*Date of testing*	*Age (days)*	*Weight of cube at 28th day (kg)*	*Load on cube (kN)*	*Strength (N/mm²)*	*Average*
		F1	04/11/2015	30/12/2015	56	8.5	520	23.11	
1	M20	F2	04/11/2015	30/12/2015	56	9.2	700	31.11	32.29
		F3	04/11/2015	30/12/2015	56	8.7	960	42.66	
		G1	04/11/2015	30/12/2015	56	8.75	650	28.89	
2	M20	G2	04/11/2015	30/12/2015	56	8.86	680	30.22	29.04
		G3	04/11/2015	30/12/2015	56	8.70	630	28	
		C1	04/11/2015	30/12/2015	56	8.91	1050	46.67	
3	M20	C2	04/11/2015	30/12/2015	56	9.37	1100	48.89	48.77
		C3	04/11/2015	30/12/2015	56	9.32	1100	48.89	
		FB1	04/11/2015	30/12/2015	56	8.73	700	31.11	
4	M20	FB2	04/11/2015	30/12/2015	56	8.79	700	31.11	38.67
		FB3	04/11/2015	30/12/2015	56	8.95	1210	53.78	
		CB1	04/11/2015	30/12/2015	56	9.95	650	28.89	
5	M20	CB2	04/11/2015	30/12/2015	56	9.38	1050	46.66	34.82
		CB3	04/11/2015	30/12/2015	56	9.42	650	28.89	

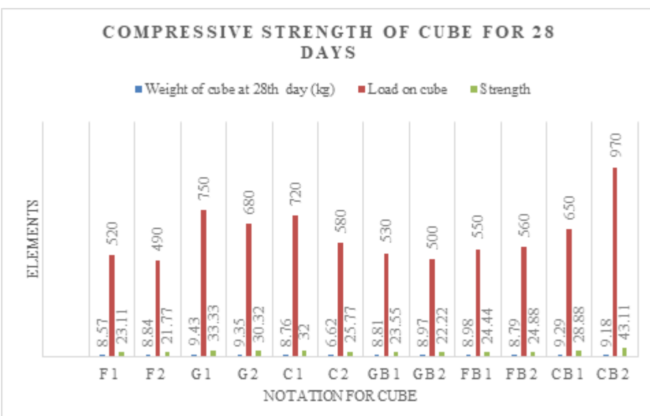

Figure 3: Compressive strength of for 28 days

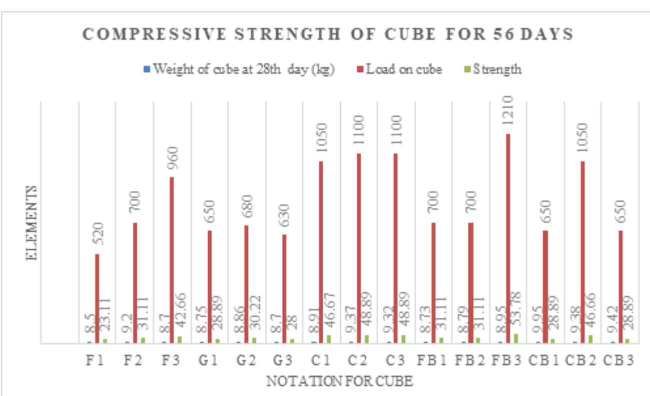

Figure 4: Compressive strength of cube for 56 days

150 mm x 150 mm x 150 mm x 150 mm x 150 mm x 150 mm x 150 mm x 150 mm x (Figure 3) After casting, all moulds were put in a room with a normal temperature and relative humidity of more than 90% for 24 hours (Table 2). The specimens were put for curing for 28 days after de-moulding (FIgure 1).

Flexural Strength Study

The inquiry aims to learn more about concrete's flexural behavior. A total of 36 simply supported balanced section beams are cast and tested. Ordinary Portland cement was used to make concrete samples. Moulds with dimensions of 500, 100, and 100 mm were utilized (Figure 4). All moulds were put in a normal temperature environment with a relative humidity of greater than 90% for 24 hours after casting. The specimens were put for curing for 56 days after de-moulding (Figure 2).

Advantages and Disadvantages of Bacterial Concrete

Advantages of Bacterial Concrete

- Self-healing fractures without the need for external assistance.
- Significantly higher compressive and flexural strengths as compared to ordinary concrete.
- Protection against freeze-thaw assaults.
- Reduces permeability of concrete;
- Reduces steel corrosion owing to crack formation; increases the durability of steel-reinforced concrete.
- Bacillus bacteria are non-toxic to humans, so they may be utilized efficiently.

Disadvantages of Bacterial Concrete

- The cost of bacterial concrete is double that of regular concrete.
- Bacterial growth is undesirable in any environment or medium.
- The self-healing ingredient is held in clay pellets that make up 20% of the concrete volume. This may become a shear zone or fault zone in the concrete.

- There is no IS code or other code available to design bacteria-infested concrete.
- Calcite precipitate research is expensive.

Conclusions

From this research work the following conclusion is made:

- Because of its eco-friendly nature, self-healing powers, and increased durability of various construction materials, bacterial concrete technology has proven superior to many traditional technologies.
- When comparing conventional concrete to bacterial concrete (which is made by directly adding bacteria (*B. subtilis*)), bacterial concrete has higher compression strength, with a compressive strength value of 10% higher than conventional concrete and the ability to self-heal.
- However, based on a review of the literature, we discovered that the strength of bacterial concrete, in the form of chemically generated bacteria, was only enhanced by 7% when compared to ordinary concrete.

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