International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-3 Issue-6, August 2014

# Experimental Study on Concrete with Bamboo Leaf Ash

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***Abstract- The use of waste materials with pozzolanic properties in concrete production is a becoming a worldwide practice. The assessment of the pozzolanic activity of cement replacement materials is becoming increasingly important because of the need for more sustainable cementing products. In this paper, bamboo leaf ash is used as partial replacement for cement in ranges of 5%, 10%, 15%. Strength and durability tests were carried out to assess the feasibility of using bamboo leaf ash as partial replacement of cement in concrete.***

***Index Term- Bamboo Leaf Ash, Concrete, Compressive Strength, Durability tests.***

## I. INTRODUCTION

The use of waste materials with pozzolanic properties in concrete production is a worldwide practice. The assessment of the pozzolanic activity of cement replacement materials is becoming increasingly important because of the need for more sustainable cementing products. One way is to use certain low cost materials for partial replacement of Portland cement clinker. Low cost materials used are industrial and agricultural by-products (wastes). Mixture of Portland cement and the above by-products are known as 'blended cements' or 'composite cements'. By definition blended cements are hydraulic binders in which a part of Portland cement is replaced by other hydraulic or non hydraulic materials. Their general behaviour is quite similar to that of Portland cement since they harden when mixed with water and form the same hydration products. The most common ingredients for blending with Portland cement clinkers are latent hydraulic component (blast furnace slag), or a pozzolanic component such as pozzo-lana, fly ash, rice husk ash, condensed silica fume, burnt clay or filler component such as lime stone and other waste materials. Bamboo is probably the fastest-growing and highest yielding natural resource and construction material available to mankind. However, the use of bamboo generates other residues not used as fibres, such as the bamboo leaf. In some countries, significant amounts of bamboo are processed, generating high volumes of solid waste. These wastes are often burnt in open landfills, negatively impacting the environment. In literature, the studies about the pozzolanic properties of bamboo wastes are scarce.

## II. LITERATURE REVIEW

Little research has been carried out to study the bamboo leaf waste as a pozzolanic material.

**Manuscript published on 30 August 2014.**
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Dwivedi (2006) reported the reaction between calcium hydroxide (CH) and bamboo leaf ash for 4 h of reaction, using the differential scanning calorimetry (DSC) technique. Ernesto Villar (2010) was represents a characterization and study of the pozzolanic behavior between calcium hydroxide (CH) and bamboo leaf ash (BLA), which was obtained by calcining bamboo leaves at 600°C for 2 h in a laboratory electric furnace. To evaluate the pozzolanic behavior, conductometric method was used, which is based on the measurement of the electrical conductivity in a BLAsh/CH solution with the reaction time. Later, the kinetic parameters are quantified by applying a kinetic-diffusive model. The kinetic parameters that characterize the process (in particular, the reaction rate constant and free energy of activation) were determined with relative accuracy in the fitting process of the model. The pozzolanic activity is quantitatively evaluated according to the values obtained of the kinetic parameters. The results show that this kind of ash is formed by silica with a completely amorphous nature and a high pozzolanic activity. The correlation between the values of free energy of activation and the reaction rate constants are in correspondence with the theoretical studies about the rate processes reported in the literature. Massazza.F (1979) was identified the structure complexity and the wide variability of chemical and mineralogical composition of pozzolanas justify the difficulties which arise in establishing general validity relations between chemical and physical characteristics and activity of pozzolanas. Singh et al (2000) discussed that ecofriendly composite cements may be obtained by partial replacement of Portland cement with certain low cost materials. They studied the hydration of bamboo leaf ash in a blended Portland cement. It was concluded that bamboo leaf ash is an effective pozzolanic material. When 20 wt.% of bamboo leaf ash was mixed with PPC the compressive strength values of mortars at 28 days of hydration were found to be quite comparable to those of PPC. Villar-Cociña et al (2010) conducted a study on Sugarcane leaf ash (SCLA). Hydration of 10 wt% SCLA composite Portland cement was studied by using powder X-ray diffraction, FTIR spectroscopy, differential scanning calorimetric and other techniques. The result have shown that the pozzolanic reaction of sugarcane leaf ash increases with time. They proposed a new kinetic-diffusive model that allows characterizing the pozzolanic activity of sugar cane waste mixed with clay for all ages of the reaction by computing the kinetic coefficients (reaction rate constant, fundamentally) of the CH/sugar cane-clay ash reaction. The results obtained showed a good correlation between the experimental and theoretical data.


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Thus it is understood that if a good quality pozzolanic material in suitable amounts, is added during the hydration of Portland cement, the cementing quality is enhanced. There is a continuous search for alternative supplementary materials, which may have hydraulic/pozzolanic properties. This is much more important in developing countries, where there is shortage of power and good quality raw materials. In an attempt to this, we found that ash obtained from bamboo leaf is amorphous in nature and has pozzolanic properties. The annual production of bamboos all over the world is about 20 million tonnes but about 10 million tonnes are produced in India, China and Japan (Vatsala, 2003). In this paper, BLA was added as partial replacement for cement and specimens are named respectively as BLA 5, BLA10 and BLA15. The strength and durability properties of BLA 5, BLA10 and BLA15 are investigated. Hernandez JF (1998) was conduted by waste materials Mineralogical studies of different wastes of the sugar industry, mainly sugar cane bagasse ash and sugar cane straw ash, have shown that such by-products are likely to be pozzolanic. Their use in lime-pozzolana binders could become an interesting alternative for developing countries. This paper presents a study that was aimed at monitoring the reaction between lime and wastes of the sugar industry having pozzolanic properties by evaluating 1) content of calcium hydroxide, dependent on time; 2) development of the pore structure, dependent on time; 3) study of the reaction products at different stages; and 4) mechanical properties of hardened pastes. The presence of calcium hydroxide was confirmed by x-ray diffraction analysis and thermogravimetic analysis of powder from samples of hydrated lime-pozzolana pastes. The reaction products in hydrated pastes were observed in a scanning electron microscope, and the pore structure was assessed using a mercury intrusion porosimeter. The results of the study show that sugar cane bagasse ash does not act like a reactive pozzolana, mainly due to the presence of unburned material and carbon, whereas sugar cane straw ash shows good pozzolanic activity comparable to that of rice husk ash. Nachbaur. L (2001) was researched in dynamic mode rheometry was used to study the evolution of the structure of cement and pure tricalcium silicate pastes from mixing up to setting and even after setting, together with the nature of the forces responsible for the mechanical properties of the pastes. A special mixer-type tool was used to study rheology during the very first minutes following the end of mixing, which are out of reach with classical tools. Both kinds of pastes have the same behavior. It was found that the main evolution of the structure of the pastes occurs during the very first minutes following the end of mixing, while there is no change in interparticular forces up to setting and even a few hours later. Setting, as defined by the Vicat needle, is not related to any particular change of the nature of the forces or structural transition within the paste. Detwiler R.J (1991) Numerous investigations of the pore structure of portland cement paste have demonstrated that higher curing temperatures result in a coarser pore structure. Elevated curing temperatures are known to reduce the long-term strength of concrete. It is reasonable to expect reductions in durability as well, yet very little research has been done on this topic. The paper describes a preliminary investigation of the ability of concrete to withstand the corrosion of reinforcing steel. Concretes of 0.40, 0.50, and 0.58 water-cement ratio were made without chemical or mineral admixtures. Mixing and curing took place at constant temperatures of 5, 20, and 50 C (41, 68, and 122 F). Curing times were varied to allow for an equal degree of hydration of approximately 70 percent. Two types of tests measured the rate of chloride diffusion. An accelerated corrosion test compared the ability of the concretes to withstand the corrosion of reinforcing steel. Both test methods are described in detail. The results of both tests indicate clearly that, at a given water-cement ratio, elevated curing temperatures reduce the ability of portland cement concretes to withstand chloride diffusion and the consequent depassivation of reinforcement. This effect is more pronounced at lower water-cement ratios. These findings should be taken into account in the construction of concrete structures for which durability is a concern. Chandramouli K (2010) was researched that Corrosion of reinforcing steel due to chloride ingress is one of the most common environmental attacks that lead to the deterioration of concrete structures. Corrosion related damage to concrete structures is a major problem. This durability problem has received widespread attention in recent years because of its frequent occurrence and the associated high cost of repairs. Chlorides penetrate crack-free concrete by a variety of mechanisms: capillary absorption, hydrostatic pressure, diffusion, and evaporative transport. Of these, diffusion is predominant. Diffusion occurs when the concentration of chloride on the outside of the concrete member is greater than on the inside. This results in chloride ions moving through the concrete to the level of the rebar. When this occurs in combination with wetting and drying cycles and in the presence of oxygen, conditions are right for reinforcement corrosion. The rate of chloride ion ingress into concrete is primarily dependent on the internal pore structure. The pore structure in turn depends on other factors such as the mix design, degree of hydration, curing conditions, use of supplementary cementitious materials, and construction practices. Therefore, wherever there is a potential risk of chloride-induced corrosion, the concrete should be evaluated for chloride permeability. Researchers all over the world are attempting to develop high performance concretes by using fibres and other admixtures in concrete upto certain proportions. In the view of the global sustainable developments, it is imperative that fibres like glass, carbon, aramid and polypropylene fibers provide improvements in tensile strength. Research in GFRC (Glass fibre reinforced concrete) resulted in the development of an alkali resistance fibre (AR Glass fibres High Dispersion) that provided improved long term durability. In the present experimental investigation cylinders of 100mm x 150mm of M20 grade concrete were cast with varying percentage of addition of 0.03%, 0.06% and 0.1% of glass fibre. The rapid chloride permeability tests were conducted for a period of 90, 180, 365 and 720 days. The test results show that the addition of glass fibres exhibit better performance. Singh N B (2001) was identified that Rice husk, which is a by-product of the rice paddy milling industry, has attracted more attention of ce- ment researchers than other crop residues.


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Hydration of rice husk ash (RHA) blended cements has been studied by a number of researchersN2. When rice husk is burned under controlled conditions, amor- phous silica is obtained, which reacts with Ca(OH)2 obtained during the hydration of cement and gives additional strength. In general in presence of pozzo- lanic materials the hydration reactions are slow during early hour and hence certain accelerating admixtures are needed. However, hydration of blended cements in presence of admixtures has rarely been studied. The effect of lactic acid on the hydration of 15 wt% RHA blended portland cement has been studied and the re- suits reported in this paper. Siddique (2008) was report that Non-hazardous waste materials and by-products which are mostly landfilled can be used in making concrete and similar construction materials. This book gives a summary of this usage: one chapter is devoted to each material, comprising an introduction, chemical and physical properties, usage potential, and the impact of the material on the various properties of concrete. The waste materials and by-products covered in the book are; granulated blast furnace slag, metakaolin, waste and recycled plastics, scrap-tire, waste glass, coal fly ash, rice husk ash, municipal solid waste ash, wood ash, volcanic ash, cement kiln dust and foundry sand.

## III. Materials Used

### *A. Bamboo Leaf Ash*

Bamboo leaves were dried in sun, burnt in an open air for 2 hours to have bamboo leaf ash. The ash showed a gray colour. Fig. 1. shows the ash used in the current study.

**Figure 1. Bamboo Leaf Ash**

### *B. Cement*

The paste ordinarily constitutes about 25% to 40% of the total volume of concrete. The absolute volume of cementing materials is usually between 7% and 15% and the water between 14% and 21%. Air content in air entrained concrete ranges up to about 8% of the volume of concrete, depending on the top size of the coarse aggregates. OPC grade 53 was used in this study.

### *C. Water*

Available potable water in the campus was used in this study.

## IV. Tests Carried Out

### *A. Physical Characteristics*

The physical characteristics of bamboo leaf ash such as normal consistency, setting time (initial and final), specific gravity were evaluated. The results are shown in table 1. It can be seen that specific gravity of bamboo leaf ash was lesser than that of ordinary Portland cement by 12%. The initial setting time of bamboo leaf ash was found to be 80% higher than that of ordinary Portland cement. The deviation of final setting time of bamboo leaf ash from ordinary Portland cement was minimal i.e.10%.

**Table 1 Physical Characteristics of Bamboo Leaf Ash**

| Sl. no | Physical Characteristics | Results |
|---|---|---|
| 1. | Specific gravity | 2.76 |
| 2. | Normal consistency | 32% |
| 3. | Setting time- initial | 145 min |
| 4. | Setting time- final | 270 min |

### *B. Chemical Composition*

The chemical composition of bamboo leaf ash is shown in table 2. The BLA has 59.2% silicon dioxide which confirms that it is has potential of acting as a pozzolanic material.

**Table 2 Chemical Composition**

| **Parameters** | **Percentage** |
|---|---|
| Loss on ignition | 11.2 |
| Magnesium Oxide as (MgO) | 0.54 |
| Total Sulphur as ($SO_3$) | 1.40 |
| Silicon Dioxide ($SiO_2$) | 59.2 |
| Aluminium Oxide as ($Al_2O_3$) | 61.4 |
| Iron Oxide as ($Fe_2O_3$) | 61.4 |

### *C. Compressive Strength*

The mix ratio for concrete used in this study is 1:1.5:3. The specimens are cast in cast iron moulds of dimension 100mmx100mmx100mm. These cubes were demoulded after one day of casting and specimens were immersed in water. These specimens were taken out from water for testing after 28 days. The compressive strength testing of specimens is shown in Fig 2.

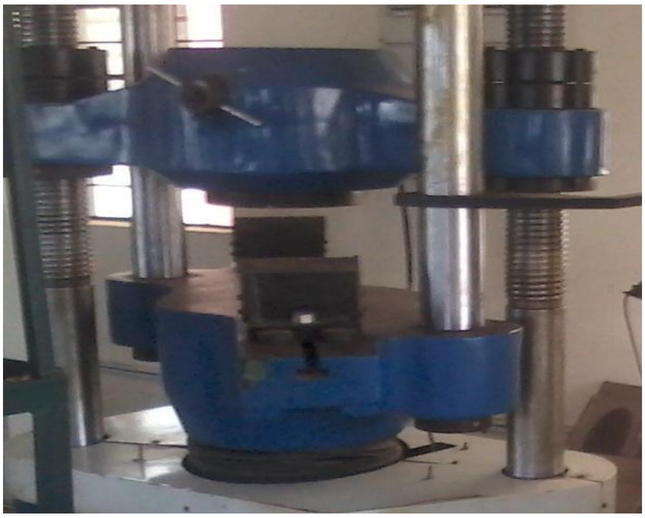

**Figure 2. Compressive Strength Test in UTM**


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### *C. Acid Resistance Test*

To determine the acid resistance of control concrete and concrete with BLA, cube specimens are cast. After 28 days of curing in water, specimens are immersed in 5% $H_2SO_4$ solution. The edges and surfaces of all the specimens were maintained without any disintegration while immersed in water during the observation period of 10 days. Before the cubes are immersed in acid solution the weight of specimens were noted. Then after 10 days take the cubes are taken out and weighed again to determine loss of weight due to acid attack. The compressive strength of specimens were determined before and after immersion to determine the strength loss due to acid attack.

### *D. Rapid Chloride Permeability Test (RCPT)*

According to ASTM C1202 test, a water-saturated, 50 mm thick, 100 mm thick diameter concrete cylinder specimen is subjected to a 60V (DC voltage) for 6 hours using the apparatus and the cell arrangement is shown in Fig 3. In one reservoir there is 3.0% NaC1 solution and in the other reservoir is 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete specimen for its chloride permeability. The specimens were fit in the chamber with the required brass as well as rubber oring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60V was passed continuously. The data logger records the readings of corresponding cells at the every record time with its initial readings. At the end of log time, the system halts after taking the final reading.

Average current flowing through one cell is calculated by,

$$I = 900 * 2 * I_{Cumulative} \text{ Coulombs} \qquad (1)$$

$$I_{Cummulative} = I_0 + I_{30} + I_{60} + I_{90} + I_{120} + I_{150} + I_{180} + I_{210} + I_{240} + I_{270} + I_{300} + I_{330} + I_{360} \qquad (2)$$

Where

$I_0$ = Initial current reading in mA.

$I_{30}$ = Current reading at 30 minutes in mA.

$I_{60}$ = Current reading at 60 minutes in mA.

$I_{90}$ = Current reading at 90 minutes in mA.

$I_{120}$ = Current reading at 120 minutes in mA.

$I_{150}$ = Current reading at 150 minutes in mA.

$I_{180}$ = Current reading at 180 minutes in mA.

$I_{210}$ = Current reading at 210 minutes in mA.

$I_{240}$ = Current reading at 240 minutes in mA.

$I_{270}$ = Current reading at 270 minutes in mA.

$I_{300}$ = Current reading at 300 minutes in mA.

$I_{330}$ = Current reading at 330 minutes in mA.

$I_{360}$ = Current reading at 360 minutes in mA.


**Figure 3. Rapid Chloride Permeability Test Apparatus**

**Table 3 Rating of Chloride ion Penetrability Based on Charge Passed as per ASTM C1202**

| **Charge Passed in Coulombs** | **Chloride Ion Penetrability** |
|---|---|
| >4000 | High |
| 2000-4000 | Moderate |
| 1000-2000 | Low |
| 100-1000 | Very low |
| <100 | Negligible |

## V. RESULTS AND DISCUSSION

### *A. Compressive Strength*

The compressive strength test of the specimens was carried out using Universal Testing Machine. It is observed from Figure 4 and Table 4 that compressive strength decreases with increase in percent of bamboo leaf ash. The compressive strength of BLA5, BLA10 and BLA10 was lesser than that of control mix by 11%, 21% and 41% respectively. Figure 5 shows the crushed specimen after compressive strength test.

**Table 4 Compressive Strength**

| **Sl. No** | **Specimens** | **Compressive Strength (28 days)** |
|---|---|---|
| 1. | Control mix | 21 N/mm² |
| 2. | BLA 5 | 18.6 N/mm² |
| 3. | BLA 10 | 16.5 N/mm² |
| 4. | BLA 15 | 12.3 N/mm² |

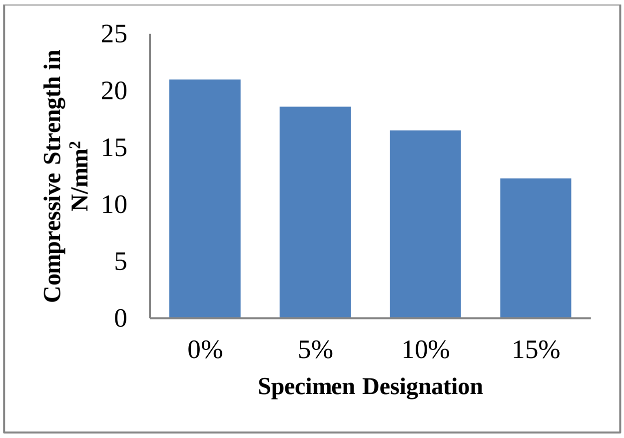


**Figure 4. Compressive Strength**

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-3 Issue-6, August 2014

Figure 5. Crushed Specimen After Completion of Compressive Strength Test

### *B. Acid Resistance Test*

The test for acid resistance is done by mixing 5% sulphuric acid solution in distilled water. The cubes are immersed in solution for 10 days. The weight and compressive strength of specimens were measured before and after test and compared. The results are shown in Figure 6 and Table 5. The weight loss of control mix, BLA5, BLA10 and BLA15 was 0.6%, 3%, 0.5% and 2.2% respectively. Hence it is seen that highest resistance to acid attack is from BLA10.

**Table 5 Weight Loss of Specimens in Acid Resistance Test**

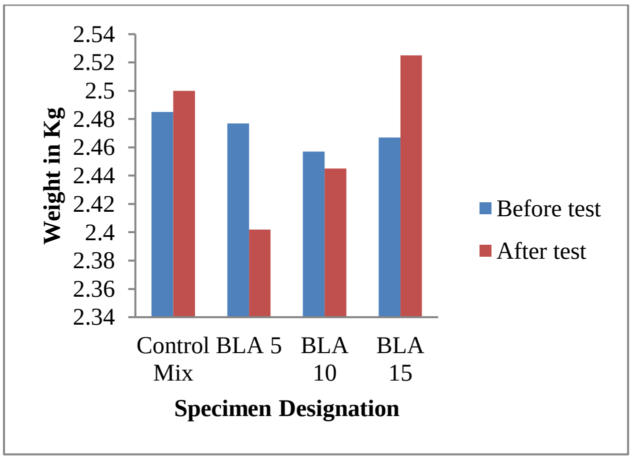


**Figure 6. Comparison of Weight of Specimens Before and After Acid Resistance Test**

**Table 6 Compressive Strength After Acid Resistance**

| Sl. No | Specimen Designation | Compressive Strength N/mm$^2$ |
|---|---|---|
| 1. | Control mix | 16.7 N/mm² |
| 2. | BLA 5 | 13.3 N/mm² |
| 3. | BLA 10 | 15.3 N/mm² |
| 4. | BLA 15 | 13.0 N/mm² |

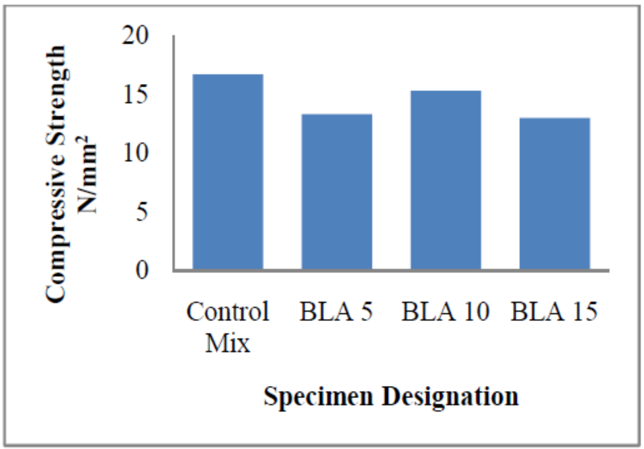


**Figure 7. Compressive Strength After Test Specimen**

### *C. Rapid chloride permeability test (RCPT)*

It is seen from Table 6 and Figure 8 that the control mix had the highest charge passed of 1678 coulomb in rapid chloride permeability test. It is 1.9times, 2.7times and 2.2times higher than that of charge passed in BLA 5, BLA 10, BLA 15 respectively. Hence it is observed as percent of BLA increases, the resistance to chloride increases but the optimum percent of BLA is 10%.

**Table 7 Charge Passed in RCPT**

| Sl. No | Specimen designation | Charge Passed in Coulombs |
|---|---|---|
| 1. | Control mix | 1678 |
| 2. | BLA 5 | 873 |
| 3. | BLA 10 | 633 |
| 4. | BLA 15 | 746 |

| Sl. No | BLA designation | Weight in Before Test | Weight in After Test |
|---|---|---|---|
| 1. | Control mix | 2.500 | 2.485 |
| 2. | BLA 5 | 2.477 | 2.402 |
| 3. | BLA 10 | 2.457 | 2.445 |
| 4. | BLA 15 | 2.525 | 2.467 |

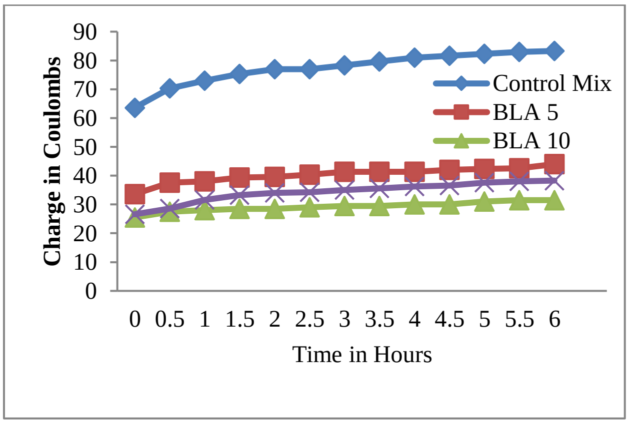


**Figure 8. Charge Passed Every Half an Hour in RCPT**

## VI. CONCLUSION

From the experimental investigation on concrete with bamboo leaf ash the following conclusions are drawn:

1. The compressive strength of concrete decreases with increase in percent of bamboo leaf ash. Though BLA contains $SiO_2$ which is required for pozzolanic reaction, the reason for reduced compressive strength was incomplete hydration at the age of 28days.
2. From durability point of view, acid resistance and chloride resistance improves considerably at 10% replacement of cement with bamboo leaf ash.

Hence concrete with bamboo leaf ash shall be used for civil engineering works where high strength is not major requirement but where durability is a major concern.



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