

Identification of Pozzolonic Activity Present in the Waste Materials

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Abstract: The consumption of cement is increasing recently due to the developing country. Many researchers working on the replacement of the cement with different agro-industrial ashes. In this paper, two tests have been performed to determine the pozzolonic property of Fly ash, Rice husk ash and Bagasse ash. The present paper investigated the physio-chemical characteristics and the pozzolonic behavior of bagasse ash (BA), rice husk ash (RHA) and fly ash (FA). From the performed tests, it is observed that the pozzolonic property present in fly ash is comparatively high than rice husk ash and bagasse ash.

Keywords: Agro-industrial ashes, Pozzolonic behavior, Pozzolonic property, Replacement.

1. Introduction

In present time, there are large volumes of materials considered as wastes or by-products produced by industrial activities. These wastes not always have the possibility of reuse, or low economic value for the companies that generate it. Thus, it adds to the cost of its management and disposal. Current production models have associated some in sufficient practices as mentioned below:

1. Resource consumption.
2. Materials and energy.
3. Waste generation
4. Economic costs [1]

In India, solid waste management is the major issue that demands attention. In only Asia, around 4.4 billion tons of solid wastes generate yearly. In India, alone agricultural sector has generated about 600 million tons of biomass waste [2]. Around 960 million tons of residual solid waste have been generated from agricultural, industrial and mining, yearly. Around 91.162 million tons of sugarcane biomass wastes generate yearly [3]. After industrial processing of raw sugarcane crop to obtain edible products, leaves the waste known as bagasse as a by-product. similarly, Rice husk (RH) is a by-product of rice milling and rice husk ash (RHA) is generated by combustion in a separate boiler. Both RH and RHA are tremendously found in rice growing countries such as China, India, Brazil, the USA, and Southeast Asia. Thus, RH has been recycled by burning it for energy production [4]. In India, around 44,000 tons of SCBA is generated per day [4]. Thus, it gives around 4.4 million tons of RHA every year. This SCBA and RHA have negative impact on the environment and therefore, a proper technique

should be adopted to overcome the disposal issues of ashes [5]. Similarly, Fly ash is the solid industrial waste generated from coal combustion process in thermal power plants. In India, around 120-150 million tons of coal fly ash is generated [28]. The behavior of many metal pollutants present in fly ash may have hazardous effects on the environment and humans as well [32]. At present, the annual generation of fly ash is approximately 112 million tones. Cement and Concrete Industry utilizes 50% Fly Ash of the total utilization of which at present is 28%. The Low-lying area fill utilizes 17%, 15% by Roads & Embankments, 4% by Dyke Raising, 2% by Brick manufacturing, etc. [34]. It contributes to air pollution and also acts like cumulative poisons since the fine particles remains in lungs for longer period of time [36]. Since, these industrial solid waste ashes have deleterious effects on both environment and human health and also dumping cause pollution of soil, it is required to utilize them in some harmless manner. Nowadays, due to the higher rate of infrastructure development, the requirement of concrete is increasing and thus increases the demand for concrete which results in the increase in consumption of their ingredients such as cement, sand, and aggregates for concrete. Due to Carbon dioxide emissions, Cement industry is highly responsible for pollution [5]. Thus, it becomes important to find out the substitutes for cement. The findings of the literature study give an effective solution about the pozzolonic property in the above selected wastes by performing various tests.

2. Pozzolonic Activity

The measure for the of degree of reaction rate between a pozzolan and Ca^{2+} or calcium hydroxide ($\text{Ca}(\text{OH})_2$) in the presence of water is known as pozzolonic property. The rate of the pozzolonic reaction is dependent on the intrinsic characteristics of the pozzolan. Since no irreversible molecular bonds are formed in the process, physical surface adsorption is not considered as being part of the pozzolonic activity [12].

3. Material Selected

There are various waste materials i.e., Industrial waste agro-industrial waste and agricultural waste available all over India. The use of Cement is tremendously high and cement is the second mostly consumed material after water [50]. In order to

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control this high consumption of cement, these waste materials can be used as a replacement of cement. Different waste materials show different properties. In this paper, three waste products namely; Fly ash, Rice husk Ash and Bagasse Ash have been selected.

A. Fly ash

India is the third largest producer of coal and contribute about 70% of the total installed capacity for power generation [27]. This coals usually contain over 40% ash content [28]. Fly ash is an industrial waste generated in thermal power plant from coal combustion process. Fly ash is generally fine powdered ferro alumino silicate material with Al, Ca, Mg, Fe, Na and Si as its elements. Large quantities of coal fly ash cause a serious threat to the environment as a major source of inorganic pollution. It causes deleterious effects on the environment as well as on human health [32].

Chemical Composition of fly ash is ash shown in the table below:

Table 1
Chemical Composition for Fly Ash (Expressed as Percent by Weight)

Components	Content (% by wt)
Silicon dioxide	57
Aluminum oxide	20
Iron oxide	2.5
Carbon oxide	5.8
Magnesium oxide	2.4
Sulphur trioxide	2.0
Sodium carbonate	1.5
Potassium oxide	2.8

B. Rice husk and rice husk ash

The natural covering that forms around rice grains during their growth is known as Rice husk. This rice husk is widely in the rice-producing countries. This rice husk is considered as agricultural waste material. It is important in some countries, like China, India, Indonesia, Malaysia and Bangladesh [46, 47]. The production rice produces a high volume of rice husk, which is a low-density residue [48]. Dumping this waste causes significant environmental problems. A huge amount of RHA is produced all over the world and found to be growing at more than 7.5 million tons, or around 1.1% each year [46].

Chemical composition of husk ash consists of the following:

- Cellulose (C₅H₁₀O₅)
- Lignin (C₇H₁₀O₃)
- Hemicellulose
- SiO₂
- Holocellulose

The chemical composition of rice husk ash includes silicon dioxide, Aluminum dioxide, Iron Oxide, Calcium Oxide, Magnesium Oxide, Sodium Oxide, Potassium Oxide.

C. Bagasse Ash or Sugarcane Bagasse Ash (SCBA)

Bagasse ash is the agricultural waste generated from sugarcane. The pozzolanic property of sugarcane bagasse ash depends on the physical properties and the chemical composition of bagasse ash [51].

- Physical properties and chemical composition of SCBA plays an important role in its pozzolanic

behavior. Physical properties include particle size, specific gravity and density.

- The chemical composition of sugarcane bagasse ash includes silicon dioxide, aluminum oxide, iron oxide, calcium oxide, and the potassium oxide). The sugarcane bagasse composed of approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin [52].

Table 2
Chemical Composition of Rice Husk Ash

Particulars	Proportions
Silicon Dioxide	80.45%
Aluminum Dioxide	0.25%
Iron Oxide	0.95%
Calcium Oxide	1.25%
Magnesium Oxide	0.4%
Sodium Oxide	0.5%
Potassium Oxide	2.18%

Table 3
Physical properties of SCBA

Physical properties	SCBA
Particle size	5.56 micro meter
Specific gravity	2.12
Density	2340kg/m ³

Table 4
Chemical properties of SCBA

Oxide composition	SCBA
SiO ₂	51.35%
Al ₂ O ₃	12.45%
Fe ₂ O ₃	1.2%
MgO	7.43%
K ₂ O	1.84%
SO ₃	2.74

4. Types of Tests Performed On the Selected Ashes

1. Electrical conductivity test
2. Chapelle Activity test

The ashes collected from industries or factories possess carbon content in it. The samples containing carbon content cannot be directly tested. In order to remove the carbon content present in ashes, these ashes are allowed to heat at 6000C for 6 hours. After 6 hours, allow this oven dried ashes to pass through 90micron sieve and perform the tests on the sample passing through sieve.

A. Electrical conductivity test

The instrument used in this test is known as Electric conductivity meter. This instrument consists of electrical meter, electrode and magnetic stirrer. Readings are measured by electrical meter and are in micro-sec/meter. The pozzolanic activity of the material can be investigated by measuring its electrical conductivity in aqueous suspensions of Calcium hydroxide. The influence of the calcium hydroxide concentration in the suspension is analyzed by calcium hydroxide solution. The temperature of suspension influences the chemical reaction between pozzolanic material and the calcium hydroxide, which ultimately affects the degree of reaction. The readings are observed at the beginning and at the

end. The difference between the first and the final reading noted during the process is known as Electrical conductivity. There are certain ranges of Electrical conductivity which determines the pozzolanic property present in a particular ash. The table given below shows those ranges of electrical conductivity.

Table 5
Range of electrical conductivity for pozzolanic property

Range of Electrical conductivity	Pozzolanic property
< 1.2	Not pozzolanic
1.2 – 1.4	Good pozzolanic
> 1.4	High pozzolanic



Fig. 1. 150ml of Calcium hydroxide + fly ash



Fig. 2. 150ml of Calcium hydroxide + Rice husk



Fig. 3. 150ml of Calcium hydroxide + Bagasse ash

Observation:

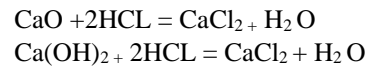
From the observations, it is found that fly ash is having highest pozzolanic property, whereas Rice husk ash and Bagasse ash possess average that is good pozzolanic property.

Table 6
Testing reading of electrical conductivity test

S.No.	Type of sample	Initial reading	Final reading	Electrical conductivity	Pozzolanic property of the sample
01	Fly ash	3.350	5.30	1.95	High pozzolanic
02	Rice husk ash	1.705	0.363	1.342	Good pozzolanic
03	Bagasse ash	1.051	0.227	1.274	Good pozzolanic

B. Chapelle activity test

This method is lime-pozzolana reaction-based method and it quantifies the pozzolanic reactivity of any material. This test depends on the physical properties and chemical characteristics of any material. C-S-H is the product obtained by the reaction with lime, which improves the mechanical properties. According to this method, the consumption of lime by pozzolana is made with the proportion of lime: pozzolana - 1:1. Here, the tests are carried out with one gram of lime. It is added in order to eliminate all the virtuous phase present in materials. The calcium hydroxide is also called as hydrated lime, on reaction with pozzolan forms CSH phase. In method involves acid-base titration, thus in order to achieve end point of titration Phenolphthalein indicator is used. The reactions occur during titration process are as follows:



The result obtained from this test is expressed in reacted milligrams of Ca(OH)₂ reacted or fixed per gram of pozzolana.



Fig. 4. 250ml of distilled water + 1gm CaO + 1gm Fly ash



Fig. 5. 250ml of distilled water + 1gm CaO + 1gm Rice husk ash



Fig. 6. 250ml of distilled water + 1gm CaO + 1gm Bagasse ash



Fig. 7. Sample in oven for 8 hours

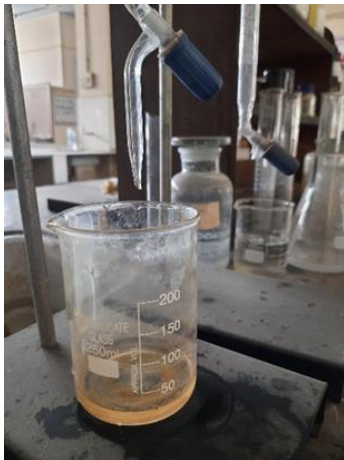


Fig. 8. Sample After adding phenolphthalein indicator



Fig. 9. After Titration

*Observation:*Table 7
Testing reading of Chapelle test

S. no.	Type of sample	Initial reading (V ₁)	Final reading (V ₂)
01	Fly ash	0.8	0.5
02	Rice husk ash	0.8	0.6
03	Bagasse ash	0.8	0.7

Calculations:

$$\text{Mg of Ca(OH)}_2 \text{ Fixed} = 2(V_1 - V_2) / V_1 \times 74/56 \times 1000$$

$$\text{Fly ash} : 2(0.8-0.5/0.8) \times 74/56 \times 1000 = 991.0714 \text{ Mg}$$

$$\text{Rice husk ash} : 2(0.8-0.6/0.8) \times 74/56 \times 1000 = 660.7142 \text{ Mg}$$

$$\text{Bagasse ash} : 2(0.8-0.7/0.8) \times 74/56 \times 1000 = 330.3571 \text{ Mg}$$

From the Chapelle Activity test, it is observed that, among fly ash, rice husk ash and bagasse ash; fly ash is having maximum pozzolanic property.

5. Conclusion

In India, due to the excessive consumption of coal, rice and sugar, there is millions of tons of fly ash, RHA and BA produced every year. At present, there are no efficient, harmless and economical technique available to recycle these materials. By recycling these materials, the natural raw materials can be conserved and will also create new revenues while protecting the environment.

In order to reduce the tremendous use of Cement and replacement of cement with selected waste materials two different tests are performed on these materials to determine their pozzolanic property. Electrode conductivity test concludes that; the range of electrical conductivity is greater than 1.4 (>1.4). Therefore, according to this test, fly ash possess high pozzolanic property whereas Rice husk ash (RHA) and Bagasse ash (SCBA) shows the range between 1.2 – 1.4 and thus they are considered as just good pozzolans. According the Chapelle test, mg of Calcium hydroxide in fly ash is far more as compared to RHA and BA, thus fly ash possess more pozzolanic property than RHA and BA. Overall, from the tests, it is concluded that Fly ash is highly pozzolanic. On the other hand, RHA and BA possess less pozzolanic property as compared to that of fly ash.

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