Rice Husk Ash as a Potential Supplementary Cementing Material

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Abstract: This article presents a study on the properties of Rice Husk Ash (RHA) and its possible utilization as a supplementary cementing material in the construction industry. RHA is usually extracted from the incineration of rice husk. The ash content in the husk is about 15-20% by the weight. Two samples of RHA1 and RHA2 extracted from burning of rice husk. The incineration of rice husk was done for three hours in a drum type burner in the laboratory and then further kept the extracted ash in muffle furnace at a temperature of 350^{o}C for two hours to get maximum amount of silica. The chemical characterization was carried out with the help of the Energy Dispersive Spectrometry (EDS) to check the silica content. It was found that the rice husk ash has 70.38% silicon dioxide, which meets the requirement of ASTM 618-03 for a pozzolanic material. The morphological characteristics were studied through Scanning Electronic Microscopic (SEM) and ash was found to be porous and multi-layered in nature. The X-ray Diffraction (XRD) analysis proved the existence of non crystalline silica in the ash. The broad diffused peak at 22o in the XRD graph validates the presence of amorphous silica content and the 28-days strength activity index also validated the pozzolanic property of the extracted RHA.

Keywords: *Amorphous silica, strength activity index, XRD, RHA, cement replacement.*

1. Introduction

Research is being carried out to make the best use of waste material to minimize the environmental pollution caused the abundant left generated wastes.Rice-husk (RH) is one of the agrarian by-product materials constituting at around 20% of the weight of rice. It is usually composed of 50% cellulose, 25–30% lignin, and 15–20% of silica. RHAis generated from rice husk when the husk is burnt. Upon burning the husk, ash contained silica is produced and subsequently cellulose and lignin are removed. Since each ton of rice generates 40 kg of the ash [1]. RHA is a very fine pozzolanic material and is a highly reactive pozzolan obtained when rice husks are calcinated below the crystallization temperature at 780^{0}C [2, 3]. RHAcould be manufactured by controlled burning of the rice husk between 550^{o}C and 700^{o}C the burning temperature for 1 h converts silica content of the ash into amorphous phase[4, 5].

Silica in the ash goes through structural alterations depending on the temperature management it undergoes whileburning. At 550–800oC an amorphous silica is formed and a crystalline silica is developed at a greater temperature. Rice husk ash blended concrete is exceptionally well in terms of strength and durability performance[6-8]. Usually after the extraction, the produced RHA is ground by using abrasion machine, however, [1] stated that non ground rice husk ash could be used to substitute 15% of Portland cement with similar mechanical and durability properties. The usage of ashes produced from the burning of other vegetable species as pozzolans in concrete have already been stated by numerous researchers [9-11].The researchers [12-14]showed that by blending RHA as cement replacement material in concrete the wide-ranging enhancement in durability properties could be attain in concrete.

The basic purpose of this study is to develop rice husk ash as a supplementary cementing material from a simple mechanism.

2. Experiential procedure

2.1.Material Preparation

Locally available rice husk in the locality of district Nawabshah, Sindh Pakistan was obtainedand was burnt in a drum type furnace made in the laboratory as shown in Fig. 1.

Figure.1. Drumtype furnace

After burningthe rice husk ash, it was allowed to cool approximately for 24 hours. After cooling, the extracted ash was sieved from # 40 sieveso as to separate less brunt particles and then the sieved ash was taken out for gridding using Los Angles machine.

2.2. Preparation of samples

Two types of the rice husk ashsamples were prepared. The very firstsample namely Rice Husk Ash (RHA1) was formed by burning of the rice husk in un-controlled temperature environment in drum furnace for 3 hours under the maximum temperature of 677^{o}C. The second sample of Rice Husk Ash (RHA2)was produced by the keeping the extracted rice husk ash(RHA1) for further burning in muffle furnace at a temperature 360^{o}C for 2 hours.

2.3. Physical characterization

Gridding of the ash was done in Los Angeles machine for one and half an hour.The physical properties of both samples of RHAs i.e. specific gravity and blaine fineness test were carried as per by ISNo.383-1970and as per EN-196-2005 method,respectively.

2.4. Chemical characterization

The chemical compositionof bothsamplesof rice husk ash (RHA1) and (RHA2)were carried out by EDS Test.Loss on Ignition was carried out in accordance with ASTM C-114. A 10 gram of the sample previously dried in oven at 110^{o}C was kept in muffle furnace to burn further at 950^{o}C for 45 minutes. The loss of ignitionwas determined in percentage.

2.5. Mineralogical and morphological characteristics

The mineralogical characteristics of rice husk ash(RHA2) were verified qualitatively by X- XRD. The diffractograms were obtained using Cumonochromator for ground sample over a 10–80^{o}at2θ range. The Morphological analyses of RHA were conducted by scanning SEMto examine the material's topographiccharacteristics.

2.6. Strength activity indexed

The mortar specimens were cast by 20% replacement of cement with extracted rice husk ash (RHA2) by weight as shown in Table 1. The reactivity index can be calculated by: SAI =(X/Y) x100,
where X= Control Mix strength and Y= RHA-modified Mix strength.

Table.1. Mix proportion of mortar

Mix ID	Cement (gms)	RHA (gms)	W/B ratio	Sand (gms)
A	1000	---	0.49	2750
B	800	200	0.49	2750

3. Results and discussion

3.1. Physical characterization of rice husk ash

The average specific gravity of both kind of ashes (RHA1)&(RHA2) are 2.01 and 2.05respectivelyas shown in Table 2.The both samples of the ash exhibited almost similar specific gravity results due to the same gridding period. The result suggests that the ash is lighter in nature. Interestingly, the measured valuesare in the range of the values seen in the other research studiesas shown in Table 2. From fineness test, the fineness of the ash (RHA1)&(RHA2) as retained on 45 µm was found 5% and 95% passing; which is within the limits defined by ASTM C618-03 and the ash conformed to grade A of dry pulverized–fuel ash based on ASTM C430[15]. The fineness value of ash (RHA1) & (RHA2) found to be within the range of other authors' research studiesas shown in Table 2.

3.2. Chemical characteristics rice husk ash

To spot and calculate the major and minor elements present in the samples ofRHA1 & RHA2, the Energy Dispersive Spectrometry (EDS) analysis was carried out. The graph in Fig. 2 illustrates the presence of silica in maximum count along with other elements in theextractedRHA1.

Table 2 Physical properties of Rice Husk Ash (RHA)

Researchers	Specific gravity	Fineness: Passing 45 µm (%)
[14]	2.06	99
[16]	2.06	99
[17]	2.10	-
[18]	2.10	-
RHA1	2.01	95
RHA2	2.05	95

The graph in Fig. 2 generated by the EDS of RHA2 shows the increased count of the silica content as compared to the extracted rice husk ash RHA1 due to further burning of sample in furnace. A typical chemical composition of RHA1 & RHA2 obtained after burring and gridding is shown in Table 3. A distinction is drawn between the chemical compositions of the both samples of ash (RHA1) & (RHA2) as shown in Table 3. From table 3, it can be observed that the quantity of SiO_2 in RHA2 is greater than that of silica in RHA1. Furthermore, the sum of major elements like SiO_2+Al_2O_3+Fe_2O_3 in RHA1 is 57% which does not meet ASTM C618-03 requirement for a pozzolanic material because of not proper burning of rice husk. While the sum of oxides i-e SiO2+Al_2O_3+Fe_2O_3 in RHA2 is 72.83 % which conforms to the requirement of ASTM C618-03 and this type of pozzolana is suitable for supplementary cementing material as per ASTM.

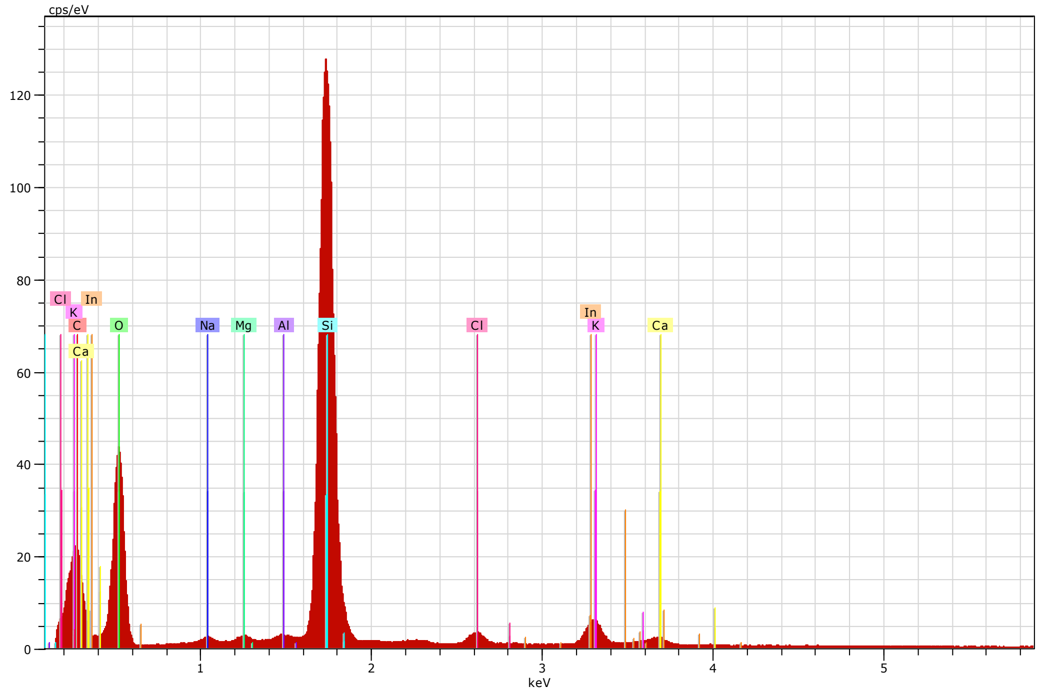


Figure.2. The chemical analysis of rice husk ash (RHA1)

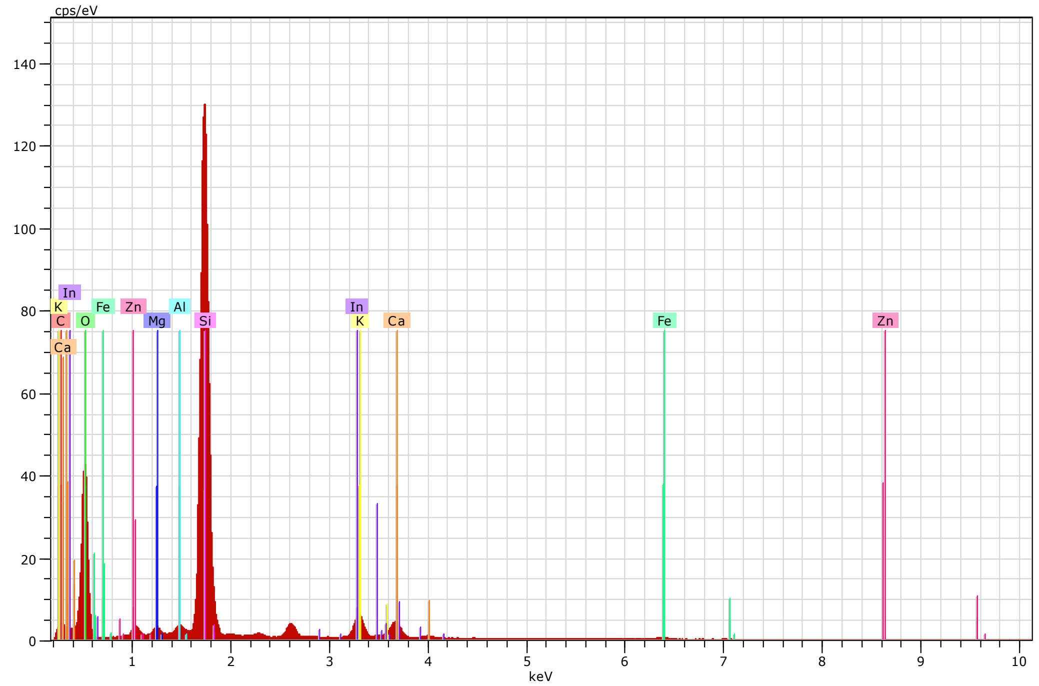


Figure.3. The chemical analysis of rice husk ash (RHA2)

The graph in Fig. 2generated by the EDS of RHA2shows the increased count of the silica content as compared to the extracted rice husk ash RHA1due to further burning of sample in furnace. A typical chemical composition of RHA1& RHA2 obtained after burring and gridding is shown in Table 3. A distinction is drawn between the chemical compositions of the both samples of ash (RHA1)&(RHA2) as shown in Table 3. From table 3, it can be observed thatthe quantity of SiO_2 in RHA2is greater than that of silica in RHA1.Furthermore, the sum of major elements like $SiO_2+Al_2O_3+Fe_2O_3$ in RHA1is 57% which does not meet ASTM C618-03 requirement for a pozzolanic material because of not proper burning of rice husk.While the sum of oxides i-e $SiO2+Al_2O_3+Fe_2O_3$in RHA2 is 72.83 % which conforms to the requirement of ASTM C618-03 and this type of pozzolana is suitable for supplementary cementing material as per ASTM.

Table.3. Physical &chemical composition RHA1 & RHA2

Samples	**Physical Properties**		**Chemical Analysis (%)**						
	Specific Gravity	Blaine(cm^2/g)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	LOI
RHA1	2.01	2248	56.07	0.76	0.86	0.97	0.65	2.16	10
RHA2	2.05	2255	70.38	1.59	0.86	3.19	3.32	2.88	5

The loss of ignition for rice husk ash is usually due to the presence of unburned carbon (indicating the burning efficiency of the furnace). The mineral phases don't remain stable at high temperature[19]. Loss on ignition of the ash (RHA1) is greater than that of the ash (RHA2) because of burning and duration. The increased loss on ignition suggests that an increased amount of un-burnt carbon content inthe ashRHA1 and such type of pozzolanic material has adverse effects when blended with cement. LOI of the rice husk ash RHA2 is 5 % which conforms to the ASTM C618-03requirement.

3.3. Mineralogical and morphological characteristics

The mineralogy of rice husk ash (RHA1) carried out by X-ray diffraction is presented in Fig. 4. The material consists essentially of an amorphous silica structure due to the broad peak on 2θ angle of 22°as shown in Fig.4.It has been reported that the diffused peak at $2\theta = 22^o$shows formation of amorphous silica [20]. The SEM test snaps show that the ash (RHA2) is multifaceted, angularwith micro absorbentsurface and images verdict its high specific surface as shown in Fig. 5(a) & (b). The colour of produced ash (RHA2) was light grey.

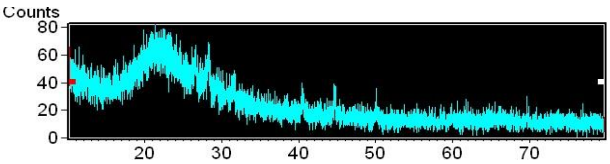


Figure.4. XRD pattern RHA2

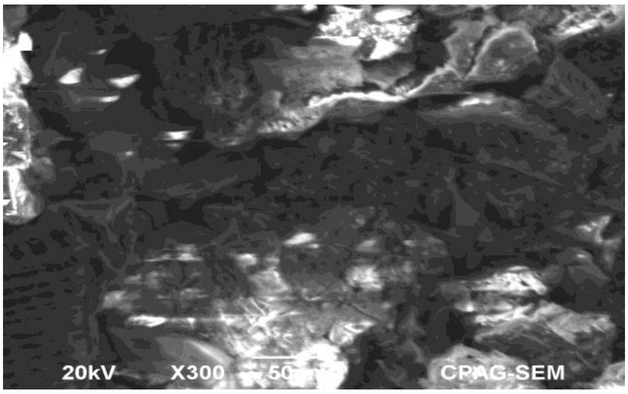
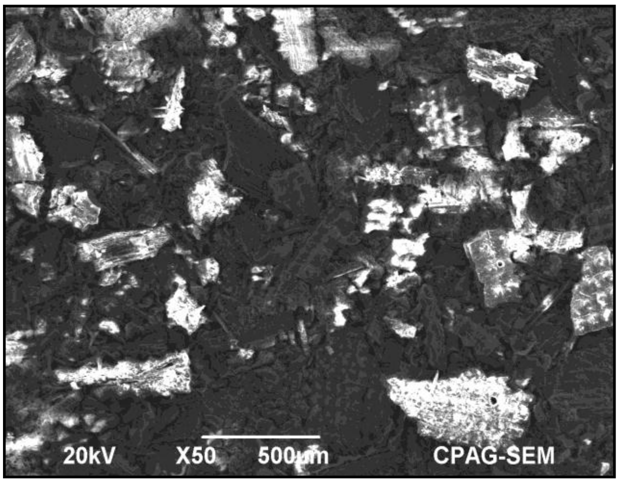


Figure.5(a).SEM images of RHA2 particles



Figrure.5 (b).SEM images of RHA2 particles

3.4. Strength activity indexed

The results of SAI demonstrates high pozzolanic activity index of the produced rice husk ash (RHA2). SAI at 28-days was 95% respectively which is above the standardsdemarcated by the ASTM C 618-03.It can be said that the produced rice huskash (RHA2) containing mostly amorphous silica that exclusively satisfy the requirements of ASTM C618-03for a pozzlonic material.

4. Conclusions

- The produced RHA2satisfies the criteria of a pozzolanic material; which is affluent in amorphous silica 70.38 % and meets the prerequisitestandardsdemarcated by ASTM C 618-03 for a pozzolanic material and it has the potential to be used as partial cement replacement material in construction industry.
- The burning duration and temperature parameters play a collective and effective role in influencing the reactivity of rice husk ash pozzolans. Burning Rice husk under un-controlled temperaturewhich results in smaller quantity of silica in ash. An increased temperature and duration is proved to be the most effective in the extraction of supplementary cementing material from rice husk.

- The XRD pattern and strength activity index show that silica in the rice husk ash exists in the amorphous form which confirms the non-crystallization of rice husk ash.

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