Effect of Bacteria on Partial Replacement of Cement with Rice Husk Ash

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ABSTRACT

This paper presents the results of an experimental investigation carried out to evaluate the influence of *Bacillus pasteurii* bacteria on the compressive strength and permeability of concrete made without and with Rice Husk Ash. Cement was replaced with three percentages (2, 4 and 6) with Rice Husk Ash by weight. Three different cell concentration (0, 10^3,10^5,10^7 cells/ml) of bacteria were used in making the concrete mixes. Test results indicated that inclusion of *B. pasteurii* in Rice Husk Ash concrete enhanced the compressive strength, reduced the porosity and permeability of Rice Husk Ash concrete. The present work highlights the influence of bacteria on the properties of concrete made with supplementing cementing material such as like Rice Husk Ash. Usage of bacteria like *B. pasteurii* improves strength and durability and strength of Rice Husk Ash concrete through self-healing effect.

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1. Introduction

Concrete is the most widely used man made construction material in civil engineering world. It has specialty of being cast in any desirable shape but plain concrete however possesses very low tensile strength, limited ductility and little resistance to cracking. As a matter of fact, advancement in concrete technology has been generally on the strength of concrete. It is now recognized that strength of concrete alone is not sufficient, the degree of harshness of the environmental condition to which concrete is exposed over its entire life is very important. Therefore, both strength and durability have to be considered explicitly at the design stage. To do this, a durable structure needs to be produced. For concrete buildings, one of the major forms of environmental attack is chloride ingress, which leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability and aesthetics of the structure. This may lead to early repair or premature replacement of the structure. Rice Husk Ash is generally used as replacement of cement, as an admixture in concrete. This study explores the possibility of replacing part of cement with Rice Husk Ash as a means of incorporating significant amounts of Rice Husk Ash. All building materials are porous. This porosity of building material along with ingress of moisture and other harmful chemicals such as acids, chlorides and sulfates affect the material and seriously reduce their strength and life. An additive that seals the pores and cracks and thus reduces the permeability of the structure would immensely improve its life.

Bacteria are relatively simple, single celled organisms. The bacteria used were *Bacillus pasteurii.* It is a bacterium with the ability to precipitate calcium carbonate in the presence of any carbonate source. The bacterium is used in this project for the same and for the improvement in the strengths of the concrete test specimens were observed. The microbes are a bacillus species and are completely not harmful to human beings. They precipitate inorganic crystals hence the healing of the cracks takes place in the concrete and it can withstand any temperature conditions doing so. Using microbes such as Bacillus pasteurii which as properties of bio calcification can secrete calcium carbonate as an extracellular product thus filling the pores and the cracks internally making the structure more compact and resistive to seepage. As the texture becomes more compact the compressive strength is also considerably increased. Thus, this process can reduce the seepage considerably permanently.

Rice milling generates a by-product known as husk. This surrounds the paddy grain. During the milling of paddy about 78% of the weight is received as rice. Rest of 22% of the weight of paddy is received as husk. This husk is used as a fuel in the rice mills to generate steam for boiling process. This results in rice husk ash (RHA). This RHA contains around 85% to 90% amorphous silica. So for every 1000Kg of paddy milled, about 220Kg of husk is produced and when this husk is burnt in the boilers, about 55Kg of RHA is generated. Globally, approximately 500 million tons of rice paddies produced each year. On average

20% of the rice paddy is husk, it means that about 100 million tons of rice husk are available. India is major rice producing country and 20 million tons of RHA is produced. In the majority of rice producing countries much of the husk produced from the processing of rice is either burnt or dumped as a waste. Because of tough, woody, abrasive nature of hulls resistance to weathering and high ash contents the use or disposal of rice husk ash frequently proved difficult. The ash contains more than 85% silica, which is highly porous and lightweight, with very high external surface area. Its absorbent and insulating properties are useful to many industrial applications. RHA is a good super pozzolana, which is much finer than cement having very small particle size less than 45 microns and fills the voids between cement and aggregate which gives the strength and density to the concrete. So it can reduce the amount of cement in the concrete mix. RHA is used to make special concrete mixes. There is growing demand for fine amorphous silica in the production of special concrete of high performance, high strength, and low permeability concrete. For use in bridges, marine environments, nuclear power plants etc.

Advantages of bacterial concrete

i. Microbial concrete in cracks remediation: - Specimens were filled with bacteria, nutrients and sand. Significant increase in compressive strength and stiffness values as compared to those without cells was demonstrated

ii. Improvement in compressive strength of concrete: - Compressive strength test results are used to determine that the concrete mixture as delivered meets the requirements of the job specification. So, the effect of microbial concrete on compressive strength of the concrete and mortar was studied and it was observed that significant enhancement in the strength of concrete and mortar can be seen upon application of bacteria.

iii. Better resistance towards freeze –thaw attack reduction :-
Application of microbial calcite may in resistance towards Freeze-thaw Reduction due to bacterial chemical process and it can reduce the permeability than freezing process decreased

iv. Reduction in permeability of concrete: - Effect of microbial concrete on permission properties was studied by different researches. Permeability can be investigated by carbonation tests as it is increasingly apparent that decrease in gas permeability due to surface treatments results in an increased resistance towards carbonation and chloride ingress. Carbonation with larger pores giving rise to higher carbonation depths

v. Reduction in corrosion of reinforced concrete :- Application of microbial calcite may help in sealing the paths of ingress and improve the life of reinforced concrete structure. B. pasteurii to check its effect on permeability resistance and acid attack and reported that bacterial calcites improves surface permeability resistance and resist the attack of acid (PH >1.5)

Disadvantages of bacterial concrete

i. Cost of bacterial concrete is double than convention concrete :- Cost of bacterial concrete is double than conventional concrete said DR.Henk Jonkers in 2011 but it can be reduce this cost by growth of these techniques

ii. Growth of bacteria is not good in any Atmosphere and media :- Different types of nutrients and metabolic products used for growing calcifying microorganism, as they influence survival, growth, biofilm and crystal formation. More work should be done on the retention of nutrients and metabolic products in the building material

iii. Design of mix concrete with bacteria there is no available any IS code or other code :- Due to it is a new research material and not famous to use in construction area hence no any code is provided to use it so , it is hard to calculate the doses of bacteria use in concrete to get optimum performance

iv. Investigation of calcite precipitation is costly studied :- Different types bacteria have different properties to produce an amount calcite precipitation to identify this amount it should be requires be requires investigation of bacteria and for that " Scanning by Electron Microscopy '' and this method is costly and requires good skill to carry out this test.

Objective of Investigation

The main objective of this work is to study the suitability of *Bacillus pasteurii* bacteria with Rice Husk Ash for cement replacement in concrete and it is expected that the strength properties of concrete will be improved. The use of concrete has become increasing day by day, so it is very important to find the alternative to cement and to make the concrete economical. Also it is an attempt made to use the agro based waste product as cement replacement up to some extent beyond which it affects the strength properties of concrete. The main objective of this project is to develop the concrete using *Bacillus pasteurii* bacteria with Rice Husk Ash as a source material for partial replacement of cement, which satisfies the various structural properties of concrete like compressive strength, flexural strength and tensile strength. It is also expected that the final outcome of the project will have an overall beneficial effect on the utility of *Bacillus pasteurii* bacteria with Rice Husk Ash concrete in the field of civil engineering construction work.

2. LITERATURE REVIEW

2.1 Literature Survey

The following are some reviewed literatures of available papers and the same has been discussed and presented here.

M.V. Seshagiri Rao, *et. al*. [1] studied that "*Bioengineered Concrete - A Sustainable Self-Healing Construction Material*" in this paper describes it is a well known fact that concrete structures are very susceptible to cracking which allows chemicals and water to enter and degrade the concrete, reducing the performance of the structure and also requires expensive maintenance in the form of repairs. Cracking in the surface layer of concrete mainly reduces its durability, since cracks are responsible for the transport of liquids and gasses that could potentially contain deleterious substances. When micro cracks growth reaches the reinforcement, not only the concrete itself may be damaged, but also corrosion occurs in the reinforcement due to exposure to water and oxygen, and possibly CO 2 and chlorides too. Micro-cracks are therefore the main cause to structural failure. One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of biominerilization of bacteria in concrete. The applicability of specifically calcite mineral precipitating bacteria for concrete repair and plugging of pores and cracks in concrete has been recently investigated and studies on the possibility of using specific bacteria as a sustainable and concrete -embedded self healing agent was studied and results from ongoing studies are discussed. Synthetic polymers such as epoxy treatment etc are currently being used for repair of concrete are harmful to the environment, hence the use of a biological repair technique in concrete is focused. In the present paper, an attempt is made to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength and durability of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, due to its high internal pH, relative dryness and lack of nutrients needed for growth, is a rather hostile environment for common bacteria, but there are some extremophilic spore forming bacteria may be able to survive in this environment and increase the strength and durability of cement concrete. Overview of development of bioengineered concrete using bacterial strain Bacillus subtilis JC3 and its enhanced mechanical and durability characteristics will be briefly described in this paper.

C. C. Gavimath, *et. al.* [2] *studied that "Potential Application of Bacteria to Improve the Strength Of Cement Concrete''*. In this paper it is described that the objective of the present investigation is to study the potential application of bacterial species i.e. *B.sphaericus* to improve the strength of cement concrete. Here we have made an attempt to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the strength of the concrete. Water which enters the concrete will activate the dormant bacteria which in turn will give strength to the concrete through the process of metabolically mediated calcium carbonate precipitation. Concrete, however, is due to its high internal pH, relative dryness and lack of nutrients needed for growth, a rather hostile environment for common bacteria, but there are some extremophilic spore forming bacteria may be able to survive in this artificial environment and increase the strength and durability of cement concrete. In this study we found that incorporation of spore forming bacteria of the species Bacillus will not negatively affect the compressive and split tensile strength of the cement concrete.

Ravindranatha, N. Kannan, Likhit M. L, [3] studied that *"Effect of Bacteria On Partial Replacement Of Concrete With Fly-Ash"* in this the responsibility of the paper. In this paper it is discus that construction industry is not only to provide quality construction but also to provide a clean environment. With the rapid industrialization and urbanization, the generation of industrial by-product is also increasing very rapidly. This is not only pollutes the environment but also creates disposal problems. This paper gives information about the research carried out on cement with a partial replacement with fly ash and GGBS with bacteria in the mix giving great results and being highly sustainable and eco-friendly. From the results of the investigation, it has been observed that, the performance of blended cement concrete is better than that of the conventional concrete. The application of concrete is rapidly increasing worldwide and therefore the development of sustainable concrete is urgently needed for environmental reasons. As presently about 7% of the total anthropogenic atmospheric CO2 emission is due to cement production, mechanisms that would contribute to a longer service life of concrete structures would make the material not only more durable but also more sustainable. One such mechanism that receives increasing attention in recent years is the ability for self-repair, i.e. the autonomous healing of cracks in concrete. In this study we investigated the potential of bacteria to act as self-healing agent in concrete, i.e. their ability to repair occurring cracks. A specific group of alkali-resistant spore-forming bacteria related to the genus *Bacillus* was selected for this purpose. Bacterial spores directly added to the cement paste mixture remained viable for a period up to 4 months. A continuous decrease in pore size diameter during cement stone setting probably limited life span of spores as pore widths decreased below 1_m, the typical size of *Bacillus* spores. However, as bacterial cement stone specimens appeared to produce substantially more crack-plugging minerals than control specimens, the potential application of bacterial spores as self-healing agent appears promising.

Godwin A. Akeke, *et. al.* [4] in their experiment studied *"The structural properties of Rice Husk Ash concrete"*. They carried out the investigation on the effects of introducing rice husk ash (RHA) as a partial replacement of ordinary portland cement (OPC) on the structural properties of concrete. Rice husk ash which is an agro-waste and known to be a super pozzolana have been used for mass concrete and found to have compressive strength ranging from 33-38.4n/mm2 at replacement percentages of 10-25% in a mix of 1:1.5:3. A further study was carried out on its flexural properties to determine their modules of rupture as well as its tensile strength characteristics for the determination of cracking, the values obtained at 28days are 3, 2.5 and 2.4N/mm2 while the tensile strength values are 1.94, 1.17 and 0.91N/mm^2 at replacement percentages of 10%, 20% and 25%. This research has proved that RHA Concrete can be used as a Structural Concrete at suitable replacement percentages. The compressive strength and workability test suggests that RHA could be substituted for OPC at up to 25% in the production of concrete with no loss in workability or strength. Based on the results of split Tensile Strength test, it is convenient to state that there is no Substantial increase in Tensile Strength due to the addition of RHA. The Flexural strength studies indicate that there is a marginal improvement with 10 to 25% RHA replacement levels. Rice Husk Ash concrete possess a number of good qualities that make a durable and good structural concrete for both short term and long term considerations. It is good for structural concrete at 10% replacement level.

2.2 Conclusion on literature reviewed

During the last decade, a number of studies have been conducted on strength properties of concrete by using rice husk ash and bacteria separately. Various parameters of concrete such as workability, importance of water to cement ratio, admixtures etc, by using rice husk ash and *Bacillus pasteurii* bacteria are studied widely. The main aim of researchers is to use the by product which is been either dumped or treated as a waste material. From all the literatures available it is came to know that no experimental investigation is carried-out on the effect of bacteria on concrete with partial replacement of rice husk ash of cement on strength properties of concrete. Hence in the present work, an attempt is made on the effect of bacteria on concrete with partial replacement of rice husk ash of cement on strength properties of concrete.

3. MATERIALS AND METHODOLOGY

3.1 Experimental program

The scope of the experimental work is limited to study the influence of Bacteria and RHA on strength and workability of concrete for water to cement ratio 0.50 for the concrete mixes with three different cell concentration (0, 10^3,10^5,10^7 cells/ml) of bacteria to RHA of 0%, 2%, 4%, and 6% replacement to cement respectively. For this investigation, mix design is made by DOE method and numbers of trials are done by changing different cell concentration of bacteria and the percentage of RHA for various mixes with super plasticizer to get good workable concrete. To find workability slump and compaction factor, test is carried out and to find strength, the cube specimens are casted.

3.2 Material Properties

3.2.1 Isolation and morphology of bacteria

Calcium carbonate precipitating bacteria were isolated from NCIM, Pune. The samples were suspended in a sterile saline solution (0.85% NaCl), diluted properly and plated on precipitaion agar containing urea (20 g/l), $NaHCO_3$ (2.12 g/l), NH_4Cl (10 g/l), Nutrient broth (3 g/l), $CaCl_2{\cdot}2H_2O$ (25 g/l). Incubation was done at 28 °C. Colonies were assessed every 5 days with a stereo microscope (Zeiss) and selected as positive based on visual crystal formation within 10 days. Positive isolates were purified through repetitive dilution and plating (as described above). The isolated bacteria were identified as *Bacillus pasteurii* also known as *B. pasteurii* from older taxonomies. This bacteria has the ability to solidify organic nitrogen source through the process of biological cementation. *B. pasteurii* has been proposed to be used as an ecologically sound biological construction material. On the basis of Calcinate formation one dose of bacteria was selected for final preparation of concrete mixture by partial replacement of cement with RHA. Different concentrations of cells (10^3, 10^5, 10^7 cells/ml) were obtained by growing culture for different time followed by centrifugation at 8000 rpm for 10 min at 4 °C.

3.2.2 Preparation of Bacterial Solution

Primarily 12.5g of Nutrient broth (media) is added to a 500ml conical flask containing distilled water. It is then covered with a thick cotton plug and is made air tight with paper and rubber band. It is then sterilized using a cooker for about 10-20 minutes. Now the solution is free from any contaminants and the solution is clear orange in colour before the addition of the bacteria. Later the flasks are opened up and an exactly 1ml of the bacterium is added to the sterilized flask and is kept in a shaker at a speed of 150-200 rpm overnight. After 24 hours the bacterial solution was found to be whitish yellow turbid solution.

3.2.3 Growth and Culturing Bacteria

Bacteria is a single cell organism. It is a prokaryotic cell that lack of a nucleus and other membrane enclosed structure. Typically, bacteria come in three basic shapes namely, sphere, rod-like and spiral. Some bacteria do not fit any of the preceding categories but rather have spindle shapes or irregular lobbed shapes. Bacteria can be found in every environment such as in the air, food, soil and water. Many bacteria benefits human and a few may cause disease to human. Bacteria play vital role in most of the environment cycle like biogeochemical cycle, water cycle, carbon cycle, nitrogen cycle and sulfur cycle. However, there are numbers of bacteria that is not fully characterized and only some of the bacteria have been grown in a laboratory for specific application**.** Cell division in bacteria unlike cell division in a high organism, usually occur by binary fission or budding. In a binary fission, a cell duplicates its components and divides into two cell. In cell division two identical daughter cell are produced. The daughter cell becomes independent when a partition grows between them. A bacteria population can be doubled as quickly as 9.8 min. Bacteria growths in three phases .The first phase is called the lag phase or rapid growth when bacteria receive lot of carbon sources and nutrients. The second phase of growth is the logarithm growth or exponential phase. In log phase the nutrients is metabolized until one of the nutrients deplete. The final stage of growth is the stationary phase and the nutrients are depleted.

3.3 Properties of OPC and RHA

The RHA was obtained from Manikji Metachem, Murtizapur.
Table- 3.1: Physical and chemical properties of materials.

	OPC	RHA
Physical properties		
Mean particle size (μ)	16.78	90
Surface area (m^2/kg)	359	169 00
Specific gravity (gm/cm^3)	3.12	2.02
Chemical properties	Wt%	Wt%
CaO	64	0.4
SiO2	19	91
Al2O3	5	0.1
Fe2O3	3	0.1
MgO	1	0.9
SO3	3.8	0.5
K2O	1.1	3.3
L. O. I.	3	2

3.4 Fine Aggregate

Locally available river sand is used as a fine aggregate. The sand is sieved using IS sieve of size 4.75 mm. the silt content is 4% and fineness modulus is 3.19. All properties of aggregates are tested as per IS 2386 (Part-I, II, and III)-1963 'Method of Tests for Aggregates for Concrete' and confirming to IS 383-1970. Physical properties of the fine aggregate used for the study are given in Table 3.2.

3.5 Coarse Aggregate

Crushed angular basalt stone aggregate from a local source are used as coarse aggregate. In present work 20mm aggregates are used as coarse aggregate. According to the sieve analysis the 20 mm and 12.5mm aggregates are used in 65:35 proportions. All properties of aggregates are tested as per IS 2386 (Part-I, II, and III)-1963 'Method of Tests for Aggregates for Concrete' and confirming to IS 383 1970. Physical properties of the coarse aggregate used for the study are given in Table 3.2.

Table- 3.2: Primary test results of materials.

Sr. No.	Material	Property	Value
1	Cement OPC (Ordinary Portland Cement)	Fineness	6%
		Initial setting time	40 minutes
		Final setting time	215 minutes
		Standard consistency	32%
2	Fine Aggregate (Confirming to IS 383-1970 and IS 2386 (Part-I, II, and III)-1963)	Specific gravity	2.6
		Water absorption	2.44%
		Fineness modulus	3.19
		Surface moisture	Nil
3	Coarse aggregate (Confirming to IS 383-1970 and IS 2386 (Part-I, II, and III)-1963)	Specific Gravity	2.70
		Water absorption	0.89%
		Fineness modulus	7.00
		Surface moisture	Nil

3.6 Design of Concrete Mix

Basically, the problem of designing a concrete mix consists of selecting he correct proportions of cement, fine and coarse aggregate and water to produce the concrete having the specified properties i. e. certain minimum strength and durability as economically as possible. Sometimes the fifth ingredient, as an admixture may be used in the concrete, so the mix design process must take account of those factors, which have the major effect on the characteristics of the concrete. By considering all the factors following method of mix design is finalized. The mix design is done according to 1988 British Standard Method of mix design. Presently it is identified by the name D. O. E. (Department Of Environment) method. This method is specially used for the concrete containing fly ash, rice husk ash, silica fume, etc.

4. RESULTS AND ANALYSIS

The test results showed a significant difference in the specimens tested, with bacteria along with partial replacement of cement with three percentages (2, 4 and 6) with Rice Husk Ash by weight. Here are the following table which will give clear information about the compression strength test results. The tests were carried over for 7 and 28 days.

Table -4.1: Compressive strength test results for 07 days

Sr. No.	Description	Days	Compressive Strength (Mpa)
01	0% RHA	07	15.84
02	0% RHA	28	24.07
03	2% RHA	07	17.40
04	4% RHA	07	18.89
05	6% RHA	07	19.91
06	0% RHA with 10^3 Bacteria	07	18.21
07	2% RHA with 10^3 Bacteria	07	18.67
08	4% RHA with 10^3 Bacteria	07	19.82
09	6% RHA with 10^3 Bacteria	07	22.66

5. CONCLUSIONS

The results show that the effect of bacteria has really worked out as it is giving great strength and as it is eco-friendly it is a very good material and is safe to use as it is totally harmless to living beings. This concrete can be used to prevent cracks and hence saving the structure from corrosion of steel.

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