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FEASIBILITY STUDY OF BAMBOO ASH ON CONCRETE MEMBERS

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Abstract

This study investigates the strength performance of concrete using partial blends of cement and bamboo ash. The bamboos were dried under sunlight and burnt in air. Bamboo ash was obtained after passing the residual through 200µm sieve. Elemental analysis was conducted on bamboo ash and ordinary portland cement, OPC by EDXRF (Energy Dispersive X-ray Fluorescence) technique to evaluate its percentage composition. Bamboo ash shows pozzolanic activity and it was used as supplementary cementitious material. Bamboo ash was then used to replace OPC by weight in ratio of 0%, 5%, 10%, 15%, 20% and 25% in concrete (M-15 & M-20). Base upon the quantities of ingredients of the mixes (1:2:4), M-15 grade and mixes (1:1.5:3), M-20 grade concretes were prepared. Twelve pieces of 150 mm concrete cubes were prepared. These cubes were tested at 28 days of curing ages and then maximum load and compressive strength of cubes were determined respectively. To investigate the pozzolanic behavior of bambo ash , (95%OPC+5% bamboo ash) and (90% OPC+10% bamboo ash) concrete crushes were analyzed by XRD analysis.

***Keywords:* –** *bamboo waste ash, EDXRF , pozzolanic, compressive strength, concrete*

Introduction

Agricultural wastes are widely available, renewable and virtually free and it is important resource. Researchers all over the world today are focusing on ways of utilizing either industrial or agricultural waste, as a source of raw materials for industry. Agricultural wastes are converted into heat, steam, charcoal, methanol ethanol, bio diesel as well as raw materials (animal's feed, composting, energy and biogas construction etc.). The production of energy from agricultural waste has been utilized to varying degrees in different parts of the world. This waste, utilization would not only be economical, foreign exchange earnings and environmental pollution control. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. Natural pozzolans by

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themselves possess little or no cementing value, but finely ground in the presence of moisture, they will chemically react with calcium hydroxide at ordinary temperature to form hydrated phases possessing cementing properties. Nowadays, some industrial by-products and wastes are attracting much research because of their high silica and/or alumina content for the use as additives in commercial Portland cements. It is well known that hydrated phases formed during pozzolanic reaction commonly improve the performance of concrete.

Pozzolan is a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide Ca(OH)2 to form compounds possessing hydraulic cementitious properties. Ordinary Portland Cement is the most extensively used construction material in the world. Since the early 1980's, there has been an enormous demand for the mineral admixture and in future this demand is expected to increase even more. If some of raw material having similar composition can be replaced by weight of cement in concrete then cost could be reduced without affecting its quality. For this reason bamboo ash is one of the main byproduct can be used as mineral admixture due to its high content in silica (SiO2). Also in this modern age every structure has its own intended purpose and hence to meet this purpose modification in traditional cement concrete has become essential. This situation has led to the extensive research on concrete resulting in mineral admixture to be partly used as cement replacement to increase workability in most structural application. We found that ash obtained from bamboo 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. Bamboo is one of the fastest-growing plants on Earth, with reported growth rates of 250 cm (98 in) in 24 hours. However, the growth rate is dependent on local soil and climatic conditions, as well as species, and a more typical growth rate for many commonly cultivated bamboos in temperate climates is in the range of 3-10 centimeters (1.2-3.9 in) per day during the growing period. Primarily growing in regions of warmer climates during the late Cretaceous period, vast fields existed in what is now Asia. Bamboo is the fastest growing, renewable natural resource known to us. It is a small wonder, therefore, that this material was used for building extensively by our ancestors. It has a long and well established tradition as a building material throughout the tropical and sub-tropical regions. It is used in many forms of construction, particularly. It has also been found that bamboo acts very well in buckling but due to low stresses than compared to steel and due to it not being straight it may not be very good. Further, it has been established that in seismic zones the failure of bamboo is very less as the maximum absorption of the energy is at the joints. Cellulose is the main component present in bamboo which is the main source of mechanical properties of bamboo. Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement that hardens over time. Most concrete used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements. When aggregate is mixed together with dry Portland cement and water, the mixture forms a fluid mass that is easily moulded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix that binds the material together into a durable stone-like material that has many uses.

Experimental

Materials and Methods

Preparation of Samples

The bamboo wastes were collected from Tanintharyi region of Dawei, Myanmar. They were dried under sunlight to reduce the moisture content in wastes. The dry bamboo wastes were burnt in air and the gray bamboo ash was obtained. Bamboo ash was then sieved with a 200 µm standard sieve and purified bamboo ash was obtained. Bamboo ash and ordinary portland cement OPC were analyzed by (Energy Dispersive X-ray Fluorescence) EDXRF technique, to evaluate their chemical composition. By observing the EDXRF results, the chemical composition of bamboo ash and OPC were determined. For concrete cubes sample preparation, the main ingredients are Ordinary Portland Cement (OPC), bamboo ash, sand, coarse aggregates and water. In this experimental work, twelve 150mm concrete cubes, grade M-15 (1:2:4) and grade M-20 (1:1.5:3) were designed. Based upon the quantities of ingredient of the mixes, OPC (replacing cement by 0% bamboo ash) concrete cube, which is regarded as "sample 1" and the bamboo ash was used for 5%, 10%, 15%, 20% and 25% replacing cement concrete cubes which were marked out as sample 2,3,4,5,6 were prepared for concrete grade M-15 and M-20 respectively. The ingredients of concrete were thoroughly mixed in pan and during mixing the ingredients of concrete, water were used to form concrete paste. Water to cement ratio (w/c) was different for different specimens and then uniform thoroughly consistency concrete paste was achieved and concrete specimens were casted by using the plastic mould as shown in figure 1. These concrete cubes were produced for 28 days curing age. These were tested by compression machine, the maximum load and compressive strength of concrete cubes were determined. To investigate the pozzolanic behavior of bamboo ash, (95%OPC+5% bamboo ash) and (90% OPC+10% bamboo ash) concrete crushes were analyzed by XRD analysis. For sample preparation, bamboo ash, cement, sand and coarse aggregates weight ratio for concrete cubes were shown in table (1&2).

EDXRF Analysis of the (5% & 10% bamboo ash) admixture cement paste

The chemical composition of bamboo ash determined by EDXRF analysis was shown in table 3.The chemical composition of bamboo ash illustrates that it contains high amount of silicon (Si) as dominant element and the second dominant elements are potassium (K),calcium (Ca) , Iron (Fe) and in addition to small amount of sulfur (S), manganese (Mn), titanium (Ti), zinc (Zn) ,rubidium (Rb), copper (Cu), strontium (Sr) and yttrium (Y).

The chemical composition of OPC by EDXRF analysis was shown in table 4. The chemical composition of OPC illustrates that it contains high amount of calcium (Ca) as dominant element and the second dominant elements are silicon (Si) , Iron (Fe), potassium (K) , sulfur (S), titanium (Ti) manganese (Mn), strontium (Sr) and zirconium (Zr).

XRD analysis of the (5% & 10% bamboo ash) admixture cement paste

In this research, an XRD analysis is used to investigate the pozzolanic behavior of bamboo ash and to identify the hydration products formed during the hydration of OPC in concrete making is shown in Fig 2 (a & b). By observing the XRD patterns of (5% and 10% bamboo ash) admixture cement paste at curing age 28 days (concrete crushes), it was found that calcium silicate hydrate, C-S-H, calcite, $CaCo_3$ and calcium hydroxide, Ca $(OH)_2$ peaks were observed in both patterns. The most intense C-S-H peaks were observed on both observed file and the XRD pattern of (5% bamboo ash) has more intense peaks than (10% bamboo ash). This C-S-H peaks indicate the pozzolanic reaction between $Ca(OH)_2$ and amorphous silica present in bamboo ash. This additional hydration product C-S-H has the cementitious properties and it improves the compressive strength of concrete.

Maximum load and Compressive Strength

The maximum load and compressive strength of all concrete cubes were measured and tested at Myanmar Engineering Society, MES Quality Control Laboratory, Compression Test of Concrete Specimens room, Hlaing University Campus, Hlaing Township, Yangon Myanmar. The compressive strength of 5, 10, 15, 20 & 25% (bamboo ash concretes) grade M-15 did not exceed than that of OPC and it had nearly equal value of OPC. The maximum load and compressive strength were tested by 2000kN compression machine and the results were shown in Table 5&6. The maximum load and compressive strength of MES results were shown in Figure 3 and bar graphs were shown in Figure4(a, b)&5(a, b).

Target Strength of Concrete

According to IS, the target strength of the compressive strength of the concrete mixture is defined as:

Target Strength = $\mathbf{f_{ck} + 1.65\sigma}$ **,**

Where σ is the standard deviation and f_{ck} is the characteristic strength [Quantity Control Issue].

The results were shown in Table 7&8.

Target Strength of Concrete Grade M-15 (1:2:4) and M-20 (1:1.5:3)

For Grade M-15 (1:2:4)

Target Strength,

$f_t = f_{ck} + 1.65\ \sigma$

$f_t = 15 + 1.65 \times 3.5$ (Standard Deviation for grade M-15 is 3.5)

$\mathbf{f_t = 20.775\ MPa}$

For Grade -20 (1:1.5:3)

Target Strength,

$f_t = f_{ck} + 1.65\ \sigma$

$f_t = 15 + 1.65 \times 4$ (Standard Deviation for grade M-20 is 4)

$\mathbf{f_t = 26\ MPa}$

Figure 1: The photograph of concrete paste pour in plastic mould

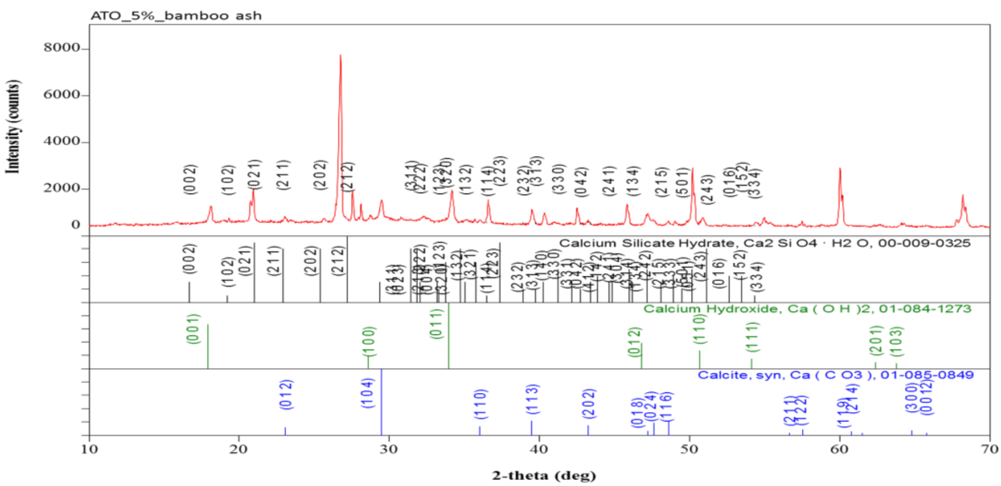


Figure 2: (a) The XRD pattern of 5 % bamboo ash admixture cement paste

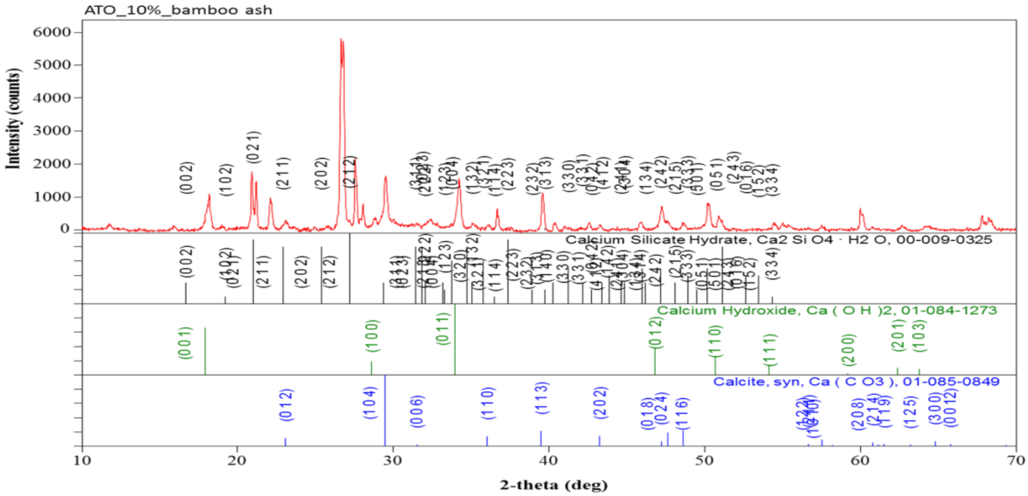
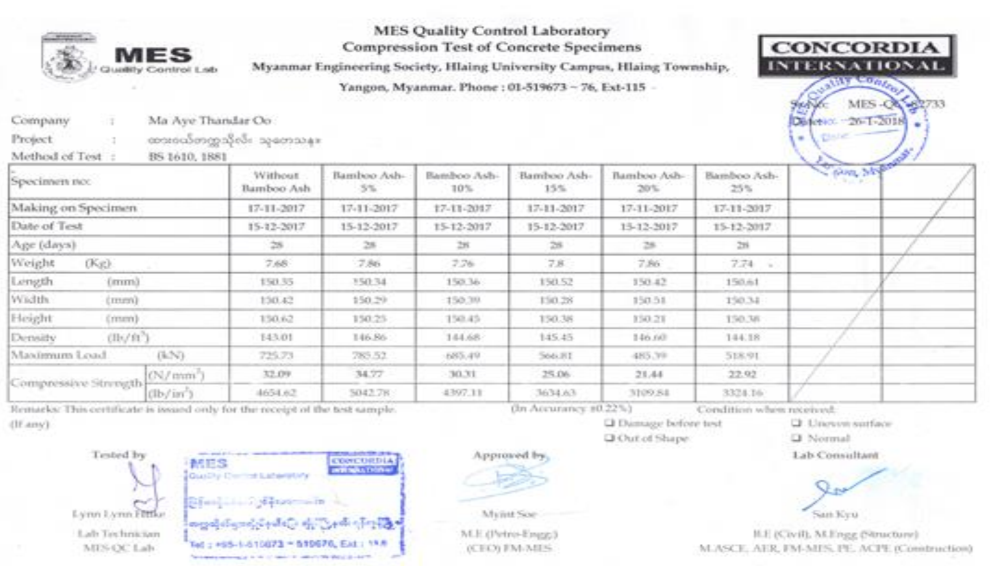


Figure 2: (b) The XRD pattern of 10 % bamboo ash admixture cement paste



MES Quality Control Laboratory
Compression Test of Concrete Specimens
Myanmar Engineering Society, Hlaing University Campus, Hlaing Township,
Yangon, Myanmar. Phone : 01-519673 ~ 76, Ext-115

MES Quality Control Lab

CONCORDIA INTERNATIONAL

Sr. No: MES -QC-2733
Date: 26-1-2018

Company : Ma Aye Thandar Oo
Project : [illegible]
Method of Test : BS 1610, 1881

Specimen no:		Without Bamboo Ash	Bamboo Ash-5%	Bamboo Ash-10%	Bamboo Ash-15%	Bamboo Ash-20%	Bamboo Ash-25%		
Making on Specimen		17-11-2017	17-11-2017	17-11-2017	17-11-2017	17-11-2017	17-11-2017		
Date of Test		15-12-2017	15-12-2017	15-12-2017	15-12-2017	15-12-2017	15-12-2017		
Age (days)		28	28	28	28	28	28		
Weight (Kg)		7.68	7.86	7.76	7.8	7.86	7.74		
Length (mm)		150.35	150.34	150.36	150.52	150.42	150.61		
Width (mm)		150.42	150.29	150.39	150.28	150.51	150.34		
Height (mm)		150.62	150.25	150.45	150.38	150.21	150.38		
Density (lb/ft^3)		143.01	146.86	144.68	145.45	146.60	144.18		
Maximum Load (kN)		725.73	785.52	685.49	566.81	485.39	518.91		
Compressive Strength	(N/mm^2)	32.09	34.77	30.31	25.06	21.44	22.92		
	(lb/in^2)	4654.62	5042.78	4397.11	3634.63	3109.84	3324.16		

Remarks: This certificate is issued only for the receipt of the test sample. (In Accuracy ±0.22%) Condition when received:
(If any)
❑ Damage before test ❑ Uneven surface
❑ Out of Shape ❑ Normal

Tested by
Lynn Lynn Htike
Lab Technician
MES-QC Lab

Approved by
Myint Soe
M.E (Petro-Engg.)
(CEO) FM-MES

Lab Consultant
San Kyu
B.E (Civil), M.Engg (Structure)
M.ASCE, AER, FM-MES, PE, ACPE (Construction)

Figure 3: The photograph of MES's certificate

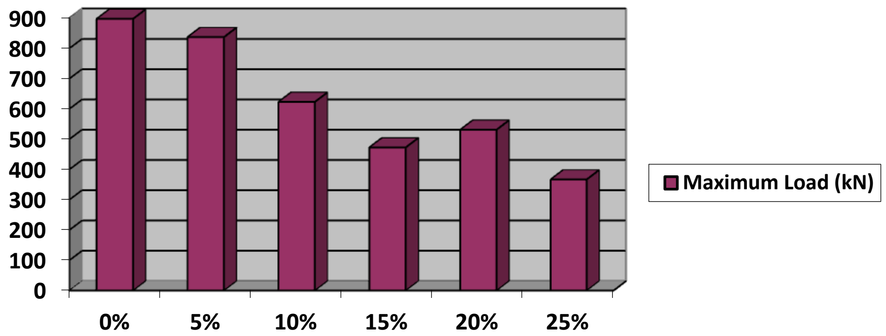


Figure 4: (a) Maximum load bar graph of M-15 concrete cubes

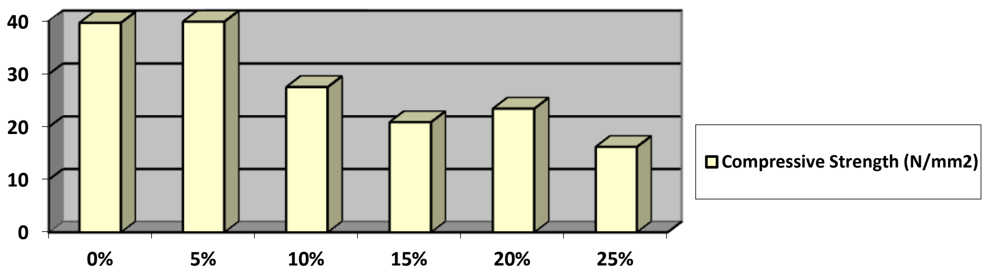


Figure 4: (b) Compressive Strength bar graph of M-15 concrete cubes

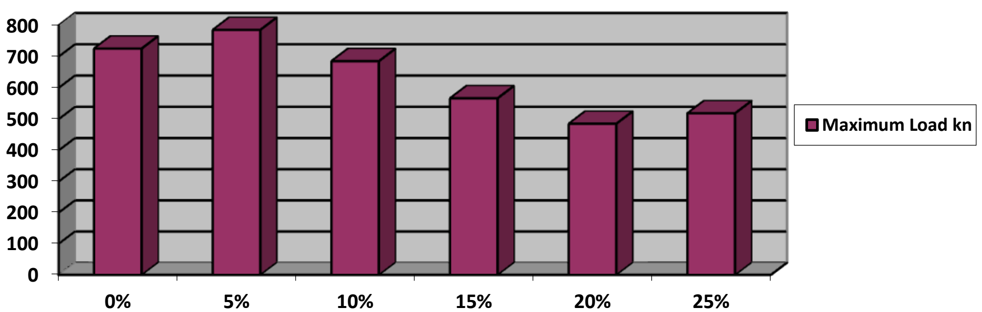


Figure 5: (a) Maximum load bar graph of M-20 concrete cubes

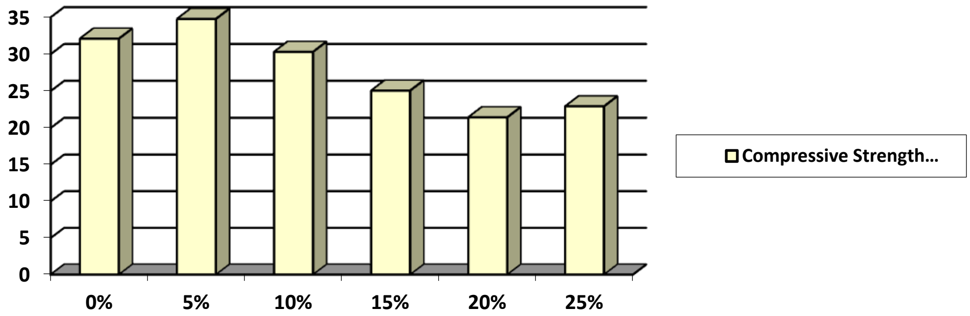


Figure 5: (b) Compressive Strength bar graph of M-20 concrete cubes

Table 1: Cement, bamboo ash, sand, coarse aggregates and water to cement ratio for grade M-15 concrete

Sample No.	**Cement (%) (1)**	**Sand (2)**	**Coarse Aggregates (4)**	**Bamboo ash (%)**	**Total Weight**	**Water to Cement ratio (w/c)**
Sample (1)	1.071kg (100%)	2.142kg	4.284kg	0kg (0%)	7.5 kg	**0.5** (0.53) kg
Sample (2)	0.97 kg(95%)	2.142 kg	4.284 kg	0.05 kg (5%)	7.5 kg	**0.35** (0.38)kg
Sample (3)	0.9639 kg (90%)	2.142 kg	4.284kg	0.1071kg (10%)	7.5kg	**0.35** (0.38)kg
Sample (4)	0.9103kg (85%)	2.142kg	4.284kg	0.1606kg (15%)	7.5kg	**0.35** (0.38kg)
Sample (5)	0.8568kg (20%)	2.142kg	4.284kg	0.2142kg (20%)	7.5kg	**0.35** (0.38kg)
Sample (6)	0.803kg (25%)	2.142kg	4.28kg	0.268kg (25%)	7.5kg	**0.4** (0.43kg)

Table 2: Cement, bamboo ash, sand, coarse aggregates and water to cement ratio for grade M-20 concrete

Sample No.	Cement (%) (1)	Sand (1.5)	Coarse Aggregates (3)	Bamboo ash (%)	Total Weight	Water to Cement ratio (w/c)
(1)	1.3636 kg (100%)	2.045kg	4.09 kg	0kg (0%)	7.5 kg	0.6 (0.82) kg
Sample (2)	1.295 kg(95%)	2.045 kg	4.09 kg	0.0686 kg (5%)	7.5 kg	0.5 (0.68)kg
Sample (3)	1.227 kg (90%)	2.045 kg	4.09 kg	0.1366 kg (10%)	7.5kg	0.57 (0.78)kg
Sample (4)	1.159kg (85%)	2.045 kg	4.09 kg	0.2046 kg (15%)	7.5kg	0.55 (0.75)kg
Sample (5)	1.091 kg (20%)	2.045kg	4.09 kg	0.2726 kg (20%)	7.5kg	0.56 (0.76)kg
Sample (6)	1.023 kg (25%)	2.045kg	4.09 kg	0.3406 kg (25%)	7.5kg	0.56 (0.76)kg

Table 3: Chemical composition of bamboo ash by EDXRF analysis

Component	Si %	K %	Ca %	Fe %	S %	Mn %	Ti %	Zn %	Rb %	Cu %	Sr %	Y %
Bamboo Ash	51.47	14.98	14.44	9.12	1.47	1.11	0.59	0.59	0.09	0.08	0.07	0.07

Table 4: Chemical composition of ordinary portland cement, OPC by EDXRF analysis

Component	Ca%	Si%	Fe%	K %	S %	Ti %	Mn %	Sr%	Zr%
OPC	83.87	6.55	6.37	1.58	1.02	0.41	0.1	0.8	0.23

Table 5: Maximum Load and Compressive Strength of specimens (grade M -15, 1:2:4 cement replacement by bamboo wastes ash)

Specimen No.	Sample (1) 0% Bamboo ash	Sample (2) 5% Bamboo Ash	Sample (3) 10% Bamboo Ash	Sample (4) 15% Bamboo Ash	Sample (5) 20% Bamboo Ash	Sample (6) 25% Bamboo Ash
Making on Specimen	10.10.17	10.10.17	14.10.17	12.10.17	12.10.17	14.10,17
Date of Test	7.11.17	7.11.17	11.11.17	9.11.17	9.11.17	11.11.17
Age(days)	28	28	28	28	28	28
Weight (kg)	7.58	7.4	7.65	7.5	7.66	7.7
Length (mm)	150.12	150.26	150.13	150.21	150.27	150.12
Width (mm)	150.5	150.84	150.47	150.3	150.42	150.51
Height (mm)	150.39	150.3	150.58	150.42	150.5	150.85
Density (kg/m^3)	141.50	137.79	142.65	140.09	142.83	143.30
Maximum Load(kN)	897.26	836.95	622.91	472.6	531.01	366.66
Compressive Strength (N/mm^2)	39.71	36.93	27.57	20.93	23.49	16.23
(lb/in^2)	5760.51	5356.21	3999.96	3036.36	3407.55	2353.84

Table 6: Maximum Load and Compressive Strength of specimens (grade M -20, 1:1.5:3 cement replacement by bamboo wastes ash)

Specimen No.	Sample(1) 0% Bamboo ash	Sample(2) 5% Bamboo Ash	Sample(3) 10% Bamboo Ash	Sample(4) 15% Bamboo Ash	Sample(5) 20% Bamboo Ash	Sample(6) 25% Bamboo Ash
Making on Specimen	17.11.17	17.11.17	17.11.17	17.11.17	17.11.17	17.11.17
Date of Test	15.12.17	15.12.17	15.12.17	15.12.17	15.12.17	15.12.17
Age(days)	28	28	28	28	28	28
Weight (kg)	7.68	7.86	7.76	7.8	7.86	7.74
Length(mm)	150.35	150.34	150.36	150.52	150.42	150.61
width(mm)	150.42	150.29	150.39	150.28	150.51	150.34
Height (mm)	150.62	150.25	150.45	150.38	150.21	150.38
Density (kg/m^3)	143.01	146.86	144.68	145.45	146.60	144.18
Maximum Load(kN)	725.73	785.52	685.49	566.81	485.39	518.91
Compressive Strength (N/mm^2)	32.09	34.77	30.31	25.06	21.44	22.92
(lb/in^2)	4654.62	5042.78	4397.11	3634.63	3109.84	3324.16

Table 7: Comparison of Measurable Compressive Strength and Target Strength for grade M-15 (bamboo Ash)

Sample No	Concrete Grade	Measurable Compressive Strength (MPa)	Target Strength (MPa)	Curing Age (Days)	Remark
1(0%)	M-15	39.71	20.775	28	**MCS>TS**
2(5%)	M-15	36.93	20.775	28	**MCS>TS**
3(10%)	M-15	27.57	20.775	28	**MCS>TS**
4(15%)	M-15	20.93	20.775	28	**MCS>TS**
5(20%)	M-15	23.49	20.775	28	**MCS>TS**
6(25%)	M-15	16.23	20.775	28	**MCS<TS**

Table 8: Comparison of Measurable Compressive Strength and Target Strength for grade M-20 (bamboo Ash)

Sample No	Concrete Grade	Measurable Compressive Strength (MPa)	Target Strength (MPa)	Curing Age (Days)	Remark
1(0%)	M-20	32.09	26.6	28	MCS>TS
2(5%)	M-20	34.77	26.6	28	MCS>TS
3(10%)	M-20	30.31	26.6	28	MCS>TS
4(15%)	M-20	25.06	26.6	28	MCS<TS
5(20%)	M-20	21.44	26.6	28	MCS<TS
6(25%)	M-20	22.92	26.6	28	MCS<TS

Conclusion

Pozzolanic behavior of bamboo ash in partial cement replacement in concrete has been studied. By observing the EDXRF analysis of bamboo ash, it was found that bamboo ash contains high amount of silica and second dominant elements were potassium and calcium. The elements contain in bamboo ash and OPC were almost the same. For concrete grade M-15, according to MES's results, the measured value of maximum load and compressive strength of blended concretes did not exceed than OPC (0%) concrete. However, 5%, 10%, 15% and 20% blended concretes reached the target strength. For concrete grade M-20, from the results, the measured value of maximum load and compressive strength of 5% blended concrete was higher than that of OPC (0%) concrete. But, only 5% and 10% blended concretes reached the target strength. By observing the XRD patterns of 5% and 10% bamboo ash of concrete crushes , it was found that the hydration product, calcium silicate hydrate, C-S-H formed during the hydration of OPC and it was shown that the pozzolanic behavior of the bamboo ash. Fineness of bamboo ash is also the important factor affecting the compressive strength of concrete. So, grade M-20 for 5% and 10% of bamboo ash is quite suitable for partially cement replacements

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