Experimental Investigation on Effect of Bamboo Leaf Ash Replacing Cement on Compressive Strength

Thu Thu Hnin
Department of Civil Engineering
Technological University (Thanlyin)
Republic of the Union of Myanmar

Kyaw Lin Htet
Department of Civil Engineering
Technological University (Thanlyin)
Republic of the Union of Myanmar

Ni Ni Moe Kyaw
Department of Civil Engineering
Technological University (Thanlyin)
Republic of the Union of Myanmar

Abstract: Due to the emission of harmful gas that pollute the atmosphere and rising cost of Ordinary Portland Cement (OPC), the use of waste material is considering as a replacement for cement. In this research, the use of agricultural waste on experimental investigation on the use of Bamboo Leaf Ash (BLA) as a partial replacement for cement. The content of percentage replacement of OPC with BLA from 0%. 5%, 10% and 15% by weight with 0.4 and 0.5 water-cement ratios. The compressive strengths were tested with a total of 72 (150 x 150 x 150) mm concrete cubes according to American Concrete Institute (ACI) provisions at 7 days, 14 days and 28 days respectively. In this study, local product of 'Apache' brand Portland cement, 'wanet' bamboo leaves, crushed stones and river sand were used. The chemical composition of BLA are tested by Energy Dispersive X-ray Fluorescence Spectroscopy (EDXRF) method. Research findings have carried out that the workability and strength of the concrete depend on the percentage of the ash, water-cement ratio, mixing time and age of the curing days. In this research, 5% and 10% BLA was optimum for medium grade concrete. As a conclusion, BLA have a high silica content and good supplementary cementitious properties and so it can be used for partial replacement of concrete for reducing environmental wastes and emission of carbon dioxide (CO_2) in production of cement and reducing costs.

Keywords: Bamboo Leaf Ash (BLA), Ordinary Portland Cement (OPC), Energy Dispersive X-ray Fluorescence Spectroscopy (EDXRF), water-cement ratio, agricultural waste, carbon dioxide (CO_2), compressive strength

1. INTRODUCTION

Cement is an essential part of binding material to become concrete in the construction industry. To produce the cement, not only consume a lot of energy and high temperature (about 1500 °C) but also emits harmful gas such as CO_2, NO_3 and CH_4 to the atmosphere. By solving this problem, researchers are considered for a partial replacement for cement using waste materials.

There are two types of waste materials for replacing of cement ; (i) industrial waste and (ii) agricultural waste. And then these wastes are subdivided into natural and recycled. Some agricultural waste by-products like peanut shell ash, sawdust ash, sugarcane bagasse ash and bamboo leaf ash and so on are now considered for a partial replacement of cement mixed with OPC. Utilization of bamboo leaf ash provided as an effective way for reducing environmental wastes, saving energy and impact of greenhouse gas emission to the environment. Reusing agro-wastes for producing panels, plaster, blocks suitable for passive houses. Thus, it should be considered for the solving problem of the disposal of agro-wastes.

Bamboo is used as scaffolding for construction, paper production and household products. In Myanmar, bamboo is abundantly growing and used for variety of purposes so generating high volumes of solid waste.

There are 1250 bamboo species in the world and 102 species in bamboo diversity in Myanmar. But 18 species are commercial used in the country. Depending on the bamboo species, the chemical and physical compositions may be different. Among them, "wanet" bamboo leaves are used in this research. Because of these bamboo species are growing abundantly in research area.

Bamboo leaf ash is made up of inorganic minerals, Silica, Calcium, Potassium and Magnesium. Silica content is the highest among the minerals. When calcium hydroxide ($Ca(OH)_2$) is react with silica to form calcium silicate hydrate (C-S-H), the main secondary cementitious compound is obtained.

Thus, both economical and environmental point of view, BLA should be used for a partial replacement of cement with the optimum percentage for mortar and concrete.

2. AIM

The objective of this research is to investigate the effect of bamboo leaf ash and to save the environment from disposing waste.

3. METERIALS AND METHODS

The materials used in this research were cement, aggregates (fine and coarse), water and bamboo leaf ash (BLA). Both physical and chemical properties were tested for cement and bamboo leaf ash. And only physical properties was tested for both aggregates and water.

3.1 Materials

In this research, the used of local materials are Ordinary Portland Cement, River Sand, Crushed Stone, Water and 'Wanet' bamboo leaves.

Bamboo leaves have been collected from household productions in Pindaya township, Shan State. The collected bamboo leaves were sun dried and burnt in a closed metallic drum. After that these ashes spread on the surface and allowed to cool for 24 hours and finally got the bamboo leaves ash of gray colour.

The cement used was Type I, Ordinary Portland Cement 'Apache' brand and the fine aggregates were of sharp sand and coarse aggregates were of nominal maximum size of 19 mm respectively. The water from tube well of High-Tech Concrete Company Limited. The bamboo leaf and bamboo leaf ash were shown in Figure 1.

Figure 1. Bamboo Leaf and Bamboo Leaf Ash

3.2 Methods

Expect from chemical analysis of bamboo leaf ash the physical properties of BLA and OPC and strength tests were tested according to American Society of Testing and Materials (ASTM) standards.

3.2.1. Chemical Analysis of Bamboo Leaf Ash (BLA)

The chemical composition on the samples were analyzed by Energy Dispersive X-Ray Fluorescence Spectroscopy (EDXRF) test in West Yangon University.

3.2.2. Physical Properties of BLA and OPC

Specific gravity were tested with BLA only and consistency and setting time tests were tested with OPC mixed with a varied percentage of BLA.

3.2.3. Workability Test

The OPC was mixed with a varied percentage of BLA with the water-cement ratios of 0.4 and 0.5 and to determine the workability of concrete and consequently the compressive strength for 7 days, 14 days, 28 days and 56 days respectively.

3.2.4. Density Test

The density test was carried out with a varied percentage of BLA mixed with OPC of a fresh concrete.

3.2.5. Compressive Strength Test

The compressive strength tests, a total of 36 cubes (150 x 150 x 150) mm for each water-cement ratio were tested in High-Tech Concrete Company Limited. Three cubes were tested for each percent and then took the average.

4. RESULTS AND DISCUSSION

The research materials of the physical properties of cement, sand, aggregate, water and bamboo leaf ash were shown below.

4.1. Chemical Analysis of Bamboo Leaf Ash (BLA)

The chemical analysis of OPC and BLA were tested and compare the main chemical composition test results were shown in Table.1.

Table 1. The chemical composition of OPC and BLA

Constituent	Ordinary Portland Cement(OPC)	Bamboo Leaf Ash(BLA)
Silicon dioxide (SiO_2)	21.47 %	67.78 %
Aluminum oxide (Al_2O_3)	4.61%	-
Ferric oxide (Fe_2O_3)	3.32 %	0.156 %
Calcium Oxide (CaO)	64.61 %	6.138 %

4.2. Standard Consistency Test

The consistency test was carried out according to ASTM C 187. In this test, the higher the BLA %, the more water is added and the results were shown in Table 2.

Table 2.The standard consistency test result of OPC mixed with BLA

Test	BLA 0%	BLA 5%	BLA 10%	BLA 15%
Standard consistency	28 %	33.15 %	36.5 %	43 %

4.3. Setting Time Test

The initial and final setting time is performed according to ASTM C 191. The results show the initial and final setting time of OPC mixed with BLA is more than the OPC. The test results were shown in Table 3.

Table 3.The setting time test result of OPC mixed with BLA

Test	BLA 0%	BLA 5%	BLA 10%	BLA 15%
Initial Setting time	2 hr 30 min	3 hr 20 min	4 hr 05 min	4 hr 25 min
Final Setting time	3 hr 40 min	5 hr 00 min	5 hr 45 min	6 hr 15 min

4.4. Workability Test

The workability is determined by slump test. In this research, the increase in percentage of BLA, the decrease in workability of concrete. The greater percentage of BLA tend to be fall down in slump. The test results of the water cement ratios (w/c) and percentage of BLA were shown in Table 4. And a higher temperature reduces the workability and increases the slump loss.

Table 4. The slump Test Result of OPC mixed with BLA

W/C	0% BLA	5% BLA	10% BLA	15% BLA
0.4	170	60	35	10
0.5	225	175	130	65

4.5. Density

The density of control concrete (0%) is greater than the BLA (5, 10, 15) %. The density is decreased when the BLA added to OPC. The test results were shown in Figure 2.

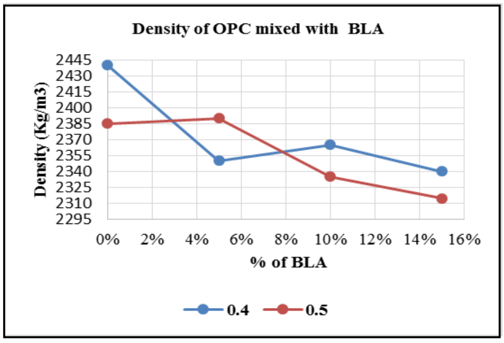

Figure 2. Fresh density with % of ash and water-cement ratio

4.6. Compressive Strength of Cement

The compressive strength of the cement is the determining the strength of cement only and mixed with BLA with their percentage within the curing periods of 3, 7 and 28 days respectively. In this paper, the compressive strength of BLA 5% replacement is higher than the OPC (0% replacement) at the standard age of 28 days period. And then the compressive strength of the replacement of 10% BLA is nearly the same as OPC and 15% replacement is slightly decreased. Figure 3 shows the compressive strength of BLA with cement with a standard mortar of the water-cement ratio of 0.485.

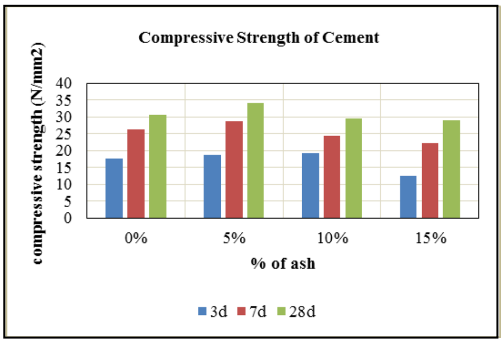

Figure 3. Compressive strength of cement

4.7. Compressive Strength of Concrete

The compressive strength of the concrete within the curing period of 7, 14, 28 and 56 days respectively. According to the strength activity index, at the standard age of 28 days period, the value of compressive strength is above 75% in 5% and 10% BLA respectively and 15% BLA is below 75%.

This show that the increase percentage of BLA reduces the decrease in strength. Based on these data, the optimum percentage level of BLA 5% and 10% for the production of medium grade concrete. Table 4 shows the compressive strength at various curing ages of BLA. Table 5 and 6 show the compressive strength of BLA mixed with cement varied water-cement ratios at 28 days curing age.

Table 4. Compressive strength at various curing ages of BLA with 0.4 water-cement ratio

% of BLA	Curing age	Compressive Strength (N/mm2)
0%	7 days	42.8
5%	7 days	36.21
10%	7 days	36.95
15%	7 days	35.45
0%	14 days	47.8
5%	14 days	42.7
10%	14 days	40.1
15%	14 days	38.6
0%	28 days	48.7
5%	28 days	40.5
10%	28 days	39.7
15%	28 days	37.6

Table 5. Compressive strength at various curing ages of BLA with 0.5 water-cement ratio

% of BLA	Curing age	Compressive Strength (N/mm2)
0%	7 days	25.6
5%	7 days	25.6
10%	7 days	24.9
15%	7 days	24.5
0%	14 days	32.95
5%	14 days	30.9
10%	14 days	29.7
15%	14 days	28.5
0%	28 days	41.8

5%	28 days	35.7
10%	28 days	32
15%	28 days	31.2

Table 5. Strength activity index of the bamboo leaf ash with 0.4 water-cement ratio at 28 days curing age

% of BLA	Compressive strength (N/mm2)	Strength activity index (%)
0%	47.6	100
5%	42.07	88.38
10%	35.63	74.85
15%	31.33	65.81

Table 6. Strength activity index of the bamboo leaf ash with 0.5 water-cement ratio at 28 days curing age

% of BLA	Compressive strength (N/mm2)	Strength activity index (%)
0%	41.77	100
5%	35.73	85.54
10%	32	76.61
15%	31.17	74.62

5. CONCLUSION

From the results, it can be concluded that ;

- The percentage of silicon dioxide in BLA is over three times more than OPC, so the calcium silicate hydrate (C-S-H) the secondary hydration is formed at later day strength.
- The more added the BLA, the more water is needed in the standard consistency test.
- The setting time of concrete increased when percentage of BLA increased.
- The workability is inversely proportional to the percentage of BLA.
- The density of OPC mixed with BLA is lighter than OPC only because the specific gravity value of BLA is smaller.
- The compressive strength of concrete decreased when the content of BLA increased.
- The strength activity index of BLA 5% and 10% is optimum because its value is above 75%.
- Finally, the replacement of BLA is convenient for Grade 30 to G 40 but not compare to the strength of OPC only.

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