# Suitability of Local Wood Ash for Concrete as a Partial Replacement of Cement

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## Abstract

Natural resources of limestone, coal, and oil are depleting day by day due to its high usage in the production of cement. Researchers are searching for easily obtainable and economical materials, which can be used as a cement replacer in concrete. Bagasse ash, wood ash (WA), and rice husk ash are pozzolanic nature materials obtained as byproducts from agriculture and industry. These are pollutants for surrounding and utilizing them as cement substitution materials will lessen the contamination as well as expense of the cement. The overall aim of this study is to evaluate the performance of the concrete for cement replacement with WA. In the current research, the effect of replacement of cement with local WA on workability and compressive strength of concrete as well as chemical composition of ashes and strength activity index of WA samples were examined experimentally. ASTM C39/C39M-17, was adopted to cast and test concrete cylinders for evaluation of the compressive strength at the age of 7 days, 28 days, and 56 days. Wood ash of three different local sources i.e. boiler of Rado 80 textile mill, kiln of the Liaquat Hall mess, and Doce bakery was used. The chemical composition of each type of the WA was determined by using wet analysis method. The control mix consisted of cement, sand and aggregates in the proportions of 1, 2, and 4, respectively, with water to cement ratio of 0.60. The test specimens were also cast in the same proportion with 10% replacement of the cement by same amount of the WA. The workability of the test mix got reduced as compared to that of the control mix. The results of compression test showed that concrete containing WA of boiler of Rado 80 textile mill, was comparatively good as compared to that of other types of the WA samples used in the investigation. The incorporation of the WA showed the potential to achieve the required strength of the concrete with low cost wood ash as replacement for cement. But detailed optimization of the percentage of the replacement of the local wood ash with cement is required.

**Keywords:** Normal strength concrete, local wood ash, cement replacement, properties improvement.

## 1. INTRODUCTION

Cement is an important and expansive ingredient of the concrete, which forms 10% to 20% of concrete's mass. The cement has the biggest part of ozone harming substance in environment. The utilization of waste material as a substitution for cement has turned out to be increasingly latest trend to save atmosphere. Number of industrial wastes like fly ash, bagasse ash, wood ash, and rice husk ash are produced during different processes in industries. Recently, some of the locally produced wastes like lime stone quarry dust, electric arc furnace slag, industrial granite sludge, bagasse ash, and glass waste sludge were investigated as a possible cement replacer (Khan et al. 2019; Amin et al. 2017; Amin et al. 2017; Amin 2017). It was reported by different researchers that some of the pozzolanic industrial wastes could be utilized as cement substitute in various types of the cement composites (Khan et al. 2019; Rukzon & Chindaprasirt 2012; Naik et al. 2003; Ganesan et al. 2007).

The use of timber processing waste and forestry biomass as fuel in various industries has caused a key problem, linked to the production of significant quantities of ash as a by-product from the burning of such biomasses. A local method of land-filling is used for disposal of large portion (about 70%) of produced wood waste ash (Etiegni and Campbell 1991; Campbell 1990). The seepage of rainwater or leakage of the heavy metal contents may arise numerous issues like contamination of ground water (Udoeyo et al. 2006). Hence, the long-term impacts of wood ash disposal through landfilling is not a safe and proper solution. These issues need suitable way of wood ash disposal as a solution. Several types of factories in Pakistan such as Gourmet foods, Doce foods, Rado 80 textile mill and many other are using wood as a fuel. Moreover, timber industries have developed boiler units at small size, which use timber wastes as fuel. In this way, wood wastes obtained from the same industry are used as fuel for boilers. Recent researches had indicated that wood waste ash was found feasible as a cement substitute material in production of concrete with satisfactory amount of durability and strength (Cheah & Ramli 2011). Naik (1999) reported that all the samples of mortar mixes obtained by 10% replacement of cement showed the maximum compressive strength. Rajamma et al. (2009) also analyzed that wood waste fly ash from wood biomass fired power plant when used as a 10% replacement with cement in mortar mix gave higher 28 days compressive strength. As the wood ash showed the potential to be used as a cement replacer. Therefore, the suitability of the locally available ash also needs to be checked as a cement replacement in concrete production. For this purpose, in the current research three different types of locally accessible ashes were analyzed as a cement replacer in the concrete mix.
In the present investigation, the wood ashes local sources of boiler of textile mill of Rado 80, Doce bakery, and kiln of the mess of Liaquat Hall were incorporated as a cement replacer in the cement mortar. The outcomes of the ash wet analysis test, strength activity index test, workability, and compressive strength tests of concrete were examined experimentally. In this study, 10% of cement weight was replaced in concrete mix by same amount of locally available wood ash.

## 2. SAMPLES CASTING, PROPORTIONING, AND DESIGNATION

### 2.1 Materials

The locally available wooden ash (WA) was used in this work. The ashes of the three different sources were used for this purpose i.e. i. ashes from boiler of Rado 80 textile mill ii. Ashes from Doce bakery situated in Lahore and iii. Ashes of kiln of mess of the Liaquat Hall located in Government College of Technology, Rasul. The wood ash was passed through 0.074 mm sieve (No. 200) to bring it within the specified size of the cement and to make it free of dust and other impurities.

### 2.2 Samples preparation and designation

The mix proportion of 1:2:4 (cement:sand:aggregates) was used for preparation of all concrete samples with a consistent water to cement ratio (W/C) of 0.60. Slump cone test was used for determining the workability of the fresh concrete. The standard size (150 mm diameter and 300 mm height) cylinders were used. Normal concrete was used as a control concrete and three specimens were cast. Twenty-seven cylindrical specimens having 10% of cement replacement with same amount of WA (nine for each type of wood ash) were cast for determining the 7 days, 28 days, and 56 days compressive strength of the concrete. Sample designation and mix proportion for each type of the mix are shown in the Table 1. The CC represents the control mix (0% of WA), BWA represents the sample had WA of boiler of Rado 80 textile mill, DWA is the sample which had the WA of Doce bakery Lahore, and MWA is the sample had WA of kiln of the Liaquat Hall mess. The mortar cubes of 50 mm side were cast for performing the strength activity test. Total of nine mortar cubes (three for each type of WA) were cast. Average of three results was considered the final value for each property.

Table 1. Sample designation and Mix proportion

| Sample | Mix Design | W/C | Binder Content | | Fine Aggregate | Coarse Aggregate |
|---|---|---|---|---|---|---|
| | | | OPC % | WA % | % | % |
| CC | 1:2:4 | 0.6 | 100 | 0 | 100 | 100 |
| BWA | 1:2:4 | 0.6 | 90 | 10 | 100 | 100 |
| DWA | 1:2:4 | 0.6 | 90 | 10 | 100 | 100 |
| MWA | 1:2:4 | 0.6 | 90 | 10 | 100 | 100 |

*OPC = Ordinary Portland cement, WA = Wood ash*

## 3. EXPERIMENTAL PROCEDURES

Slump test was performed as per the standard method of the ASTM C143/C143M-15a. The chemical composition of all the wood ash samples and cement were determined by wet analysis to check the criteria of ASTM C618-19. The compressive strength test of mortar cubes for strength activity index and concrete cylinders were carried out according to ASTM C109/C109M-16a and ASTM C39/C39M-17, respectively.

## 4. RESULTS AND DISCUSSIONS

### 4.1 Chemical content of wood ashes

Chemical composition of all the wood ash (WA) samples and cement were determined by wet analysis to check the criteria of ASTM C618-19 (Mineral Admixture Class C). Wet analysis test results are demonstrated in Table 2.

Table 2. Results of wood ash chemical analysis

| Constituents | Cement % | Boiler WA % | Doce WA % | Mess Kiln WA % |
|---|---|---|---|---|
| $SiO_2$ | 13.81 | 55.52 | 13.50 | 20.66 |
| $Al_2O_3$ | 6.85 | 3.11 | 4.21 | 3.663 |
| $Fe_2O_3$ | 0.01 | 0.401 | 1.37 | 1.2 |
| CaO | 60.52 | 9.92 | 25.76 | 17.92 |

From the chemical analysis of wood ashes, it was found that the amount of CaO was less in every type of the WA as comapred to that of the cement. The summation of the total amount of the silicon dioxide ($SiO_2$), aluminium oxide ($Al_2O_3$), and Iron oxide ($Fe_2O_3$) was found 26%, 18%, and 59%, for Boiler WA, Doce WA, and Mess Kiln WA, respectively. The Boiler WA was able to achieve the higher value of the sum of three types contents as compared to other two types of the ashes but still it did not achieve the minimum requirement for natural pozzolana for using as a mineral admixture in cement concrete according to ASTM C 618-94.

**4.2 Strength activity index**

ASTM C311/C311M-18 was followed for determinng the strength activity index (SAI) for wood ash samples. The SAI of the BWA, DWA, and MWA mortar specimens were 91%, 97%, and 91%, respectively. Hence the SAI of each of the sample was more than 75%, confirming the pozolanic activeness of the ashes as well as their suitablity for use in concrete.

**4.3 Slump Test**

Workability of concrete was determined by slump cone test in accordance with ASTM C143. The slump of 50 mm, 40 mm, 40 mm, and 40 mm was noticed for control mix having zero percent of wood ash (CC), Boiler wood ash samples (BWA), Doce wood ash samples (DWA), and Mess Kiln wood ash samples (MWA), respectively. The slump of BWA, DWA, and MWA reduced by 20% as compared to that of the CC. Slump results showed that for increase in the contents of the wood ash caused significant decrease in the slump for the same W/C ratio.

**4.3 Compressive Strength:**

The compressive strength (CS) of concrete specimens at an age of 7 days, 28 days, and 56 days were determined in accordance with ASTM C39 / C39M-17. The compressive test results are presented in Table 4. The 7 days CS of the control mix having zero percent of wood ash (CC), Boiler wood ash samples (BWA), Doce wood ash samples (DWA), and Mess Kiln wood ash samples (MWA) were 17.8 MPa, 17.1 MPa, 11.4 MPa, and 12.6 MPa, respectively. The 7 days CS of 17.1 MPa of BWA was the nearest to the 7 days CS of control mix with the slight reduction of 0.07 MPa. The lowest 7 days CS of 11.4 MPa was noticed for DWA. The 28 days CS of the CC, BWA, DWA, and MWA were 23.5 MPa, 21.2 MPa, 16.4 MPa, and 15.3 MPa, respectively.

Table 3. Compressive strength test results

| **Mix**<br>(1) | **Compressive strength 7-days (MPa)**<br>(2) | **Compressive strength 28-days (MPa)**<br>(3) | **Compressive strength 56-days (MPa)**<br>(4) |
|---|---|---|---|
| CC | 17.8 | 23.5 | 30.0 |
| BWA | 17.1 | 21.2 | 29.5 |
| DWA | 11.4 | 16.4 | 16.8 |
| MWA | 12.6 | 15.3 | 15.5 |

By comparing the 28 days CS of the wood ash samples, the highest 28 days CS of 21.2 MPa was noticed for BWA while the lowest 28 days CS was observed for MWA. The 28 days CS of the BWA was the nearest to that of the control mix with zero percent wood ash. The 56 days CS of the CC, BWA, DWA, and MWA was 30.0 MPa, 29.5 MPa, 16.8 MPa, and 15.5 MPa, respectively. By comparing the 56 days CS of wood ash samples, the BWA showed the highest CS of all. The 56 days CS of the BWA was 12.7 MPa and 14 MPa greater than that of the DWA and MWA, respectively. The 56 days CS of the BWA was slightly decreased by 0.5 MPa than that of the control mix.

The percentage comparisons of the 7 days, 28 days and 56 days compressive strengths are demonstrated in Figure 1, 2 and 3, respectively. The 7 days CS of the CC was 4%, 36%, and 29%, more than that of the BWA, DWA, and MWA, respectively. The lowest decrease in the 7 days CS was noticed for BWA incorporated samples. The 28 days CS of the BWA, DWA, and MWA were less than that of the CC by 10%, 30%, and 35%, respectively. The minimum decline of 10% was noticed in the 28 days CS of BWA than that of CC. As compared to the 56 days CS of control mix, the 56 days CS of BWA, DWA, and MWA was decreased by 2%, 44%, and 48%, respectively. A slight decrease of 2% was noted in 56 days CS of the BWA sample as compared to 56 days CS of the control mix. The 28 days strength results showed that by replacing 10% cement with BWA, drop in strength was 10% and this drop in strength reduced to 2% after 56 days probably due to delayed hydration in comparison with control concrete. Hence, the samples having wood ash of the boiler of Rado 80 textile mill, showed the highest compressive strength as compared to samples with wood ash of Doce bakery Lahore and wood ash of kiln of the mess of Liaquat Hall.

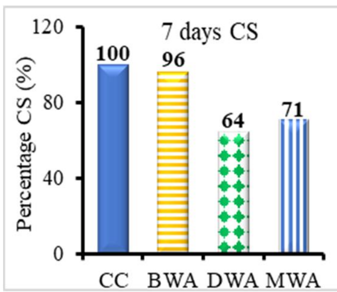


Figure 1. 7 days compressive strength

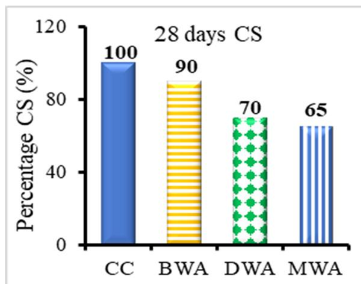


Figure 2. 28 days compressive strength

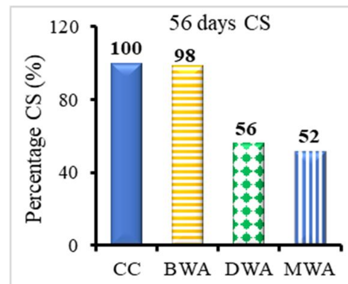


Figure 3. 56 days compressive strength

It can be concluded that the test results indicated that by addition of wood ash in concrete the compressive strength decreased, but this reduction in compressive strength was less prominent after long time curing. This may be due to the late pozzolanic action of the wood ashes. BWA performed better out of three ashes in improving the compressive strength of the samples.

## 5. CONCLUSIONS

Following conclusions were made from the current study:

- The strength activity index of the Boiler WA, Doce WA, and Mess Kiln WA mortar specimens was 91%, 97%, and 91%, respectively.
- The slump of BWA (Boiler WA samples), DWA (Doce bakery WA samples), and MWA (Mess Kiln WA samples) reduced by 20% as compared to that of the control mix (CC) "0% wood ash".
- As compared to the 7 days, 28 days, and 56 days compressive strength (CS) of the CC, the minimum reduction of 4%, 10%, and 2%, respectively, was noticed in CS of the BWA as compared to CS of other companions.
- The lowest 28 days, and 56 days CS was observed for the MWA that was 35% and 48%, respectively, less than that of the CC. While the lowest 7 days strength was noted for DWA that is 36% less than that of CC.

The experimental outcomes showed significant impact on the considered properties of concrete by addition of the wood ash as a partial replacement for cement. Further investigation is required to evaluate the optimized content of the wood ash for better strength properties of the concrete as well as cement mortars.

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