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ORIGINAL CONTRIBUTION

Usage of Green Material in Building Construction Evaluating its Outcome on Varied Properties of Concrete

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Abstract— **Rice Husk Ash was selected as a green material. Two types of Rice Husk Ash (RHA) were considered and one of them was selected for this study. The RHA was characterized and its effect on the properties of cement, especially strength and shrinkage were studied. Four formulations containing 0, 10, 15 and 20 percent of RHA were prepared for flexure, compression and shrinkage including X-ray diffraction and fluorescence test. All formulations were prepared at their standard consistency. The results indicated that the RHA used in our study was not an effective pozzolanic material and had an adverse effect on the strength and shrinkage properties of the cement formulations due to its increased water demand and large particle size. This investigation proved that it cannot be used in the projects where early higher strength is needed.**

Index Terms— **Green Technology, Green Concrete, RHA, XRD, Compression, Flexure, Shrinkage**

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I. INTRODUCTION

A green material is supposed to be made with renewable rather than non-renewable products; this suggests that the recycling and resources available in abundance are of utmost importance when considering a green material [1]. Building and Construction industry worldwide consumes over 3 billion tons of raw materials which makes up for about 40 percent of total use of raw materials. This further enhances the concept of using green materials to conserve and save up on the already dwindling resources that are available to us [2].

Green material and building promote sustainability which means that carbon emissions and the overall effect that harmful gasses have on the environment is reduced to a great extent [3, 4]. Sustainability has two parts to its definition in terms of green building materials, first one suggests the idea of not using the already dwindling non-renewable natural resources and maintaining their availability as they exist, we can guarantee this by finding other alternatives and with recycling the existing products that are going to waste for example saw dust, broken glass or Rice Husk Ask, can be used productively, secondly it suggests that the harmful gasses are kept minimal and the material that has negative effects on the environment is recycled and reused [5].

Use of green material can have many advantages depending on the way the whole idea of green buildings is implemented:

- They help preserve the environment as using the wasted products that would otherwise contaminate the environment and the raw materials that release less or no harmful gasses will help keep the environment at a healthy level
- They also help conserve energy which means using wasted products would help in reducing the energy required in producing raw products for traditional materials
- They also ensure reduced initial and replacement costs over the lifespan of the building since less energy is being utilized, and initial cost is also reduced as we use SRMs.

Disposing waste has huge impact on the environment and can cause serious health complications [6]. Most of the time the waste generated is dumped into landfills, in dug up holes, or incinerated which generates a lot of harmful gasses like methane which is a combustible and also contributes to the degeneration of the environment as a greenhouse gas. Recycling and reusing these wasted products can have a positive effect on the amount of greenhouse gasses and degeneration of the environment [7]. Recycling materials like paper, glass, wood, plastic etc. can help preserve the environment. And since the construction industry uses about 40 percent of the raw materials being consumed globally recycling or reusing wasted materials in this industry can help contribute towards a healthy society to a great extent [8].

Secondary Replacement Material (SRM) generally requires less energy when being consumed as a binder in cement. SRMs are supposed to partially replace cement having almost the same binding properties as cement

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[9]. This is required because the use of cement proves to be very hazardous for the environment, if we consider 1 ton of concrete being produced with 14 percent cement about 180 KGs of Carbon Dioxide is produced which is a greenhouse gas [10]. Generally, these materials contain no cementitious properties on their own but once they are mixed up with cement and water, they produce compounds that would rather prove to have a cementitious effect [11]. These products can also be industrial by-products. Some of the SRMs are Rice Husk Ash, Silica Fumes, Fly Ash, and Limestone Powder. These products can have a positive or a negative effect on the properties of the cement i.e., permeability, strength, water demand, temperature size, freeze-thaw property, chemical attack resistance, stability and microstructure [12]. SRMs are mostly used with Super plasticizers as they help control the water demand or rather other properties having major effects [13].

Seaweed can be used as an alternate in producing bricks. Since the bricks used are produced by burning in kilns which results in very harmful gasses being emerged into the environment [14]. To make bricks a green material we use Sea weed, which contains Alginate. Alginate can have different properties depending on where it has been extracted from (specific region of plantation) but it can be tailored to the specific requirements [15]. Alginate acts as a gelling material in general and since it is available in abundance it contributes to being a green and a sustainable material. When the alginate polymer is added to soil it forms ionic bridging with the calcium contained in the soil increasing the strength of bricks [16]. The point of significance is that bricks produced with seaweed are not produced by burning; rather they are bound together by the seaweed itself. Saw-Dust can be used as a replacement for fine aggregate in concrete. It is a by-product obtained from wood working industry. It also proves to be cheaper than sand since there is not a lot of demand for sawdust otherwise in the market [17]. Sawdust concrete is light weight and gives sufficient heat insulation and fire ratings. When tested for flexure strength it was determined that concrete containing 25 percent sawdust at 7 days had 1.15 N/mm sq. to 1.67 N/mm sq. at 28 days. Sawdust has achieved the compression strength of 3000 psi at 28 days. A phenomenon that's proved to be different than regular concrete is that the failure of sawdust concrete is more like that of a wood, where the fibers try to hold it together. In concrete, sawdust helps in gaining the type of structure where it prevents the concrete from total failure upon application of tensile forces. For coarse aggregate Broken Glass can be used to produce similar or rather better results. Glass is a 100 percent recyclable material, where most of it goes to waste in landfills. Glass concrete has great potential but Alkali-silica Reaction (ASR) might occur in the concrete causing deterioration [18, 19]. Certain suppressants can be used to mitigate this effect, like white Portland cement which has a very low alkaline content. If colored glass is used compression strength of about 40 MPa can be achieved at 28 days. Another issue with using glass in Pakistan is that it requires a working recycling system. This, unfortunately, is not present in Pakistan.

A. Research Focus and Objectives

The research was focused on selecting an adequate material that would prove to be cheap and available in abundance in the market considering the regional significance on this research. Materials that were considered included RHA, Fly Ash, Silica Fumes, Saw dust, Seaweed, Broken glass. The materials were studied in detail for adequate selection of the most suitable material that would prove to have less carbon emissions into the environment and have a cost benefit as well.

The objective of this study is to choose a suitable green material and study its immediate effects on the properties of concrete and to see if it's a viable material to be used in the construction industry.

II. MATERIALS AND METHODS

Following are the materials used in this investigation with method of stabilizing construction material by the use of green material.

A. Cement Chemistry

ASTM C-150 defines Portland cement as hydraulic cement (cement that not hardens by reacting with water but also forms a water-resistant product) produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulphate as an intern ground addition [20]. The setting and hardening properties of concrete are determined by chemical reaction caused after the contact arises between water and cement. The rate of heat of hydration of cement plays an important role in determine concrete strength and durability. On coming in contact with water, Hydration of cement starts. Hydration of cement is defined as "dissolution –precipitation process between binder grains and water".

Major constituents of OPC are tricalcium silicate (C3S), dicalcium silicate (C2S), Tricalcium aluminate (C3A) and Tetra calcium Aluminoferrite (C4AF). These constituents react with water to form hydration products such as main hydration product of C-S-H (Calcium Silicate Hydrate), portlandite (CaOH2), Ettringite (CASH, Calcium Sulfoaluminate hydrate) and calcium monosulphoaluminate C4ASH12).

B. Secondary Raw Material (SRM)

Waste products or by products of industry can be worked as SRM. SRMs are not like cement in nature but can be used as partial replacement of cement. Also enhance the properties of concrete. This increases efficiency of industry and reduces production of cement. During lime stone calcination, OPC pastes and mortars are responsible for emission of CO_2 [21].

C. Rice

Rice is a heavy staple in the world market as far as food is concerned. It is the second largest amount of any grain produced in the world. Rice husk is extremely prevalent in East and South- East Asia because of the rice production in this area [22].

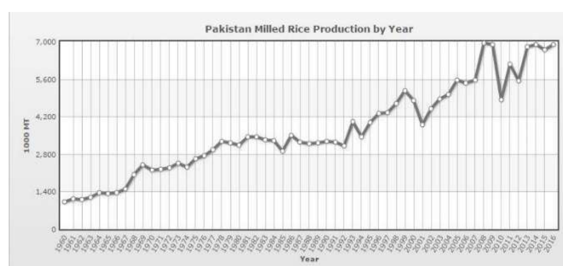

Fig. 1. Graphical representation of rice production

1 MT = 1000 kilograms

United States Department of Agriculture 6500 (1000 MT) is Pakistan last five-year average production.

D. Rice Husk Ash (RHA)

Rice husk ash (RHA) is a by-product from the burning of rice husk. The rice husk ash is a highly siliceous material that can be used as an admixture in concrete if the rice husk is burnt in a specific manner. During the burning process, the carbon content is burnt off and all that remains is the silica content. If the rice husk is burnt at too high a temperature or for too long the silica content will become a crystalline structure due to cristobalite and quartz. Similarly, if the rice husk is burnt at too low temperature or for too short period of time the rice husk ash will contain huge amount of un-burnt carbon. Optimum temperature for burning is 600-700 C and on above temperature structure is amorphous and carbon content is minimal.

E. Effect on Concrete Properties

Only 20% by weight of husk is recovered as ash when rice husk is burnt. Of which 75% is silica by weight. Silica can improve properties of fresh concrete, reduce heat evolution, reduce permeability and may increase strength at longer ages.

1) Emission of CO_2

CO_2 is emitted during the calcination of Cement Kiln Dust (CKD) in the kiln. CKD is a by-product of the kiln process and a portion of the CKD is placed back in the kiln and incorporated into the clinker. CO_2 is emitted during clinker production (not cement production). Carbon dioxide (CO_2) is a byproduct of a chemical conversion process used in the production of clinker, a component of cement, in which limestone ($CaCO_3$) is converted to lime (CaO). CO_2 is also emitted during cement production by fossil fuel combustion (Michael J. Gibbs, Peter Soyka and David Connelly ICF Incorporated).

F. Conceptual Design of Research Method

The scope of this research as defined earlier is limited to the strength and shrinkage of paste and the consistency of system is kept constant.

The rice husk used for preparation of RHA was acquired from J.B Rice mil Gakkar and it was taken into account that no water came into contact with the rice husk during whole process. The acquired rice husk which was sealed into tight containers was opened and spread over treys and put into oven. It was heated at 120°C for 2 weeks to make sure that no accumulated water was present within the rice husk. Dried rice husk was burnt in carbonize present in lab. During the burning process rice husk was constantly stirred to make sure that no heat pockets were formed. The maximum recorded temperature was 633°C. After three hours of incineration, Ash was collected and put into furnace. The temperature of finance was kept at 650°C. This was done to minimize the carbon content from ash and also to make sure that all of rice husk is burnt. The reason for keeping the temperature range below 650°C is the reactivity of different forms of silica. While in case of crystalline silica content the reactivity and pozzolanic activity is reduced. The melting point as mentioned in Mehta's research is 800°C. At this temperature silica present in rice husk is melted and when slow cooling is done then it is converted into crystalline form, which in turn reduces the pozzolanic activity the silica present in the powder is checked through XRD.

Rice husk ash was procured from rice mill located in Gakkar. In that rice mill rice husk is burnt and heat evolved is used in boiling of water which produces steam and that steam is used in softening of paddy's outer covering. The rice husk ash is produced as a byproduct during the whole process which is wasted or disposed of in the environment which causes pollution. We collected sample and checked the morphology as well as the quantity of silica content.

Cement we used was acquired from Askari cement factory and this was OPC grade 53 cement. It was packed into the sealed containers and no water came into contact during the whole process of transportation to minimize margin of error due to changing humidity.

III. RESULTS AND DISCUSSION

Following are the tests performed in this investigation on use of green material for building construction.

A. Particle Size Analysis (PSA)

Particle Size Analysis is performed to obtain information about characteristics like Mean Size, Variance and standard deviation of a material. This gives us an insight about the reactivity and its effect on the microstructure of the formulation. PSA was performed on both the cement sample and the Rice Husk Ash (RHA) sample to obtain the distribution graph and the mean size. The results are presented below.

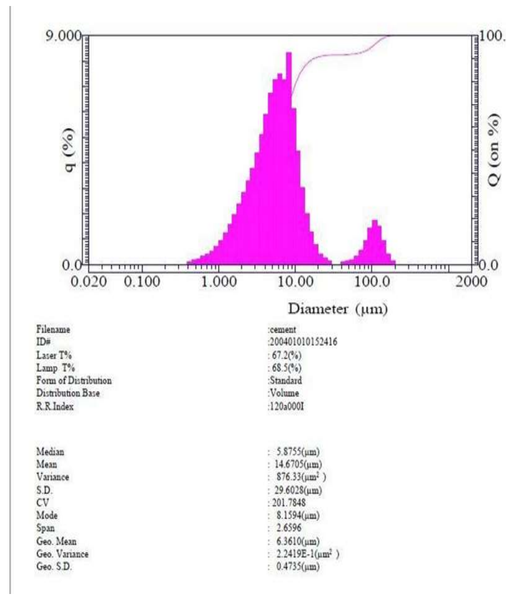

Fig. 2. Particle size distribution of cement

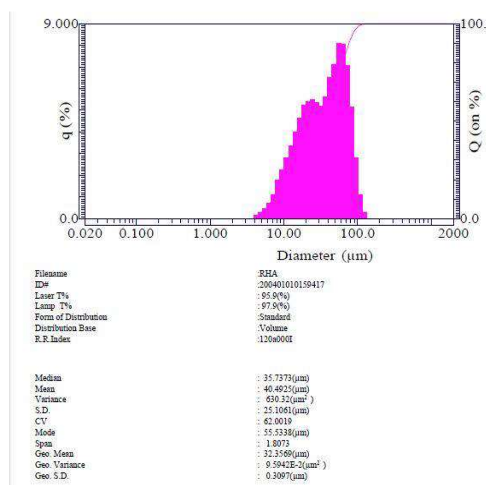

Fig. 3. Particle size distribution of RHA

The results show us that the mean size of the cement used in our study is 14.7μm while that of the RHA used is 40.5μm. Generally, it is preferred to have a fine pozzolanic material to increase its reactivity and enhance the microstructure of the formulation but this has adverse effect on the water requirement and shrinkage of the formulation. Moreover, the literature review showed that RHA may have a mean size ranging anywhere from 10μm to 50μm.

B. X-ray Fluorescence (XRF)

This test is used for the chemical analysis of a material. It gives us the percentage of certain compounds present in the specimen under consideration. There were types of RHA initially available. The first one will be referred to as 'Field RHA' as it was procured from a rice mill where the husk was burnt as a fuel to heat water. The second one will be referred to as 'Prepared RHA' as it was prepared by a PG student in NICE under controlled conditions. The compound of interest in RHA is SiO_2 as this compound in its amorphous form gives RHA its pozzolanic properties. Ideally the amount of SiO_2 should be in the range of 80-98%. But both samples of RHA do not fall in this range. Especially the Field RHA has only 59.65% SiO_2 which shows that there are other impurities, chiefly unburnt carbon, present in it due to its uncontrolled burning. The RHA prepared at NICE, although has a better proportion of SiO_2 but due to limitation of the equipment present, high amounts of SiO_2 could not be obtained.

TABLE I
XRF OF ASKARI CEMENT

Serial No.	Compound	Value	Unit
1	SiO_2	19.97	%
2	Al_2O_3	5.37	%
3	Fe_2O_3	2.91	%
4	CaO	64.9	%
5	MgO	1.54	%
6	K_2O	0.83	%
7	Na_2O	0.18	%
8	SO_3	2.25	%

TABLE II
XRF OF FIELD RHA

Serial No.	Compound	Value	Unit
1	SiO_2	59.65	%
2	Al_2O_3	0.68	%
3	Fe_2O_3	0.04	%
4	CaO	1.38	%
5	MgO	0.21	%
6	K_2O	0.9	%
7	Na_2O	0.07	%
8	SO_3	0.17	%

TABLE III
XRF OF PREPARED RHA

Serial No.	Compound	Value	Unit
1	SiO_2	71.23	%
2	Al_2O_3	1.29	%
3	Fe_2O_3	0.76	%
4	CaO	1.94	%
5	MgO	3.85	%
6	K_2O	2.82	%
7	Na_2O	1.43	%
8	SO_3	0.32	%

C. X-Ray Diffraction (XRD)

XRD gives us information about the Morphology and phase detection of a material. The broader the peaks the more amorphous the material will be. Below are the results of XRD of both RHA samples.

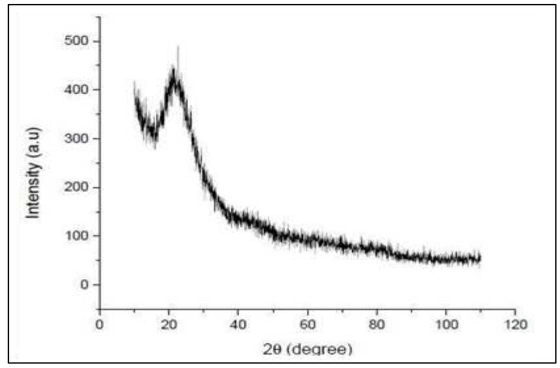

Fig. 4. XRD of field RHA

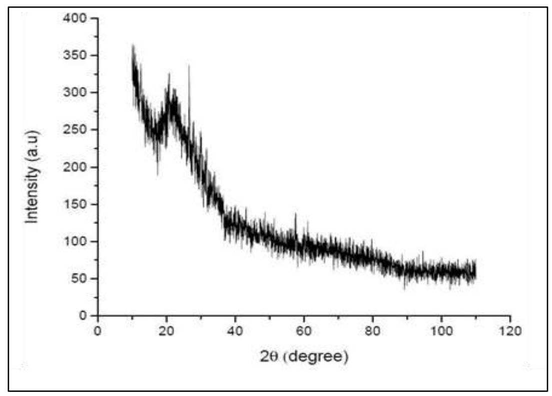

Fig. 5. XRD of prepared RHA

For proper pozzolanic reactivity of RHA the SiO_2 present should be of the amorphous nature as crystalline SiO_2 does not react with the cement reactants and only acts as a filler material.

Both samples of RHA show similar broad characteristic peaks at 22° signifying their amorphous structure. It can be observed that the field RHA sample shows a more intense peak as compared to the prepared RHA signifying more crystalline SiO_2 presence in the field RHA.

D. Consistency Test

The consistency test conforming to ASTM C-187, gives us the amount of water to cement ratio to be used for further tests including flexure test and compression test. Moreover, it gives us a measure of 'workability' of the formulation. Workability is broadly defined as the ease with which the cement paste can be applied or the 'flow ability' of the cement paste.

The table below shows the standard consistency of our four formulations.

TABLE IV
RELATIONSHIP BETWEEN RHA REPLACEMENT AND CONSISTENCY

Serial No.	RHA (%)	Standard Consistency
1	0	0.26
2	10	0.35
3	15	0.4
4	20	0.46

It can be clearly observed that the percentage replacement of RHA has an adverse effect on workability, i.e., more water is required to achieve the same amount of workability as more RHA is replaced with cement.

The Graph below shows the relationship between amount of RHA replacement and the standard consistency.

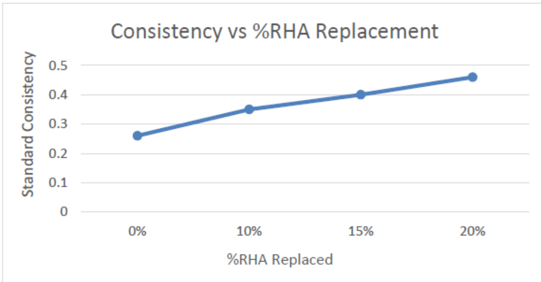

Fig. 6. Relationship between consistency and amount of RHA replacement

The relationship between RHA replacement and the standard consistency is close to linear. This increase in water requirement is consistent with other studies conducted on RHA. This may be attributed to the higher surface area of RHA and its reactivity which consumes more water early in the hydration process.

E. Compressive Strength Test

The compressive strength test was conducted in accordance with ASTM C-349 on broken prism samples. Each formulation had 3 samples which were broken into 2 giving us a total of 6 samples for each formulation. The average compressive strength was calculated and is tabulated below.

TABLE V
FINENESS MODULUS OF ALL THE DIFFERENT AGGREGATES

RHA (%)	Days	Strength (Psi)
	7	7769.58
0	14	10133.33
	28	11550.48
	7	4029.31
10	14	6208.33
	28	6601.87
	7	3724.08
15	14	5258.18
	28	5892.61
	7	2689.34
20	14	3690.25
	28	4426.85

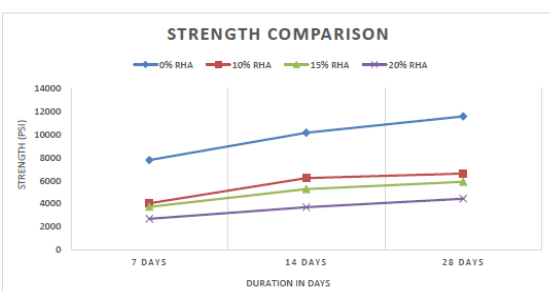

Fig. 7. Strength comparison of formulations

It can be observed that the initial addition of 10% RHA drastically reduced the strength of the cement paste. This is mostly attributed to the higher amount of water present in the RHA formulations which is a consequence of the inherent increased water demand of the RHA formulations. Moreover, another factor which may have reduced the strength further is the difference in size of RHA and cement particles. Smaller particles have been shown to enhance the strength of the formulation. Our results are consistent with other results which show lower early strength development in RHA samples. The difference in strength between 10% RHA and 15% RHA is relatively small when compared between other formulations. This seems to be the sweet spot between amount of RHA Replacement and strength.

IV. LINEAR SHRINKAGE TEST

Linear shrinkage gives us information about the volume changes in the specimens. The greater the volume changes, the more adverse effect it has on the formulations. Below is a comparative graph of the Shrinkage in the various formulations.

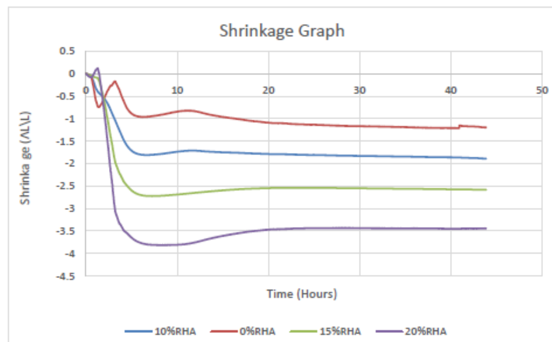

Fig. 8. Shrinkage comparison of formulations

It is a known fact that shrinkage increases with increasing amount of water. It can be seen that with the increase in amount of replacement of RHA, the shrinkage of the formulation increases as well. This is due to the fact that the amount of water is greater in formulation with RHA present. It should be noted that there is no drastic increase in shrinkage in the 10% RHA formulation compared to the control sample with no RHA as opposed to the drastic decrease in strength observed with 10% RHA sample. This may hint towards better shrinkage performance of RHA if the amount of water is kept the same. But in its original form, RHA drastically increases the water requirement hence leading to greater amounts of shrinkage.

V. CONCLUSION

The following conclusions can be drawn from the research undertaken:

- The preparation of RHA is a delicate process as it requires controlled temperature. Moreover, the current infrastructure present in Rice mills is inadequate to produce amorphous as well as carbon free RHA.
- RHA drastically increases the water demand of formulations. There is an approximately linear relation between amount of RHA replaced and the water demand.
- Due to the inherent property of RHA to increase water demand, it significantly reduces the strength of cement formulation. This eliminates the use of RHA in high strength concrete.
- With increasing RHA replacement, the shrinkage of the formulations increases. Though this increase is rather linear and not abrupt or drastic as compared to the decreased strength in RHA samples.
- RHA slows the rate of strength gain i.e., RHA is unsuitable for applications requiring early strength.

VI. RECOMMENDATIONS

We suggest the following recommendations to make RHA a viable cement replacer:

- As w/c in concrete is kept high (0.4-0.6) further Studies have to be conducted on concrete itself to test if RHA provides sufficient strength to be used as structural concrete.
- The major problem with RHA is its requirement of greater amounts of water compared to cement. If the water demand of RHA can be reduced its strength will increase significantly.
- Refinement in RHA production is required to increase its pozzolanic activity and in turn make it a viable material to be used in cement.

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