# STUDY ON PHYSICAL AND CHEMICAL CHARACTERIZATION OF BAMBOO BASED BIOCHAR

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## Abstract

This paper reports the results of physical and chemical characterization of bamboo based biochar. The bamboo was washed with fresh water to remove impurities such as dust. Bamboo was dried in room temperature. The bamboo ash was obtained in electric furnace at 1000 °C for 3 h and 6 h respectively. Structural properties of bamboo ash were examined by X-ray diffraction (XRD). Scanning electron microscope (SEM) was used to observe the morphology of bamboo ash. Chemical characterization was carried out by X-ray fluorescence (EDXRF) and vibrational characterizations of bamboo ash was studied by FTIR spectroscopy. Each bamboo ash was used to form biochar ceramics by different amount of silica gel, PVA and DIW. These biochar ceramics were annealed at 200 ˚C for 1 h to be binder burnt out. They were annealed at 600 ˚C for 1 h to be more rigid. Physical properties such as firing shrinkage, bulk density, biochar yield, pH value of bamboo ash solution, moisture content, specific gravity and hydration capacity of Bio-char ceramics were determined.

**Keywords:** Bamboo, Bio-char, X-ray diffraction, Morphology, Chemical Properties, Physical Properties

## Introduction

Researches all over the world today are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for the industry. These wastes utilization would not only be economical, but may also result to foreign exchange earnings and environmental pollution control [V. S. Aigbodion et at (2010)]. Recent research has focused on wastes generated in different agro-industrial sectors, which are generating serious environmental and social problems, by their accumulation in landfills and uncontrolled burning. One of these sectors is the bamboo with an annual production estimated in 20 million tons all over the world, mainly in Asia and Latin America [Moisés Frías et al (2012)]. Bamboo is natural, cheap,

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widely available material .It is strong both in tension and compression. [G.N.V Sai Teja et al (2015)]. In recent years there has been increasing interest in utilization of agricultural waste ashes in concrete. If the waste can be reused and recycled, natural resources are used efficiently, wastes are kept out of landfills and the waste disposal costs are saved. Utilization of the waste as cement replacement not only reduces the economic and environmental problems associated with the waste disposal. Therefore , partial replacement of cement with bamboo culm ash (BCAsh) in concrete/mortar has twofold effect; (1) reducing the waste and the problems associated with them and (2) reducing the cement content in concrete and its negative economic and environmental impacts [Sara Soleimanzadeh et al (2015)]. A combination of thermo gravimetric analysis, pH and elemental (ultimate) analysis are necessary [ E. Hernandez-Mena*a et al (2014)]. Now a day's concrete are used as the basic materials for the construction works. The concrete is good in compression but weak in the tensile strength. But it has pozzolanic properties, it means that silicate-based material which in itself possesses little or no cementitious value, when silicate-based material (bamboo) is burned under controlled conditions or at in air, it also gives ash having amorphous silica, which has pozzolanic properties. In this study the Bamboo was used as a reinforcing material without any treatment and stirrups. [Jigar K. Sevalia et al (2013)].

## Experimental Procedure

The sticks of bamboo were washed with fresh water to remove impurities such as dust and they were dried. The dry pieces of bamboos were ground with a grinding machine. Bamboo powder was obtained by a grinding machine. After firing at 1000 Ċ for 3 h and 6 h, bamboo ash was obtained. The bamboo ash was shown a gray color. This bamboo ash was characterized by XRD (X-ray Diffraction), Scanning Electron Microscope (SEM) characterization was performed to analyze their microstructural properties. Chemical characterization was carried out X-ray fluorescence (XRF) and vibrational characterizations of bamboo ash were studied by FTIR spectroscopy. The block diagram of bamboo ash preparation was shown in figure 1.

Each ash was mixed thoroughly with silica gel, polyvinyl alcohol (PVA) and distilled water (DIW) to enhance plasticity. The mixed blend was each packed into a mould box and pressed using hydraulic jack. The moulded two samples were dried in an open air at 110 Ċ for 24 h to expel any moisture and to avoid crack during firing. The dried bricks were then fired in an automatic digital electric furnace (Hood - type furnace) at a preset heating rate at 200 Ċ for 1 h to be binder burnt-out and then they were annealed at 600 Ċ for 1 h to be more rigid. Finally, two types of bamboo ash ceramics were annealed at 800 ˚C for 1 h. After firing, the two samples were allowed to cool in the furnace at a cooling rate of 1°C/min. These samples were removed from the furnace for physical test.

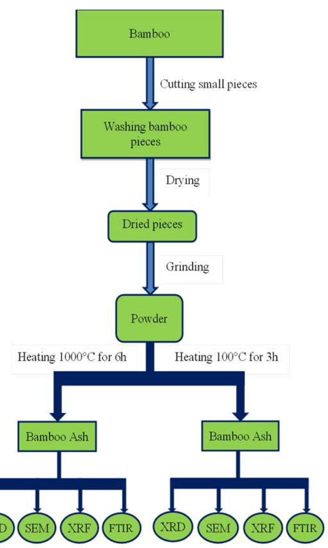


**Figure 1**. Block diagram of bamboo ash preparation

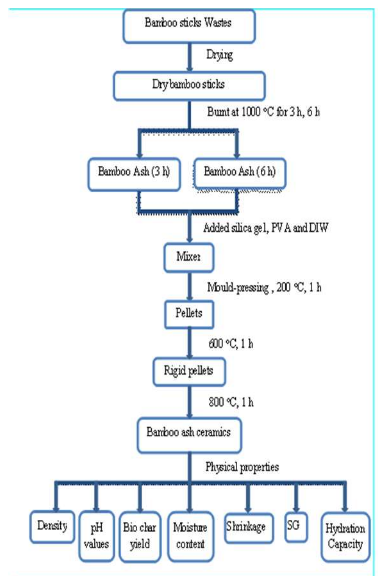


**Figure 2**. schematic representation of bamboo ash ceramic

## Results and Discussion

### XRD analysis

Figure 3 (a&b) illustrates the XRD pattern corresponding to the bamboo ash analyzed at 1000 Ċ for 3 h and 6 h. Structural properties of bamboo ash at 1000 Ċ for 3 h and 6 h were shown in table
(1 & 2).

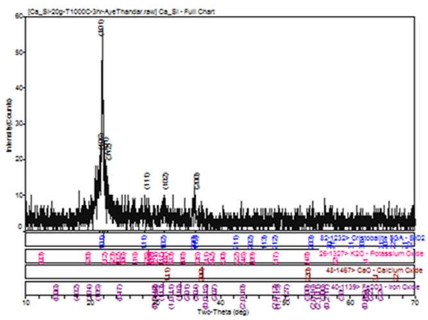

**Figure** 3(a). The XRD pattern of bamboo as at 1000 Ċ for 3 h

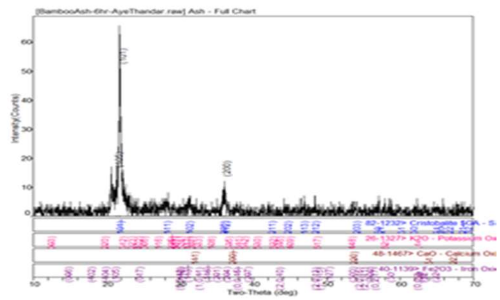

**Figure** 3(b). The XRD pattern of bamboo ash at 1000 Ċ for 6 h

**Table 1.** Diffraction angle of all identified peaks of Cristoblish ($SiO_2$) at 1000 Ċ in 3 h

| **No.** | **Peaks** | **Diffraction angles (degree)** | | **FWHM** |
|---|---|---|---|---|
| | | **observed** | **standard** | |
| 1 | (101) | 21.993 | 21.831 | 0.319 |
| 2 | (111) | 28.452 | 28.384 | 0.107 |
| 3 | (102) | 31.326 | 31.468 | 0.265 |
| 4 | (200) | 36.102 | 36.160 | 0.368 |

**Table 2**. Diffraction angle of all identified peaks of Cristobalite ($SiO_2$) at 1000 Ċ in 6h

| **No.** | **Peaks** | **Diffraction angles (degree)** | | **FWHM** |
|---|---|---|---|---|
| | | **observed** | **standard** | |
| 1 | (101) | 21.331 | 21.380 | 0.311 |
| 2 | (200) | 36.102 | 36.023 | 0.178 |

**SEM analysis**

Fig 4 (a&b) showed irregular forms not well defined and with honey comb like shape, were observed.

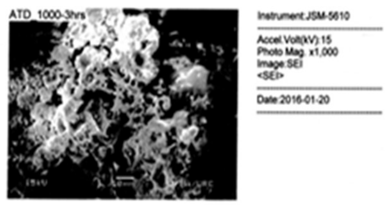


**Figure 4(a).** SEM image of bamboo ash 1000 Ċ for 3 h

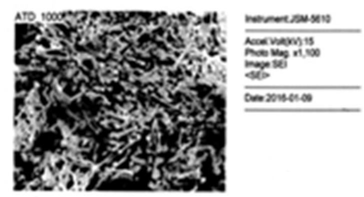


**Figure 4(b).** EM image of bamboo ash at at 1000 Ċ for 6 h

**EXDRF analysis**

Fig 5 (a&b) and table (3&4) shows the chemical compositions by EDXRF corresponding to the bamboo ash samples at 1000 Ċ for 3 h. The activated bamboo ash analyzed for this study was mainly formed by $K_2O$ and $SiO_2$ followed by CaO, FeĊ$O_3$, MnO, $SO_3$, ZnO, $Rb_2O$, CuO, NiO, SrO. These differences would be related to the different species of bamboo, soil, climate and age

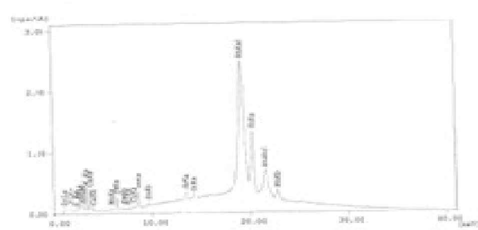

**Figure 5(a).** EDXRF analysis of bamboo ash at 1000 Ċ for 3 h

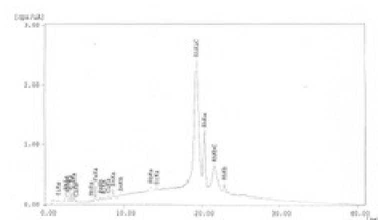

**Figure 5(b).** EDXRF analysis of bamboo ash at at 1000 Ċ for 6 h

**Table 3.** The chemical composition by EDXRF corresponding to the bamboo ash samples at 1000 Ċ for 3 h.

| Analyte | $K_2O$ | $SiO_2$ | CaO | $Fe_2O_3$ | MnO | $SO_3$ | ZnO | $Rb_2O$ | CuO | NiO | SrO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Result | 42.96% | 42.90% | 10.88% | 1.775% | 0.498% | 0.380% | 0.364% | 0.083% | 0.066% | 0.047% | 0.042% |

**Table 4.** The chemical composition by EDXRF corresponding to the bamboo ash samples at 1000 Ċ for 6 h.

| Analyte | $K_2O$ | $SiO_2$ | CaO | $Fe_2O_3$ | MnO | ZnO | CuO | $Rb_2O$ | NiO | SrO |
|---|---|---|---|---|---|---|---|---|---|---|
| Result | 41.36% | 36,49% | 13.969% | 5.909% | 0.971% | 0.616% | 0.235% | 0.205% | 0.138% | 0.098% |

## FTIR analysis

The FTIR spectrum of the starting bamboo ash figure 6 (a&b) showed two main zones of infrared absorption which are due to the presence of traces of crystalline mineralogical phases such as quartz and cristobalite and mainly of amorphous silica present in the bamboo ash.

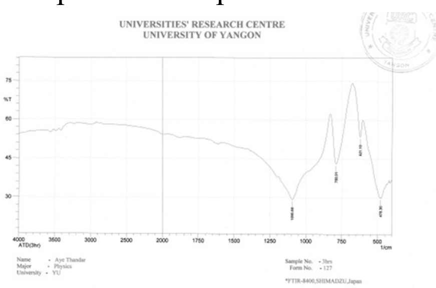


**Figure 6(a)**. FTIR spectrum of bamboo ash at 1000 Ċ for 3 h

**Figure 6(b)**. FTIR spectrum of bamboo ash at at 1000 Ċ for 6 h

## Physical Analysis

In table 5 was showed the weight loss for each reaction bamboo in the different time carried out. Analyzing Table 5, it was verified that there was decline in yields, and hence, an increased loss of weight in function of reaction time.

**Table 5**. Loss of weight in different time of bamboo ash

| Temperature ( °C ) | Reaction Time (h) | Initial weight (g) | Final weight ( g ) | Weight ( %) |
|---|---|---|---|---|
| 1000 | 3 | 49.48 | 0.88 | 98.22 |
| 1000 | 6 | 49.48 | 0.47 | 99.04 |

**Firing shrinkage**

In Table 6 was showed the weight loss for each reaction of bamboo in different time carried out. Analyzing Table 6, it was verified that there was a decline in yield, and hence, an increased loss of weight in function of reaction time.

**Table 6**. Firing shrinkage of Bamboo Ash

| Temperature ( °C ) | Reaction Time (h) | ( $V_O$) initial weight (g) | ($V_f$) final weight (g) | Shrinkage (%) |
|---|---|---|---|---|
| 1000 | 3 h | 0.9466 | 0.8632 | 8.81 |
| 1000 | 6 h | 1.0490 | 0.9730 | 7.81 |

**Density of bamboo ash ceramics**

Table 7 represented the calculated parameter of density.

**Table 7.** Density of bamboo ash ceramics

| Temperature ( °C ) | Reaction Time (h) | Mass (g) | Volume ($cm^3$) | Density ($gcm^{-3}$) |
|---|---|---|---|---|
| 1000 | 3 | 0.8632 | $48.5256\times10^{-2}$ | 1.78 |
| 1000 | 6 | 0.9730 | $53.0213\times10^{-2}$ | 1.84 |

**pH value of bamboo ash solution**

The results of pH values were shown in Table 8.

**Table 8**. The pH value of bamboo ash ceramics

| Temperature ( °C) | Reaction Time ( h) | pH value of Bamboo ash solution |
|---|---|---|
| 1000 | 3 | 6.74 |
| 1000 | 6 | 6.76 |

**Measuring moisture contents in bamboo ceramics**

The total moisture content results are shown in Table 9.

**Table 9**. The value of moisture contents in bamboo ash ceramics

| Temperature ( °C) | Reaction Time (h) | Weight of the sample prior to drying ($W_{initial}$) (g) | Weight of the sample after drying ($W_{OD}$) (g) | Moisture Contents (%) |
|---|---|---|---|---|
| 1000 | 3 | 1.1957 | 1.0352 | 13.42 |
| 1000 | 6 | 1.3836 | 1.2089 | 12.53 |

**Determination of Specific Gravity of Bamboo Ash Solution**

Specific gravity is defined as the ratio between the weight of a given volume of bamboo ash and weight of an equal volume of water. The values of specific gravity are shown in Table 10.

**Table 10.** The values of Specific Gravity of Bamboo Ash solution

| Temperature ( °C ) | Reaction Time (h) | Specific Gravity |
|---|---|---|
| 1000 | 3 | 127.71 |
| 1000 | 6 | 128.56 |

**Hydration Capacity of Bomboo ash**

Hydration characteristics of bamboo ash have been determined. The influence of compatibility based on time, temperatures, hydration index and rate were examined for different treatments. The values of hydration capacity are shown in Table 11.

**Table 11**. The values of Hydration capacity of Bamboo Ash solution

| Temperature ( °C ) | Reaction Time (h) | hydrated mass (g) | dried mass (g) | Hydration Capacity (%) |
|---|---|---|---|---|
| 1000 | 3h | 1.0937 | 0.9317 | 17.39 |
| 1000 | 6h | 1.2069 | 1.0463 | 15.35 |

## Conclusion

A mineralogical study of bamboo ash by XRD reve aled the presence of amorphous cristobalite ($SiO_2$) mainly and, traces of potassium oxide ($K_2O$), calcium oxide (CaO) and iron oxide ($Fe_2O_3$) were found at 1000 Ċ for 3 h and 6 h. As a result of SEM investigation was indicated that the structures of bamboo ash heated at 1000 Ċ for 3 h and 6 h were changed. The chemical compositions by EDXRF corresponding to the bamboo ash samples at 1000 Ċ for 3 h and 6 h. The activated bamboo ash analyzed for this study was mainly formed by $K_2O$ and $SiO_2$ followed by CaO, $Fe_2O_3$, MnO, $SO_3$, ZnO, Rb2O, CuO, NiO, SrO. The FTIR spectrum of the starting bamboo ash showed two main zones of infrared absorption: a zone between 1250 and 1000 $cm^{-1}$ and other zone at lower frequencies between 875 and 450 $cm^{-1}$.The firing shrinkage value of the bamboo ash at 6 h is lower than 3 h. The pH value of bamboo ash for 6 h is little higher than3 h. Density of the sample at 6 h is 1.835 $g/cm^3$ which means that bamboo ash is very light material. The value obtained fall within the range of density of carbon and silica which is 1.8 and 2.2 $g/cm^3$ respectively. The ash can withstand a temperature of up to 1000 Ċ for 6 h. The moisture content is dependent on reaction time. If the specific gravity of cement is greater than 319 g then, the cement is either not minced finely as per the industry standard or it has more moisture content which will affect the mix and bonding and also find lots of chunks while mixing old stock cement replacement. So the interval for heat treatment 6 h of bamboo ash is quite suitable for partially cement replacement application

## Acknowledgements

I would like to express my deep appreciation to Dr Ba Han, Rector, and Pro-Rectors, Dr Khin May Aung, Dawei University for their encouragement and kind permission to carry out this work. I also would like to thank Professor Dr Aung Myat Kyaw, Head of Department of Physics, and Professor Dr Malar Myint , Department of Physics, Dawei University, for their kind permission to carry out this work , their encouragement and help during this work.

## References

1. Anurag N et al 2013 Journal of Mechanical and Civil Engineering 8 50
2. Dr. Patel Pratima A et al 2013 International Refereed Journal of Engineering and Science 2 55
3. Jagar K S et al 2013 International Journal of Engineering Research and Application 3 1181
4. I.R. Hunter et al An INBAR Working Paper
5. Moises F et al 2012 Cement and Concrete Composites 34 1019
6. P.Asha et al 2014 International Journal of Engineering and Advanced Technology 3 2249
7. Peter M 2002 Bioresource Techanology 83 37