Application of Extracted Silica Samples from Bamboo Leaves and Rice Husk in the Formulation of Cement

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Abstract

Bamboo leaves and rice husk are agro-waste materials that can be potential source of silica. In this research, the preparation and characterization of the silica were extracted from two natural sources such as bamboo leaves and rice husk. At first, bamboo leaves ash (BLA) and rice husk ash (RHA) were prepared from bamboo leaves and rice husk by calcinations temperature from 400 °C to 1000 °C for 1 h and 2 h. Characterization of prepared these ash samples were carried out by using EDXRF, XRD, SEM and FT IR techniques. From the result of the EDXRF spectra, the maximum relative abundance of SiO_2 was achieved from BLA (1000 °C for 2 h) and RHA (800 °C for 2 h). From the XRD data, all of these BLA and RHA samples were observed about the amorphous nature. The selected samples were used in the formulation of mortar. Introducing the selected ash samples into mortar formulation enhanced the quality of cement.

Keywords: Bamboo leaves ash, Rice husk ash, Silica Xerogel, Cement

Introduction

The waste product bamboo leaves ash (BLA) and rice husk ash (RHA) are rich in silica and can be economically valuable supplementary cementitious materials for formulation of mortar. In the present research, the bamboo leaves sample was collected from Mayangone Township, Yangon Region. Rice husk (Yatana Tun) sample was collected from Thonze, Tharyarwady Township, Bago Region.

The preparation to get BLA and RHA were worked in muffle furnace from 400 $^{\circ}$C and 1000 $^{\circ}$C for 1 h and 2 h, respectively. By controlling the burning conditions like temperature and time, amorphous silica of ultrafine size and reactivity will be produced. Silica (SiO_2) is the major component in BLA and RHA. Moreover, other oxides such as CaO, K_2O , Al_2O, SO_3, Fe_2O_3, MgO and MnO are also present in them (Cocina, 2010).

Nanosilica is used mainly in concrete mixture for construction industry, nanosilica possess more pozzolanic nature (Itler, 1979). It has the capability to react with the free lime during the cement hydration and forms C-S-H get giving strength, impermeability and durability to concrete.

Materials and Methods

Sample Preparation

Bamboo leaves and rice husk were washed with water several times to remove dirt particles. They were dried at room temperature for one week.

Preparation of Bamboo Leaves Ash and Rice Husk Ash

Silicon dioxide reduction was conducted by ashing the bamboo leaves (BL) and rice husk (RH) in two stages, first by combusting the dried BL, RH and then ashing using a muffle furnace. Dried BL and RH were weighed and burned in open space for pre-ash sample. Then, this pre-ash was calcined in a muffle furnace at a temperature of 400 °C, 500 °C, 600 °C, 700 °C, 800 °C, 900 °C and 1000 °C with holding time of 1 h and 2 h, respectively. The optimum

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condition for calcination temperature of BLA is 1000 °C and RHA is 800 °C for 2 h. Once calcined, the ash was ground and sieved with 60 μm mesh. The samples were put in sealed plastic bag and this bag was stored in the desiccator at room temperature.

Characterization of the Prepared BLA and RHA Samples

The prepared ash samples were characterized by EDXRF, XRD, SEM and FT IR analyses.

Analyses of Physicochemical Properties of Selected BLA and RHA

Some physicochemical properties such as moisture content, ash content, bulk density and pH of the selected sample BLA and RHA were determined by conventional methods.

Formulation of Mortar

Alpha cement was based and which is mixed with various amounts (3 %, 5 %, 7 %) of bamboo leaves ash and rice husk ash. The obtained Cement-BLA samples and Cement-RHA samples were designated as CB-3, CB-5, CB-7 and CR-3, CR-5, CR-7. Characterization of prepared mortar samples were analyzed by physical test and mechanical test were carried out.

Results and Discussion

Preparation of Bamboo Leaves Ash and Rice Husk Ash

The collected samples were washed with water, air dried in an open vessel and pre-ashed on electrical hot plate for 2 h. Then the pre-ashed sample were calcined in muffle furnace at the temperatures of 400 - 1000 °C for 1 h and 2 h respectively to obtain bamboo leaves ash and rice husk ash. Total 14 ash samples for each sample were prepared. The percent yields of ash from the BLA samples were obtained in the range of 1.24 – 46.0 % and from the RHA samples were obtained in the range of 24.86 - 45.25 %.

Characterization of Bamboo Leaves Ash and Rice Husk Ash by EDXRF analysis

The elemental composition of bamboo leaves ashes and rice husk were determined by EDXRF analysis. These spectra showed that SiO_2, K_2O, CaO and P_2O_5 are the major constituents in BLA and RHA samples. Other oxides such as MnO, Fe_2O_3, CuO, TiO_2 and PbO in BLA were also found below 1 %. The silica percent of different bamboo leaves ashes and rice husk ash are shown in Figure 1 and Table 1.

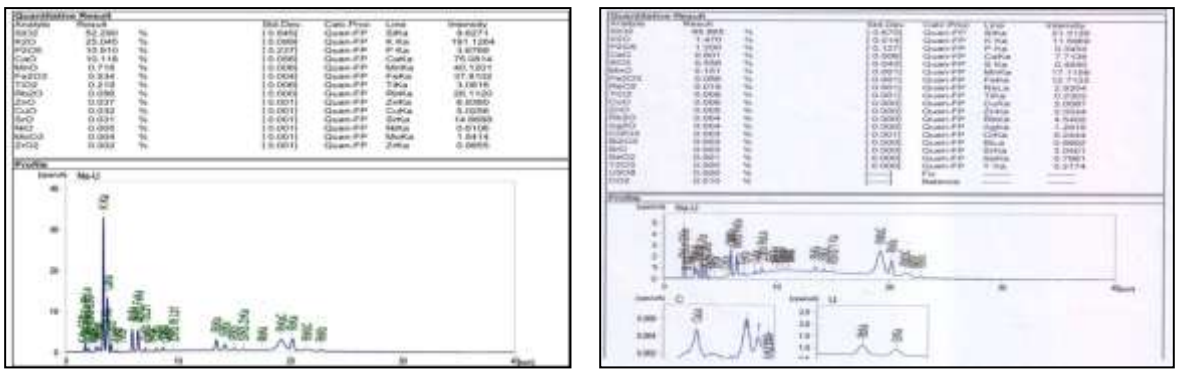


Figure 1 EDXRF spectra of BLA and RHA

Table 1. Relative Abundance of Silica and some oxides in BLA and RHA by EDXRF Analysis

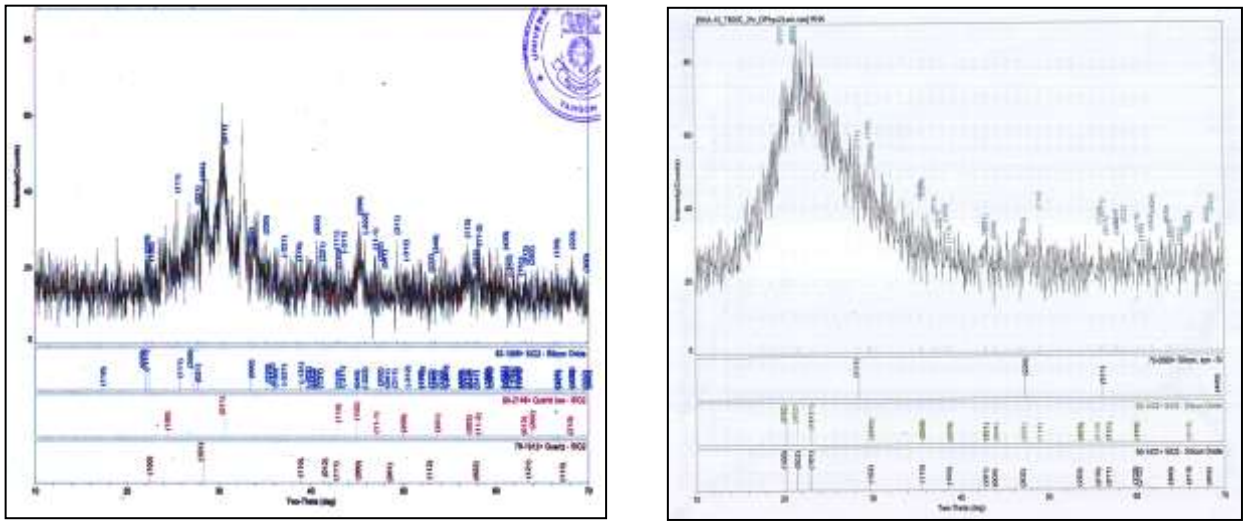
Sample	SiO_2 (%)	K_2O (%)	P_2O_5 (%)	CaO (%)
BLA	52.290	25.045	10.118	10.919
RHA	95.865	1.470	1.200	0.601

BLA = Bamboo Leaves Ash, RHA = Rice Husk Ash

Among the prepared ash samples for BLA, the maximum relative abundance of SiO_2 was achieved to be 52.29 % at the calcination temperature of 1000 °C for 2 h. For the RHA samples, the maximum relative abundance of SiO_2 was achieved to be 95.86 % at the ashing temperature of 800 °C for 2 h.

XRD analysis

X-ray diffraction is a common technique for the study of crystal structures, atomic spacing and crystallite size. Almost all of the XRD diffractograms indicated that the prepared ash samples were amorphous nature. The crystallites sizes of these ash samples were calculated by Scherrer equation. The sizes of all samples were observed within the range of nano scale. The crystallite size of BLA was found to be 19.6 nm. The crystallite size of RHA was found to be 28.28 nm. Figure 2 show the XRD diffractogram of BLA and RHA.



(i) (ii)

Figure 2 XRD diffractogram of (i) BLA and (ii) RHA

Table 2. Comparison of the crystallite size of BLA and RHA

Sample	SiO_2 (%)	K_2O (%)	P_2O_5 (%)	CaO (%)
BLA	52.290	25.045	10.118	10.919
RHA	95.865	1.470	1.200	0.601

SEM analysis

The SEM micrographs of BLA and RHA samples showed porous nature at the calcinations temperature of 400 - 1000 °C. At lower temperature of calcinations at 400 °C, 500 °C, the semi-ash or primary char of bamboo leaves and rice husk did not show well defined pores. At the temperatures of 600 °C, 700 °C, 800 °C, 900 °C and 1000 °C the surface morphology of BLA and RHA were observed about a distinct appearance of pores. Figure 3 show the SEM micrograph of BLA and RHA.

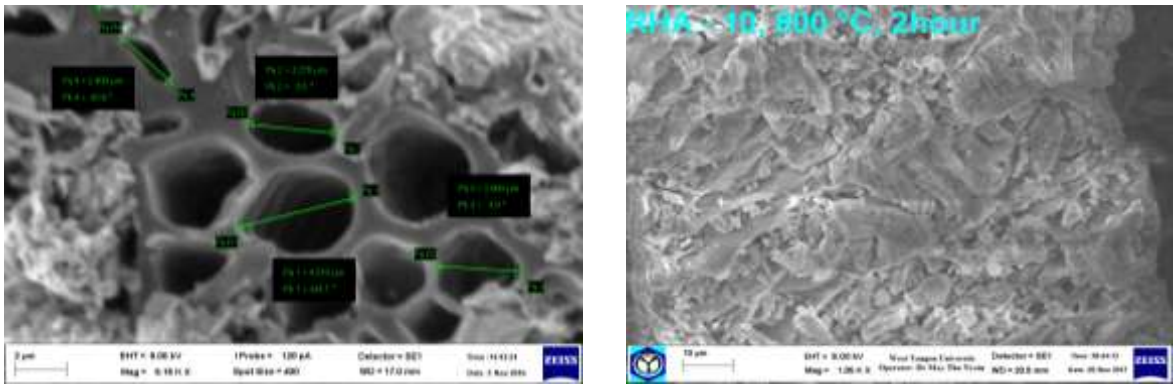


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Figure 3 SEM micrograph of (i) BLA and (ii) RHA

FT IR analysis

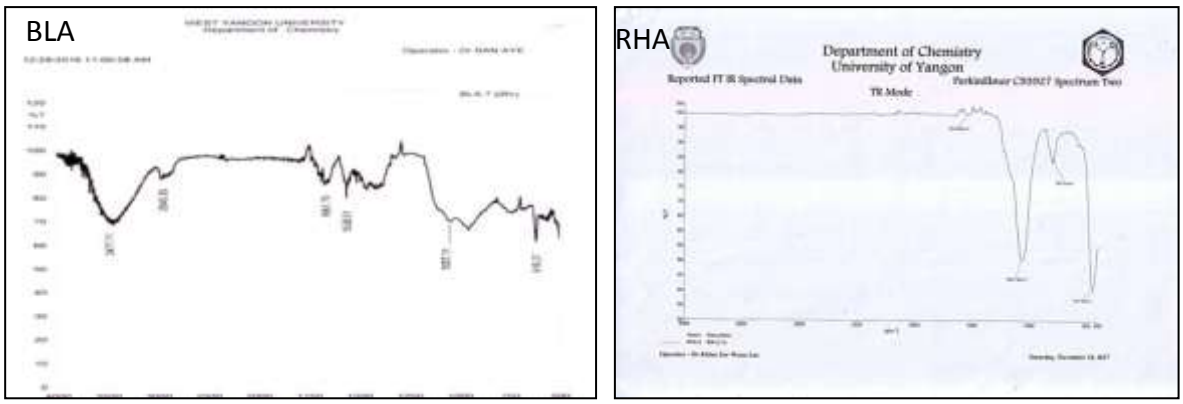


Figure 4 FT IR spectrum of BLA and RHA

Figure 4 show the FT IR spectrum of BLA and RHA. FT IR data assignments are shown in Table 3.

Table 3. Band Assignment for FT IR Spectrum of BLA and RHA

Band No.	BLA Observed wave no. (cm^{-1})	RHA Observed wave no. (cm^{-1})	*Literature wave no. (cm^{-1})	Band Assignment
1.	3477	-	3700-3200	δ_{Si-OH}
2.	1661	1531	1750-1650	ν_{Si-OH}
3.	1057	1064	1200-700	$\nu_{Si-O-Si}$
4.	616	447	<650	δ_{Si-O}

* Nakamoto, (1986), Amutha *et al., (*2010)

Physicochemical Properties of BLA and RHA

Table 4 shows some physicochemical properties of BLA and RHA samples which are relevant to moisture content, ash content, bulk density and pH.

Table 4. Physicochemical Properties of BLA and RHA

Sample	**Ash (%)**	**Moisture (%)**	**Bulk density (g mL^{-1})**	**pH**
BLA	0.38	0.3716	1.435	10.03
RHA	26.33	2.10	0.916	8.5

Physicomechanical Analysis of Cement-BLA and Cement-RHA

The quality of cement-BLA and cement-RHA (soundness, normal consistency, setting time, compressive strength and tensile strength) were improved when mixing with the selected ash sample. The results of physical test for cement-BLA and cement-RHA mortar samples were shown in Table 5.

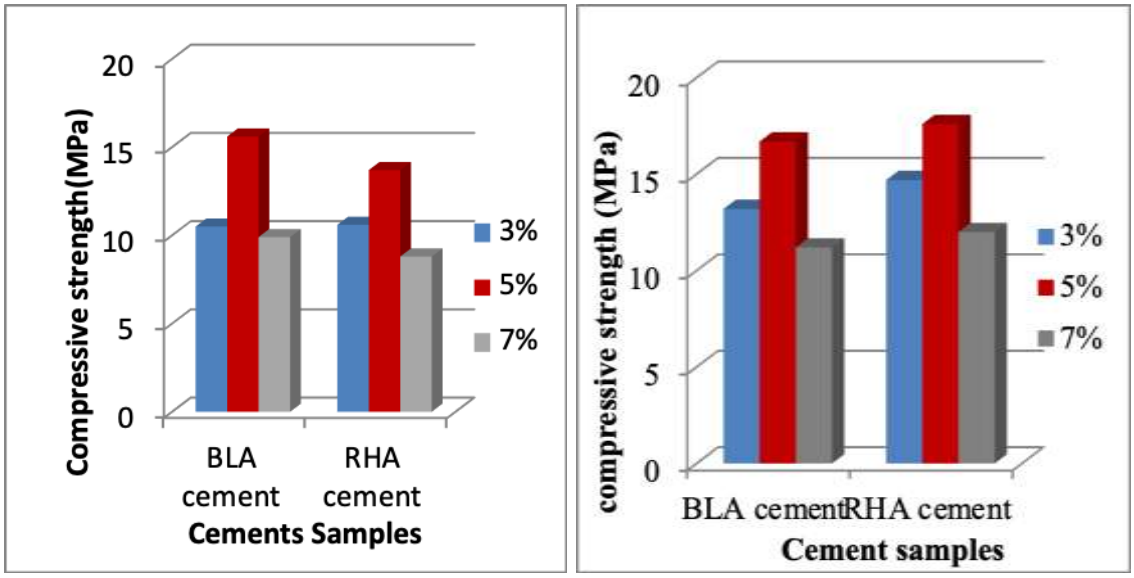
Table 5. Consistency, soundness and setting time of various cement samples containing selected BLA and RHA

Parameter	Cement	Cement-BLA			Cement-RHA		
		3%	5%	7%	3%	5%	7%
Bulk Density ($g\ mL^{-1}$)	1.678	1.535	1.498	1.545	1.567	1.484	1.560
Consistency (%)	28.5	31.2	30.8	32	31.4	30.9	34
Soundness (mm)	1.60	1.25	1.00	1.50	1.00	0.83	1.00
Initial setting time (min^{-1})	150	120	171	147	143	193	189
Final setting time(min^{-1})	256	217	234	247	203	268	302

Table 6. Comparative studies of compressive strength for prepared cement- BLA and cement- RHA sample

No.	Samples	Compressive Strength (MPa)		Samples	Compressive Strength (MPa)	
		7 Day	28 day		7 Day	28 day
1	Cement	11.3	15.7	Cement	11.3	15.7
2	CB-3	10.5	13.2	CR-3	10.6	14.7
3	CB-5	15.6	16.7	CR-5	13.7	17.6
4	CB-7	9.9	11.2	CR-7	8.8	15.4

The compressive strength of cement-BLA and cement-RHA were based on mortar test. The result are shown in Table 6 and graphically represented in Figures 5. According to the data, the highest compressive strength were more observed CB-5 and CR-5 than alpha cement. The compressive strength increased in 28 days than 7 days.



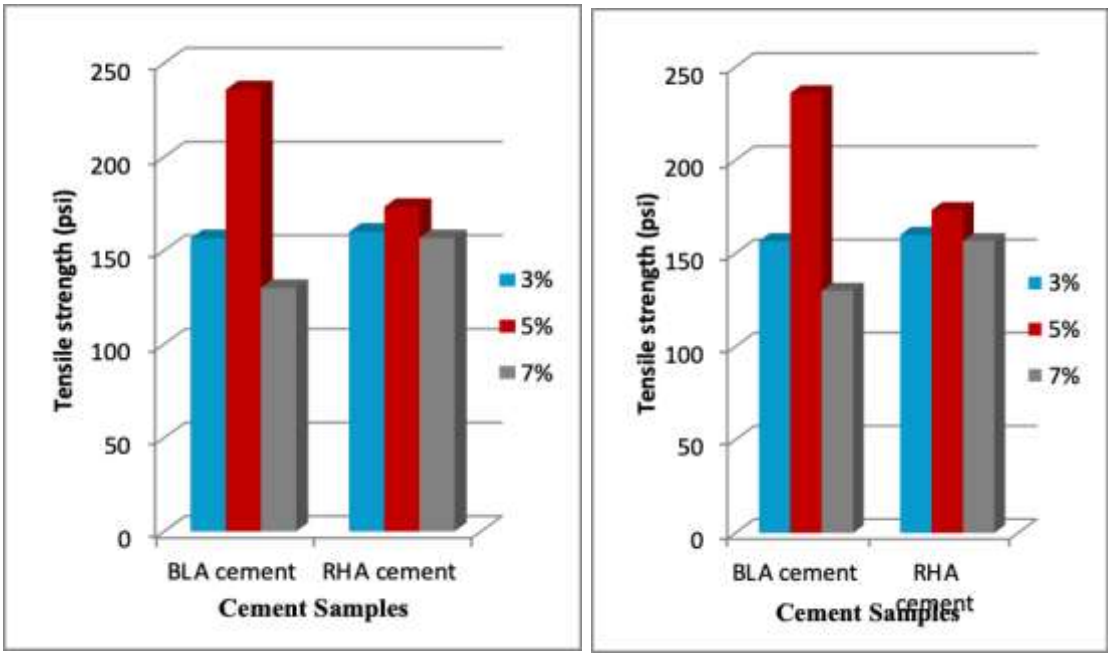
(i) (ii)

Figures 5 Compressive strength of cement-BLA and cement- RHA samples (i) 7 day (ii) 28day

The tensile strength of mortar varies with change in % of BLA and RHA. The results are shown in Table 7 and graphically represented in Figures 6 The results of the tensile strength of mortar show that the tensile strength reduced when mixing with BLA and RHA. The optimum tensile strength of cement-BLA and cement-RHA mortar was observed CB-5 and CR-5.

Table 7. Comparative Studies of Tensile Strength for Prepared Cement- BLA and Cement-RHA

No.	Samples	Tensile Strength (psi)		Samples	Tensile Strength (psi)	
		7 Day	28 day		7 Day	28 day
1	Cement	230.0	243.3	Cement	230.0	243.3
2	CB-3	156.6	213.3	CR-3	160.0	183.3
3	CB-5	236.0	243.2	CR-5	173.3	226.6
4	CB-7	156.6	220.0	CR-7	156.6	213.3



(i) (ii)

Figures 6 Tensile strength of cement-BLA and cement- RHA samples (i) 7 day(ii) 28day

Conclusion

In this research, an attempt was made to produce nanosilica from bamboo leaves ash and rice husk ash. Bamboo leaves ash and Rice husk ash are cost effective waste material. The research work is done by addition of 3 %, 5 % and 7 % of ash (BLA or RHA) as partial replacement of cement. Normal consistency increases when mixing with the ash samples. The lowest soundness was observed in CB-5 and CR-5 which is one of the characteristic parameters of mortar. Initial and final setting time of CB-5 and CR-5 are not significantly distinct which is good result of mortar. The highest compressive strength was observed CB-5 and CR-5 with good hardness properties. Maximum tensile strength was obtained at CB-5 and CR-5 which contain 5 % ash. From the experimental results of compressive strength and tensile strength, it can be inferred that addition of 5 % ash enhance the quality of cement.

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