APPLICATION OF WOOD ASH IN THE PRODUCTION OF CONCRETE

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ABSTRACT; *The production of cement involves an intensive use of raw materials and energy, while at the same time, releases high quantity of carbon dioxide (CO_2) into the atmosphere. Current energy crisis in Pakistan has created serious problems for industries which have been using natural gas and electric power as a fuel. A number of industries in Pakistan such as Doce foods, Gourmet foods, Rado 80 textile industry etc. are using waste wood as fuel and as a result of it ash is produced. The use of Wood Ash (WA) in cement concrete mix will make it cost effective and friendly disposal of the product. By reducing the demand of cement, natural reserves of limestone can be preserved, energy can be saved and pollution due to CO_2 can be reduced. To consider its environmentally friendly consumption and to determine its useful application in construction its role as partial replacement of cement in concrete was studied here. Since, various other ashes such as rice husk ash, bagasse ash etc. have been studied for their pozzolanic actions. In this study an effort was made to find optimum replacement level of WA in order to get reasonable strength of concrete. Test result showed that the WA was somewhat pozzolanic. With the increase in content of WA water demand and setting time of the concrete also increased. Compressive strength of concrete with 10% replacement of cement with WA reasonably improved with age.*

Keywords: *Wood ash, concrete, strength, cement replacement*

1. INTRODUCTION

Concrete's versatility, durability, and economy have made it the world's most useful construction material. Portland cement is a relatively expansive ingredient in concrete, and comprises of 10 to 20 percent of concrete's weight. However, it contributes the largest portion of embodied energy and greenhouse gas in atmosphere. The use of waste material as a cement replacement has become more common in recent decade. Recently research was performed to investigate the feasibility of WA as a partial replacement of hydraulic cement in concrete production. [1]

Fly Ash (FA), WA, Bagasse Ash (BA) and Rice Husk Ash (RHA) are agro-industrial wastes and are pozzolanic in nature. These are pollutants for environment and using them as Cement Replacement Materials (CRMs) will reduce the pollution as well as cost of concrete. These waste materials are produced in millions of tons as by-product. Researchers have proved that these materials can be used as CRMs [2], [3].

Tarun et. al. [4] Reported the following elements in WA: carbon (5% to 30%), calcium (5% to 30%), potassium (3% to 4%), magnesium (1% to2%), phosphorus (0.3% to 1.4%) and sodium (0.2% to 0.5%). The following compound composition limits were also reported: SiO2 (4% to 60%), Al2O3 (5% to 20%), Fe2O3 (10% to 90%), CaO (2% to 37%), MgO (0.7% to 5%), TiO2 (0% to 1.5%), K2O (0.4% to 14%), SO3 (0.1% to 15%), LOI (0.1% to 33%), moisture content (0.1% to 22%), and available alkalis (0.4% to 20%). The study revealed that all the major compounds present in WA are present in fly ash.

It is well known that cement is a costly material and its production involves consumption of limestone which is a natural resource. CO_2 is emitted in large quantity during the production of cement which is a pollutant. Energy resources like coal and oil are decreasing as they are used in the production of cement. Researchers are searching for cheap and easily available pozzolanic materials from the industry and agriculture which can be used as CRM's in concrete. Hence, incorporation of WA as CRMs in blended cement and concrete will be beneficial not only in environmental terms but also in production costs of the aforesaid material.

2. MATERIAL AND METHOD

The WA used in this work was raw material collected from three different sources namely boiler of Rado 80 textile mill, Doce bakery Lahore and kiln of the Liaquat Hall mess situated in GCT Rasul. The WA was sieved through ASTM sieve # 200 sieve to collect fine particles of ash. Pozzolanic activity was determined by strength activity index test in accordance with ASTM C311 [6]. All concrete samples were cast with mix proportion of 1:2:4 and water to cement ratio (w/c) was kept constant (i.e. 0.6) for all concrete mixes. Workability of concrete was measured by slump test. Cylinders having diameter 150 mm and height 300 mm were cast. 9 cylinders were cast with normal concrete and are considered here as control concrete. While 9 cylinders each from the concrete mix with 10%, 15% and 20% cement replacement were cast and were tested for compressive at the age of 7, 28 and 56 days according to ASTM C 39 [7].

3. RESULTS AND DISCUSSION

3.1 CHEMICAL COMPOSITION OF WOOD ASH

Chemical compositions of WA samples are presented in Table 1.1. It was observed that the Mess WA contains silica content approximately 5 times higher than OPC. The three collected WA samples contain CaO lesser than OPC. The sum of contents of silicon dioxide (SiO2), aluminum oxide (Al2O3) and iron oxide (Fe2O3) in the Mess WA, Doce WA and Boiler WA is 59.031%, 17.71%, 25.523% respectively. Hence, Mess WA almost fulfils the requirement of ASTM C-618 (Mineral Admixture Class C), which indicates that it has good binding properties and can be used as a partial replacement of cement [8].

Table 1.1: Chemical composition of wood Ashes

Constituents	Cement (Lucky) %age by wt. of sample	Mess WA %age by wt. of sample	Doce WA %age by wt. of sample	Boiler WA %age by wt. of sample
SiO_2	13.81	55.52	13.50	20.66
Al_2O_3	6.85	3.11	4.21	3.663
Fe_2O_3	0.01	.401	1.37	1.20
MnO	0.01	--------	--------	--------
MgO	7.59	2.32	5.48	5.72
CaO	60.52	9.92	25.76	17.92
Na_2O	6.50	-------	--------	---------

3.2 X-RAY DIFFRACTION (XRD) ANALYSIS

The XRD analysis of the Boiler WA samples depicts small humps or broad peaks in their graphical representations at an angle of 22º 2θ as shown in Fig.1.1. Small humps at 22º 2θ confirm the presence of small amount of reactive amorphous silica in Boiler WA.

The sharp peaks which are an indication of the presence of crystalline silica are also visible. The crystalline silica is non-reactive and does not show any pozzolanic activity throughout the chemical reaction between the OPC and water. Amorphous silica reacts with free lime released during the hydration of cement and forms new hydration product as additional calcium silicate hydrate (CSH) which increases the mechanical properties (strength) of concrete.

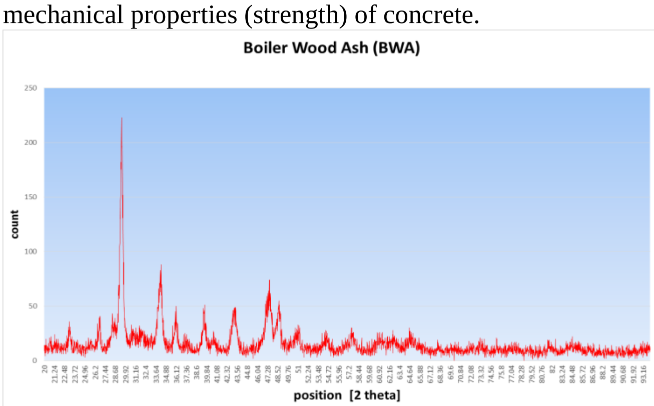

Figure 1.1 : XRD Pattern for Boiler WA

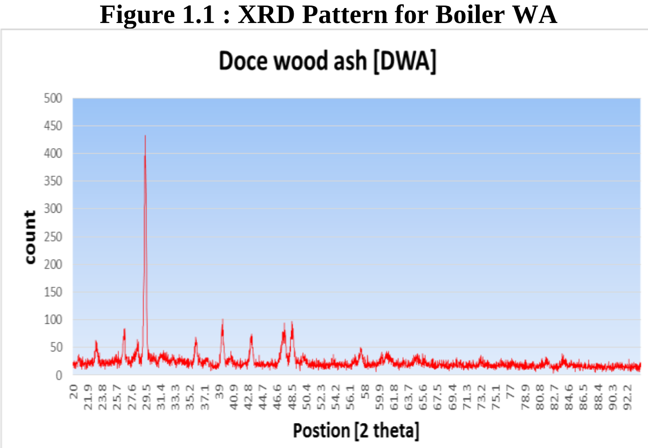

Figure 1.2 : XRD Pattern for Doce WA

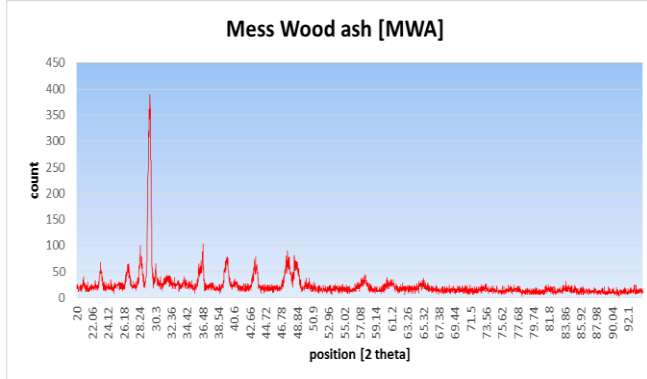

Figure 1.3 : XRD Pattern for Mess WA

Fig. 1.2 indicate small humps at 22º 2θ which reveal the presence of small amount of amorphous silica. There are also few sharp peaks which is an indication of the presence of crystalline silica in Doce WA. Fig 1.3 show some small humps at 22º 2θ which confirms the presence of small amount of amorphous silica in Mess WA. The pointing sharp peaks also indicate the presence of crystalline silica in Mess WA.

3.3 CONSISTENCY OF CEMENT

ASTM C-187 is used to determine the consistency of cement paste. The standard consistency test results are summarized in table 1.2. It is noticeable that the water demand is increased by replacing cement with WA. The test results show that the water demand of the sample containing Doce WA is the highest which is due to the more surface area of the Doce WA. The Doce WA is lighter in weight and the number of particles in 50g is more than cement. Hence, more water will be required to lubricate the total surface area.

Table 1.2: Comparison of consistency of cement and test mix (cement 90% and ash 10%)

Ingredients	Wt of cement (gm)	Wt of ash (gm)	Wt of water (gm)	plunger from bottom	Consistency %
Cement 100% (CC)	500	-	160	7	32
Cement 90%, Boiler WA 10%	450	50	175	6	35
Cement 90%, Mess WA 10%	450	50	180	6	36
Cement 90%, Doce WA 10%	450	50	185	7	37

3.4 SLUMP TEST

ASTM C-143 is used to determine the workability of concrete. Slump test results are summarized in Table 1.3. Test results show that for constant w/c ratio, slump value decreased as WA content increased.

Table 1.3: Slump test results

Replacement of OPC by WA (%)	0	10	15	20
Water/cement (W/C)	0.6	0.6	0.6	0.6
Slump (mm)	50	40	35	30

This reduced strength is due to the presence of relatively high WA content in concrete.

3.5 SPECIFIC GRAVITY OF WA SAMPLES

The specific gravity (SG) of the three WA samples is determined and it was noticed that the Boiler WA was the heaviest among the studied ashes while the Doce WA is the lightest among the three. SG of the ashes are shown in table 4. The SG of Boiler WA is nearly close to cement.

Table 1.4: Specific Gravity of Mess WA, Boiler WA and Doce WA

Sample type	Mess WA	Boiler WA	Doce WA
Gs	2.69	3.083	2.41

3.6 BULK DENSITY OF COARSE AGGREGATES

ASTM C-29 was used to determine the bulk density of fine and coarse aggregates. Rodding method was used to determine the bulk density of coarse as well as fine aggregate. Results are shown in table 1.5.

Table 1.5: Bulk Density of Coarse and Fine Aggregates

	Lawrencepur Sand	Margla Crush
Bulk Density in Compacted Condition (kg/m^3)	1538	1614
Bulk Density in Loose Condition (kg/m^3)	1332	1462

3.7 SIEVE ANALYSIS

ASTM C-33 is used to perform the sieve analysis of aggregates. Tables 1.6 and 1.7 show the results of the sieve analysis of fine and coarse aggregates.

4. COMPRESSIVE STRENGTH OF CONCRETE SPECIMENS

The Table 1.8 and Fig 1.4 shows the compressive strength result of control concrete mix at 7, 28 ad 56 days. The results show that concrete with 0% WA had the highest compressive strength. Concrete mix with 10% Boiler WA showed highest compressive strength. Compressive strength decreased by increasing WA content.

Table 1.6: Sieve analysis of fine aggregate (Lawrancepur sand)

Sieve #	Dia (mm)	Wt. Retained (gm)	%age retained	Cumulative %age passing	Cumulative %age retained
3/8"	9.5	0	0	100	0
4	4.75	74	3.7	96.3	3.7
8	2.38	96	4.8	91.5	8.5
16	1.18	196	9.8	81.7	18.3
25	600 µm	336	16.8	64.9	35.1
50	300 µm	906	45.3	19.6	80.4
100	150 µm	296	14.8	4.8	95.2
Pan		96	4.8	0	100

Fineness modulus of Lawrancepur sand = 2.4

Table 1.7: Sieve Analysis of Coarse Aggregates (Margalla crush)

Sieve #	Dia (mm)	Wt. Retained (gm)	%age retained	Cumulative %age passing	Cumulative %age retained
1 ½"	38.1	0	0	100	0
1"	25.4	0	0	100	0
¾"	19.0	0	0	100	0
½"	12.5	1428	28.56	71.44	28.56
3/8"	9.5	1768	35.36	36.08	63.92
4	4.75	1772	35.44	0.64	99.36
8	2.36	32	0.64	0	100
Pan		0	0	0	100

At 56 days the compressive strength of concrete containing WA increased considerably indicating strength development at later age. Hence, 10% replacement of cement with WA can be considered as optimum value.

Table 1.8: Compressive Strength of concrete cylinder (w/c =0.6)

Mix Designation	Compressive strength (MPa) 7-days	Compressive strength (MPa) 28-days	Compressive strength (MPa) 56-days
CC	17.8	23.5	30.0
B-WA-10	17.1	21.2	29.5
D-WA-10	11.4	16.4	16.8
M-WA-10	12.6	15.3	15.5
B-WA-15	13.7	16.9	23.5
D-WA-15	11.3	17.7	19.1
M-WA-15	12.1	18.3	21.3
B-WA-20	14.4	21.0	15.4
D-WA-20	9.4	11.8	14.6
M-WA-20	9.8	12.1	13.4

5. CONCLUSIONS

Based on the experimental study on the application of WA in concrete production following conclusions can be drawn:

1) The XRD analysis results of B-WA, D-WA and M-WA shows the presence of a little amount of amorphous silica in these ashes. The compressive strength results of concrete specimens also show that with cement replacement, the compressive strength of concrete was dropped. So, it can be concluded that all the three raw ashes with minimum value addition have a little pozzolanic activity.

2) The compressive strength results of the concrete specimens show that the B-WA is relatively better out of all the three ashes studied in this research. It gives maximum compressive strength when used as CRM.

3) The 28 days compressive strength results of the concrete specimens show that by replacing 10% cement with B-WA, the drop in strength is 10 % and this drop in strength reduced to 2% after 56 days in comparison with CC.

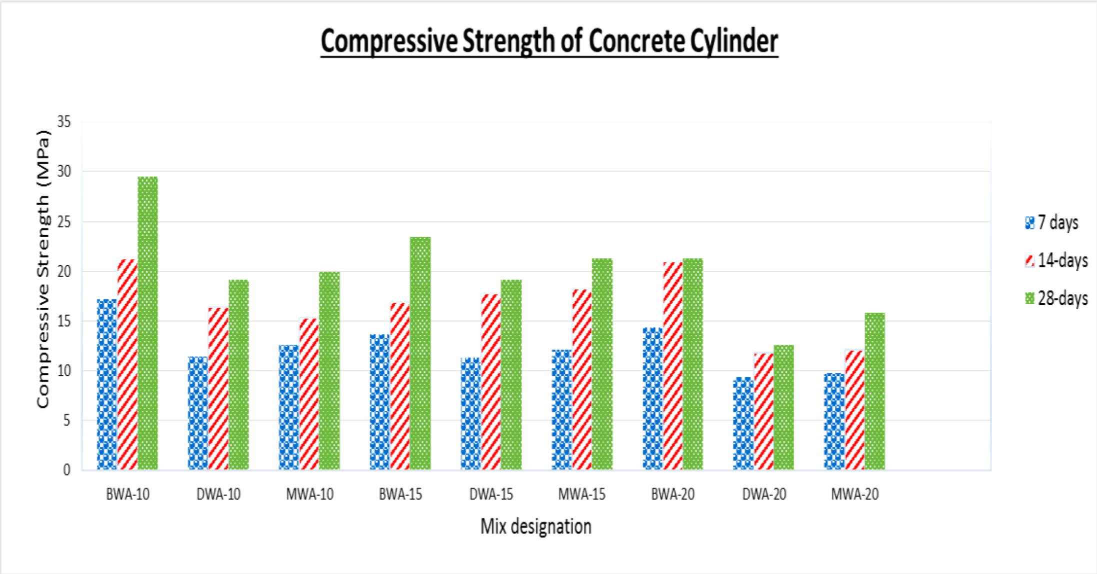

Figure 1.4: Graph showing the Compressive Strength of concrete cylinder (W/C=0.6)

4) The replacements of 15% cement with B-WA dropped strength by 22% and at 20% replacement level it reduced by 35%. 10% cement replacement with D-WA, the reduction in strength is 45% and with 20% replacement, strength dropped by 51%. When 10% cement is replaced with M-WA, the strength reduced up to 49% and with 20% replacement, the strength reduced to 56%. The water requirement increased with the increase in the WA content.

5) So it can be concluded from the results of compressive strength that B-WA can be used as a partial replacement of OPC at replacement levels up to 10% by total binder weight. Hence, it can be used to produce structural grade concrete or mortar with acceptable strength properties.

6. REFRENCES

[1] Cheah Chee Ban et al "The implementation of wood waste ash as a partial cement replacement material in the production of structural grade concrete and mortar": University Sains Malaysia, 11800 Penang, Malaysia, [February 2011]

[2] K.Ganeasan et al "Evaluation of bagasse ash as supplementary cementitious material" [2007]

[3] Muhammad Amir Shezad "Study of compressive strength of concrete by using rice husk, wheat straw and bagasse ashes as pozzolanic material", UET Lahore [2014]

[4] Tarun R. N et al "Use of Wood Ash in Cement-based Materials", A CBU Report, CBU-2003-19 (REP-513),

[5] BS 812, "Sampling and Testing of Mineral Aggregates, Sands and Fillers", British Standards Institution, London, [1975].

[6] BS 1377, "Methods of Testing for Soil for Civil Engineering Purpose" British Standards Institution, London, [1990]

[7] ASTM C-311-07, "Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete" American Society for Testing and Materials, ASTM [2007]

[8] ASTM C-39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens" American Society for Testing and Materials, ASTM [2004]

[9] ASTM C 618-94, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete" American Society for Testing and Materials, ASTM [1994].

[10] BS 1881, Part 102, "Methods of Determination of Slump", British Standards Institution, London, London, [1983].

G. F. Kheder, A. M. Al Gabban, and S. M. Abid. "Mathematical Model for the Prediction of Cement Compressive Strength at the Ages of 7 and 28 Days within 24 Hours." Materials and Structures 36, 693-701, 2003.