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Strength and Durability Properties of Bacterial Rice Husk Ash Concrete

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Abstract*:- Concrete is most widely used construction material used all over the world and usually considered as indestructible because of their longer service life as compared with the most constructional products. However, continuous exposure of hard weathering leads to an increase of the porosity of concrete and as a result, the mechanical features decreases. The permeability of the concrete depends on the porosity and on the connectivity and /or structure of the pores. A unique way of concrete design crossbreed between biology and engineering study of concrete called microbial concrete has been introduced, which involves the utilization of bacteria to increase the strength and durability of concrete. These microorganisms are used for calcium carbonate precipitation in concrete, it is highly desirable because the calcite precipitation induced as a result of microbial activities is pollution free and natural. The Calcite precipitation occupies the voids between cement matrixes and therefore leads to denser concrete. The approach does not deplete any natural resources since the bacteria used can be easily reproduced by cultivation process. The use of biological approach in concrete is also considered as a green technology as its production does not involve greenhouse gas emission.The significant objective of the research work further involved the use of bacteria. The bacteria present in the concrete rapidly sealed freshly formed cracks through calcite production. In concrete mix, 0, 5, 10, 15 and 20% cement weight was replaced with rice husk ash. The experiments were carried out to evaluate the effect of bacteria of concentration 10^5cfu/ml on the compressive strength, water absorption, water porosity, abrasion and rapid chloride permeability of concrete made with rice husk ash up to the age of 7, 28 and 56 days.

I. INTRODUCTION

Concrete is a composite material consisting of relatively inert aggregate particles, with a wide size distribution and variable mineralogical composition, embedded in a matrix of hydrated cement paste (hcp). The hardened matrix itself is derived from hydration reactions between Portland**,** cement and water. Producing cement is an energy intensive process and harmful to the environment. Globally, 1.5 billion tons of cement are used each year. Cement production releases approximately one ton of CO_2 for every ton of cement produced, which makes up 7% of all CO_2 emissions produced globally (Mehta and Monteiro, 2014).So, in addition to portland cement, water, and aggregates, modern concretes generally contain at least some of the following additional ingredients:

- Chemical admixtures.
- Pozzolanic materials, such as fly ash, silica fumes, or blast furnace slag.
- Discontinuous fibers, made of steel, glass, or natural, synthetic, or organic materials, which are used in fiber reinforced concrete.

DURABILITY OF CONCRETE

According to the American Concrete Institute in ACI 116 R durability of concrete is defined as its ability to resist weathering action, chemical attack, abrasion, and other conditions of service. Also durability of concrete is defined as the capability of concrete by itself of keeping the original properties for a certain period.

II. LITERATURE REVIEW

Ismail and Waliuddin (1996) reported the effect of rice husk ash passing through #200 and #325 sieves as 10-30% partial replacement of cement on workability of high strength concrete. Mix proportion ratio was set as 1:1.07:1.90 with cement content of 571 kg/m^3.It was seen that with minor variations slump values and density decreased with increase in RHA content.

Khassaf et al. (2014) studied the effect of rice husk ash on slump of the concrete. Water cement ratio was kept constant at 0.58 while cement was replaced by 10, 20 and 30 % of mass. Values of slump were 70, 55, 45 and 15 mm for 0, 10, 20 and 30% replacement of cement by mass respectively. This showed that the value of slump decreased with the increasing amount of rice husk ash.

Habeeb and Mahmud (2010) studied compression properties of 0 to 20 % RHA replacement of cement. It was found RHA concrete gave excellent improvement in strength for 10% replacement (30.8% increment compared to the control mix), and up to 20% of cement could be valuably replaced with RHA without adversely affecting the strength. The results showed that at early ages the strength was comparable, while at the age of 28 days, finer RHA concrete exhibited higher strength than the concrete with coarser RHA. At replacement level of 10%, the percentage of increment for RHA concretes compared to the control OPC mix were 22.2, 26.7 and 30.8% for 5, 10 and 15 % replacement, respectively.

Saraswathy and Song (2007) investigated the effect of rice husk ash as partial replacement of fine aggregate on the compressive strength with cement replacement of 0 to 30% and 28 days of curing. Compressive strength test was carried out in concrete cubes of size 100 mm using 1:1.5:3.0 mix with W/C ratio of 0.53. It was concluded that the compressive strength for all replacement levels increased with blending percentage and with age. The maximum strength at 7 days was found to be at 30% cement replacement of rice husk ash while at 28 days it was found to be at 25 % cement replacement. ***Coutinho (2003)*** determined the rapid chloride permeability of concrete with partial replacement of cement with RHA at 10, 15, 20%. From the results it was seen that 2349.3, 435, 322, 260 C of charged passed at 0, 10, 15, 20 % replacement of cement by rice husk ash. It is evident from the result that the inclusion of RHA significantly reduced the charge passed. The maximum decrease in charge came between 0 and 10% when there was a decrement of 81.4%.

Zhang and Malhotra (1996) investigated the chloride ion penetration resistance of concretes made with 10% RHA. Water cement ratio was kept constant at 0.40 and the testing was done after 28 and 90 days of curing. The values of chloride ion resistance control concrete after 28 and 90 days were 3175 and 1875 C respectively whereas the values for 10% replacement after 28 and 90 days were 875 and 525 coulombs respectively. So after replacement of 10% cement by rice husk ash, chloride ion penetration decreased by 72.4% after 28 days and by 72% after 90 days. All these values are less than 1000 C. As per ASTM C1202 when charge

Ganesan et al (2008) determined the optimum level of replacement for permeability properties of concrete. In this, eight different proportions of concrete mixes (RHA ranging from 5% to 35% by weight of cement) including the control mix were prepared with a water to binder W/(C + RHA) ratio of 0.53. Cylindrical specimens of 100 mm diameter and 50 mm height were cast from each mix for chloride penetration tests and were tested at 28 and 90 days of curing. It can be seen that the total coulombs charge passing through RHA blended concrete specimens continuously decreases with increase in RHA content up to 30%. At 35% RHA there is an increase in total charge passed value and this value is also lower than that of control concrete. This observation is true for both 28 and 90 days cured specimens. Chloride permeability is considerably reduced by partial replacement of OPC with RHA up to 30%. Particularly the total charge passed for 30% RHA blended concrete is considerably reduced (more than 70% reduction) both at 28 and 90 days cured concretes

III. PROPERTIES OF RICE HUSK ASH

Rice husk ash was collected from KGR Agro Fusions Private Limited, Ludhiana, Punjab. Physical and chemical properties of RHA were analysed. Rice husk ash has a very high content of amorphous silicon dioxide and consists of fine spherical particles along with small amounts of iron, magnesium, and alkali oxides. Sieve analysis and physical properties results are given in Table1 .1

Table 1.1: Chemical properties of rice husk ash

Constituent	Constituent %
SiO_2	90.38
K_2O	2.86
Al_2O_3	1.74
Fe_2O_3	1.58
CaO	1.38
MgO	0.69
Na_2O	0.34
SO_3	0.10

3. DESIGN OF CONCRETE MIX

The compressive strength of concrete is considered as the strength and index of its quality. Therefore the mix design is generally carried out for a particular compressive strength of concrete with adequate workability so that the fresh concrete can be properly mixed, placed and compacted. The proportions for the mix were calculated adopting the requirements of water as specified in BIS: 10262-1982. The proportioning of concrete mixes consists of three interrelated steps.

(i) Selection of suitable materials and ingredients- cement, supplementary cementing materials, water, coarse and fine aggregates.

(ii) Determination of the relative quantities of these materials in order to produce a concrete that has desired strength and durability.

(iii) Careful quality control of every phase of the concrete making process.

A. M20 design mix Data

Characteristic strength at 28 day = 20 N/mm^2 Maximum size of aggregate = 12.5mm

Type of exposure

Concrete use = Concrete structure.

B. Table 1.2: Mix Proportion M20

Unit of Batch	Water (l)	Cement (kg)	Fine Aggregate	Coarse Aggregate
Cubic meter content	195	390	568.7	1164.12
Ratio of ingredients	0.5	1	1.45	2.98

MIX COMPOSITION

The concrete mixes were designed with constant cement, fine aggregate, coarse aggregate. Control concrete mixture was designed as per IS 10262-1982 to have 28-day compressive strength of 28 MPa. Then cement was partially replaced with 0, 5, 10, 15 and 20% rice husk ash by weight of cement with 10^5 cfu/ml; of bacteria concentration.

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C. Plate 1.1: Rice husk ash used in the study

IV. RESULT

A. *SEM Analysis*

Figs. 4.27- 4.31 show the scanning electron microscope (SEM) analysis of control and bacterial concrete containing 0%, 5%, 10%, 15% and 20% RHA. SEM images show the formation of calcium silicate hydrate (CSH) and dense structure in R10 due to the hydration reaction in the concrete specimen. In control concrete specimen for R10 (Fig 4.29 a) , more CSH and dense structure was observed after 28 days of curing whereas in R0 (4.27 a) , R5 (4.28 a), R15 (Fig 4.30 a) and R20 (Fig 4.31 a) concrete samples, a significant amount of unreacted calcium hydroxide or portlandite (CH) was observed. Jumate and Manea (2011) observed that after 28 days, CSH forms a mass that exhibits more density, more compactness and more continuity leading to increase in strength. Similar observations were made for bacterial concrete BR10 (Fig 4.29 b) that showed CSH gel formation. Calcite(C) can be observed in all bacterial concrete samples responsible for improvement in strength in bacterial concrete. More voids were found in BR0 (Fig 4.27 b), BR5 (Fig 4.28 b) , BR15 (Fig 4.30 b) and BR20 (Fig 4.31 b) compared to BR10 which had a dense structure. The dense matrix in control and bacterial (10% RHA) showed higher compressive strength and lower water absorption and porosity due to the growth of calcite crystals within the pores of the cement–sand matrix (Enein et al., 2013)

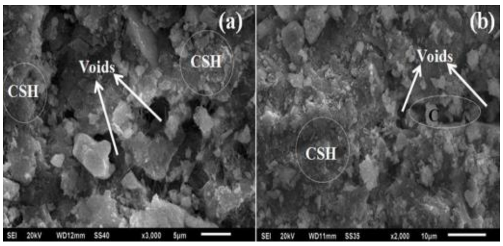

Fig1.2 : SEM analysis of (a) R0 and (b) BR0 at 28 day

B. *XRD ANALYSIS*

This technique was used to observe concrete for CSH gel and calcite formation for concrete and bacterial concrete. XRD analysis of concrete samples with or without bacterial rice husk ash showed peaks of quartz (Q), calcium silicate hydrate (CSH), calcite (C), larnite (L) and ettringite (E) phases.It was observed that in BR0, BR5, BR10, BR15 and BR20, the increased formation of CSH gel and calcite resulted in increased strength compared to R0, R5, R10 and R15. Formation of CSH was high in R10 and BR10 resulting in more strength as compared to other control concrete and bacterial concrete samples. In control concrete, the maximum CSH peaks were seen in R10 in Fig 4.21 signifying more CSH and therefore more strength among the control concrete samples. X-ray analysis of the samples with and without bacteria shows that there were some extra peaks in the XRD spectra of the bacteria treated samples, whichare absent in the control samples. (Dick et al., 2006). Calcite peaks as confirmed by XRD analysis are responsible for lowering the permeability of the specimens (Ramakrishnan et al., 2001). XRD analyses revealed that majority of carbonate deposits were present as calcite crystals along with other components such as quartz (Dhami et al., 2012)

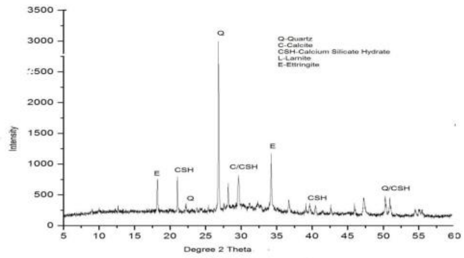

Fig 1.3: X-ray diffraction of control concrete (R0) at 28 day

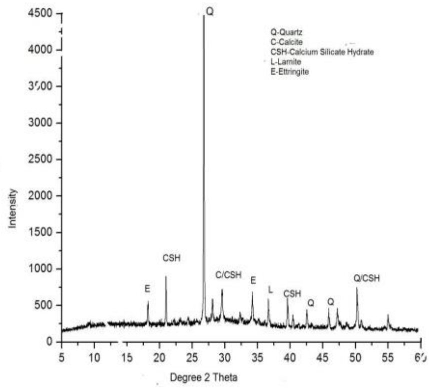

Fig 1.4: X-ray diffraction of bacterial concrete (BR0) at 28 day

C. *Water Absorption*

The influence of control and bacteria concrete on the water absorption of RHA concrete

RHA %	7 days		28 days		56 days	
	Control	Bacterial	Control	Bacterial	Control	Bacterial
0	2.61	1.989	1.872	1.179	1.701	0.954
5	2.367	1.809	1.62	1.071	1.485	0.819
10	2.259	1.674	1.494	0.927	1.323	0.72
15	2.322	1.791	1.584	1.008	1.395	0.765
20	2.475	2.917	1.746	1.125	1.575	0.855

It can be observed from the Table 4.4 that water absorption capacity decreases with age. As shown in Figs 4.11 and 4.12, the minimum percentage of absorption was observed in R10 and BR10, respectively. The water absorption in R10 was 2.51, 1.66 and 1.47% at the age of 7, 28 and 56 days while in BR 10 water absorption was 1.86, 1.03 and 0.80% respectively.

The results were supported by Givi et al. (2010) where decrease in percentage of water absorption in 10% RHA was observed with increasing the age of moist curing from 7 to 56 days during the hardening process of the concrete. Formation of CSH gel as a product of pozzolanic reaction between calcium hydroxide and silica filled the voids and increased the density of concrete resulting in decreased porosity (Chopra et al.,)

V. CONCLUSION

The present work investigated the influence of bacteria on partial replacement of fine aggregate cement by RHA concrete. On the basis of the results from the present study, following conclusions are drawn

1. WATER ABSORPTION AND POROSITY

i. Increased water absorption and pore size decreased the compressive strength and vice-versa. The water absorption of R0 at the age of 28 days was 2.08%, whereas 5, 10, 15 and 20% control RHA concrete showed water absorption of 1.8, 1.66, 1.76 and 1.94%, respectively. At 28 days, minimum water absorption of 1.66% and 1.03% was observed in 10% RHA replaced control and bacterial concrete.

ii. At 7 days of curing bacterial concrete had minimum water absorption of 1.86% for 10% RHA compared to control concrete which showed water absorption of 2.51%. Similarly at 56 days bacterial concrete at 10% RHA replacement had water absorption value of 0.80% compared to 1.47% of control concrete.

iii. Similarly for porosity, the minimum values of 5.46, 3.90 and 3.12% were observed by 10 % replacement of control concrete at 7, 28 and 56 days compared to porosity values of 3.32, 2 and 1.52 % of bacterial concrete at 7, 28 and 56 days.

iv. Increased percentage of RHA upto 10% lead to decrease in water absorption and pororsity and made concrete structure more dense.

v. Water porosity and absorption was less in mixtures where bacteria was added as compared to the mixtures without bacteria. This indicates that the pores of the concrete may have been reduced in number or may have been blocked, which was the result of calcite precipitation by bacteria.

2. SCANNING ELECTRON MICROSCOPE (SEM)

i. SEM analysis reveal increased formation of CSH gel for mixes which supports the increased compressive strength upto 10% RHA in control and bacterial concrete.

ii. Pores were observed maximum for 0% replacement of RHA. Most dense structure was observed in case of R10 and BR10 that results in highest compressive strength for 10% RHA replacement.

3. X-RAY DIFFRACTION

i. XRD analysis revealed the increase formation of CSH gel which supports increase in compressive strength for mix containing RHA.

ii. XRD analysis confirmed the formation of higher calcite peaks in bacterial concrete compared to control concrete which causes an improvement in the strength of material.

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