

# EVALUATION OF WOOD ASH AS A PARTIAL REPLACEMENT TO CEMENT

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## Abstract:

The potential of wood ash as an admixture to cement in the construction industry is explored in this study. Wood ash limited to the grain size of less than 75 micrometer is added to cement by weight percentage of 10%, 20% and 30% by the method of replacement by weight. The samples were hydrated at different time intervals ranging from one hour to 4 weeks. Those hydrated samples were subjected to FTIR, SEM and compressive strength analysis. The hydration mechanism is analyzed with FTIR and SEM micrographs and correlated with compressive strength measurements in the light of available literature.

## Key words:

Cement, compressive strength, FTIR, SEM, wood ash.

## I. INTRODUCTION.

The phenomenal pace of population growth and urbanization drives the cement requirement to many fold in the past three decades. The leaps and bounds of progress of scientific achievements in the mentioned period with such a rapid change in technologies had initiated a global emphasis on greener cleaner and environment friendly techniques in all fields. The quantum jump in production of cement results in alarming level release of CO<sub>2</sub> to the atmosphere. One way of addressing this issue is to reduce the CO<sub>2</sub> emission from cement manufacturing process by replacing cement with locally available byproducts which are pozzolanic in nature. Ashes are one such byproduct available around us from various sources from industries to agriculture. Rice husk ash and fly ash, are major players which already proven to be effective mineral admixtures to cement at various percentages [1], [2].

Wood ash (WA) is also a similar waste materials produced from wood burning industries which is mainly used as a fertilizer for soil. Significant quantities of wood ash is currently landfilled near the industries that uses wood as a fuel partially or fully which poses a threat to the environment in many ways to life stock around. The possibility of adding wood ash with cement and concrete was explored by Abdullahi.M [3].

Marathong suggested by analyzing the hydration characteristics of saw dust ash admixed cement that 10% addition of wood ash with cement is optimum [4]. High calcium wood ash and densified silica fume blended cement paste was characterized by Cheah Chee Ban [5]. Chemical analysis of wood ash shows that it has pozzolanic property [6], and using it as a partial replacement to cement may be one of the best application in the current environment scenario.

## II. MATERIALS AND TESTING METHODS.

Wood ash is a residue powder that is left after combustion of wood in home or in industries. Typically 6-10% percent of the mass of burnt wood result in ash [7]. The type of wood, combustion temperature and combustion time plays a vital role in the quantity of ash produced and its chemical composition. The percentage of CaO which is one of the important compound in wood ash varies from 4% to 70% in wood ash that makes it a potential substitute in cement industry either in production or in application stage. The ash containing less CaO and significant quantity of SiO<sub>2</sub> may be used for replacement of cement and the ash containing high CaO may be used as a raw material in cement production [8].

For the present study commercially available 43 grade OPC is used (ASTM type 1). The wood ash is collected from Sri Manakulavinayagar Rice Bran Oil Mill, Thirubuvanai, Pondicherry, India. The wood ash samples collected were burnt at 600<sup>o</sup> C for 4 hours in an oven to remove any unburnt residues and sieved using 75µm test sieve. For hydration studies, the anhydrous OPC is mixed with WA at 10%, 20% and 30% by weight by the method of replacement. The samples were mixed thoroughly and water added at a water to cement ratio of 0.45 and mixed for two minutes in the plastic container. The water mixed samples were allowed to hydrate for the fixed time intervals. The hydration studies were carried out at the intervals of 1 hour(1h), 1 day(1d), 1 week (1w) and 4 weeks(4w). The hydration was stopped by soaking them in acetone to remove any evaporable water content. Then they were oven dried at 120<sup>o</sup> C for two hours and grounded to a fine power using a agate mortar for half an hour with a constant pressure to maintain

uniform grain size. The powdered samples were stored in a desiccator for FTIR and SEM investigations.

FTIR Spectra were recorded with the help of Perkin Elmer Rx1 spectrometer and SEM micrographs were recorded with JEOL JSM 5610LV scanning electron microscope with a maximum accelerating voltage of 20Kv at high vacuum mode.

For measuring compressive strength the samples were mixed with river sand sieved with 600µm test sieve and water at a water to cement ratio of 0.45 and sand to cement ratio of 1.3. The samples were made to a paste by thorough mixing and filled into a 7cmX 7cm X 7cm. After 24 hours the specimen were demoulded and cured for different ages. Compressive strength was measured with the help of Unico compressive strength testing machine.

The chemical composition of OPC and WA was identified using Bruker S4 Pioneer XRF Spectrometer and listed in Table I.

**Table I. Chemical composition of OPC and WA**

Oxide Composition	OPC	WA
SiO <sub>2</sub>	25.9	46.05
CaO	59.31	18.23
Fe <sub>2</sub> O <sub>3</sub>	4.11	8.12
Al <sub>2</sub> O <sub>3</sub>	5.33	7.55
MgO	0.81	2.1
K <sub>2</sub> O	1.08	4.2
Na <sub>2</sub> O	0.23	1.5
TiO <sub>2</sub>	0.6	0.1
MnO	0.11	2.85
P <sub>2</sub> O <sub>5</sub>	0.2	1.7
SO <sub>3</sub>	1.67	1.4
LOI	0.65	6.2

### III. RESULT AND DISCUSSION

The chemical composition of the tested WA samples show the presence of CaO, SiO<sub>2</sub> and small amount Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub> and K<sub>2</sub>O. Fig. 1 shows the compressive strength of OPC compared with 10%, 20% and 30% WA admixed samples cured for 1h, 1d, 1w and 4w.

The compressive strength of cement increases significantly over hydration time. The compressive strength of 20% WA sample shows more strength at 4 week sample and 30% samples exhibits less compressive strength throughout the study. The strength gain of the 20% sample in 4 weeks hydration time may be due to pozzalonic reaction between SiO<sub>2</sub> from WA and CaOH from cement hydration. So for the current work 20% WA sample is compared with OPC.

### FTIR and SEM analysis

The FTIR patterns of OPC and 20% WA samples hydrated for 1h, 1d, 1w and 4w are presented in Fig. 2 and Fig. 3 respectively.

In the OPC hydrated paste 3629cm<sup>-1</sup> band corresponds to the stretching vibration of OH in Ca(OH)<sub>2</sub>. Its intensity increases upon hydration visualized in 1w and 4w which is a clear evidence of progress of hydration reaction. The band at 3422 cm<sup>-1</sup> may be due to the symmetrical stretching of water[9]. The band at 2923 cm<sup>-1</sup> and 2853 cm<sup>-1</sup> are due to the carbonate present in the sample added during the production process of cement. As hydration proceeds the carbonate bands decreases and it may be attributed to substitution of carbonate ions for sulfate in AFt and AFm phases [10], [11].

The broad band at 1650 cm<sup>-1</sup> may be attributed to the ν<sub>2</sub> bending vibration of irregularly bound water [12], [13]. 1430 cm<sup>-1</sup> band may be due to the ν<sub>3</sub> asymmetric stretching of carbonate whereas 875 cm<sup>-1</sup> band may be due to out of plane bending vibration of carbonate [14]. The band at 1102 cm<sup>-1</sup> may be due to ν<sub>3</sub> mode of vibration of SO<sub>4</sub><sup>2-</sup> group in sulfate. The broad feature in the region may represent the amorphous nature of sulfate. The band at 669 cm<sup>-1</sup> attributed to ν<sub>4</sub> vibration of sulfate [15], [16].

The band at 519 cm<sup>-1</sup> may be due to ν<sub>4</sub> mode of out of plane vibration of silicate in C<sub>2</sub>S and the band at 470 cm<sup>-1</sup> may be due to ν<sub>2</sub> mode of vibration of silicate in C<sub>3</sub>S. The increase and shift in the band to higher degree indicates the completion of hydration reaction[17]. The presence of small shoulder in WA admixture sample in 1794 cm<sup>-1</sup> [14], [18] may be due to carbonate. The increase in band at 978 cm<sup>-1</sup> for WA samples may be due to dissolution of C<sub>3</sub>S clinker phase during hydration and silicate polymerization. The shift of band at 940 cm<sup>-1</sup> which is due to ν<sub>3</sub> mode of silicate to higher wave number for 20% WA sample indicates the hydration progress. The intensity decrease in the ν<sub>4</sub> mode of silicate at 510 cm<sup>-1</sup> and increase in ν<sub>2</sub> mode of silicate at 467 cm<sup>-1</sup> indicate the polymerization of silicate which was well observed in 20% sample.

The SEM micrographs of OPC and 10%, 20% WA hydrated samples of 1d, 1w and 4w are shown in Fig 4 and Fig. 5 respectively

At the one day OPC sample needle like ettringite is observed which is a consequence of initial hydration. As time evolves the ettringite begin to disappear and long oriented CH crystals are appeared. In one week sample, honey comb structure of CSH gel and well developed Ca(OH)<sub>2</sub> were observed indicating the progress of hydration reaction [19]. In the 4w sample CSH formation became denser and rigid which evidence the silicate polymerization of the precipitated CSH. It was in agreement with compressive strength measurement. In the WA sample the progress of

hydration is well visualized by the presence of ettringite in the 1d sample and CSH and  $\text{Ca(OH)}_2$  in

later periods [20].

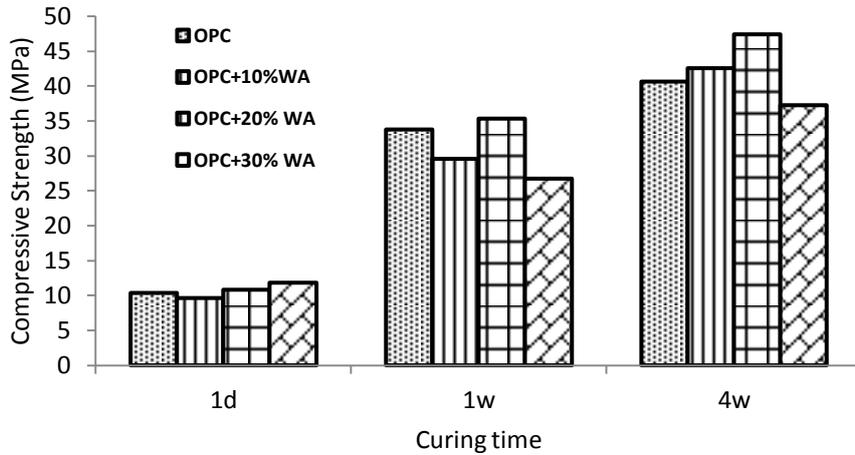


Fig. 1 Compressive Strength of OPC and OPC+10%, OPC+20%, and OPC+30%,

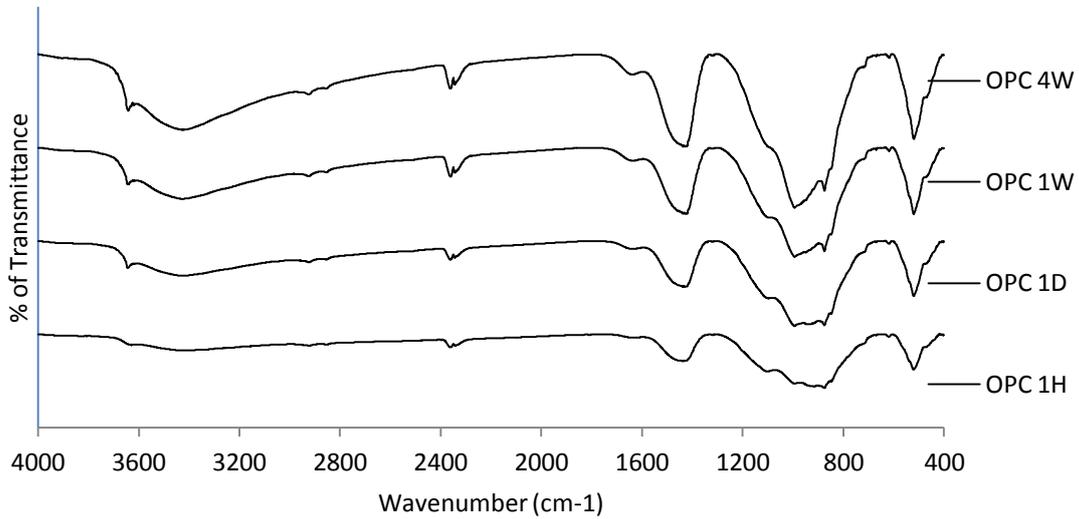


Fig 2. FTIR Spectra of OPC hydrated for 1h, 1d 1w, and 4w

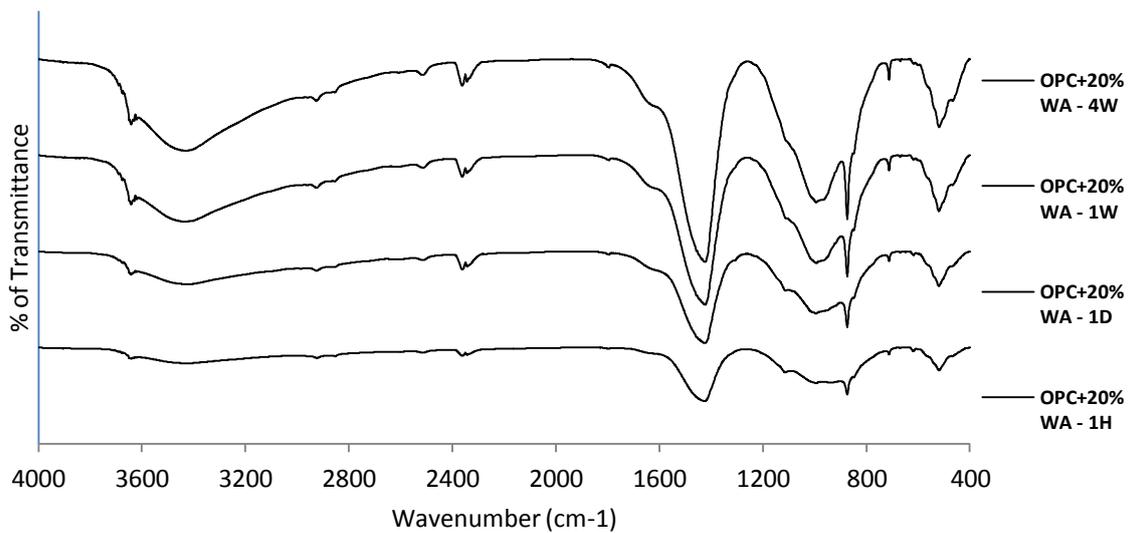


Fig 3. FTIR Spectra of OPC + 20% WA hydrated for 1h, 1d 1w, and 4w

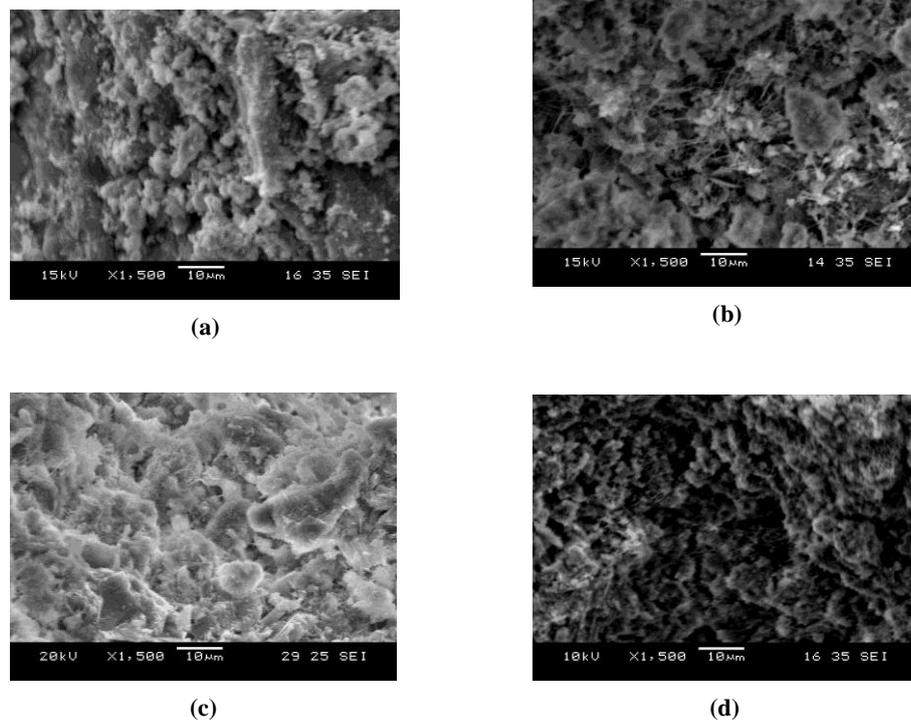


Fig. 4. SEM Micrographs of OPC Hydrated for (a) 1 h, (b) 1d, (c) 1w, and (d) 4w

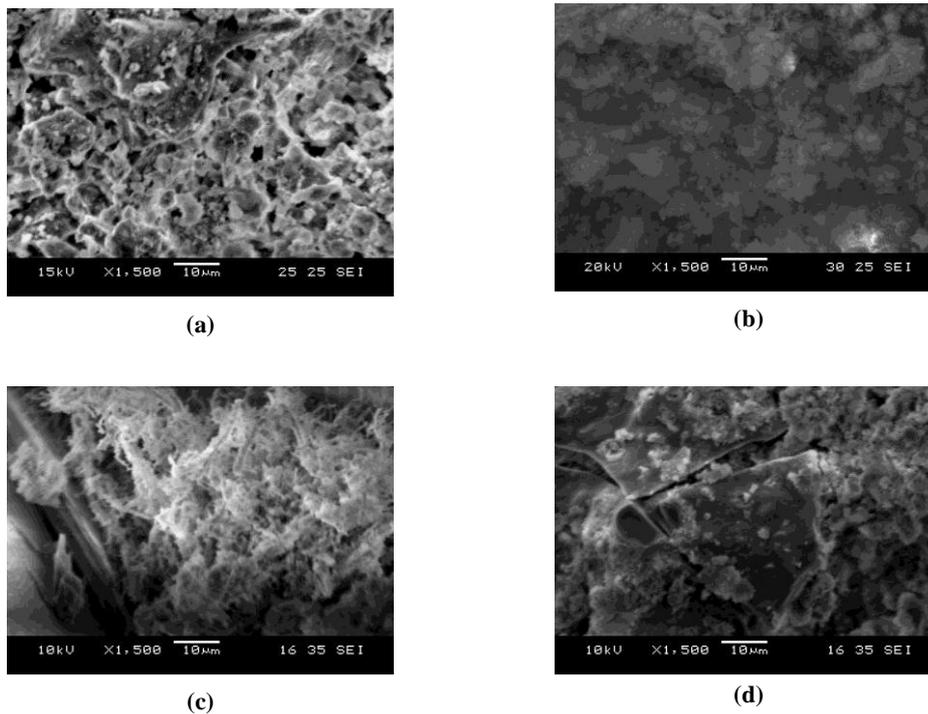


Fig. 5. SEM Micrographs of OPC +20% WA Hydrated for (a) 1 h, (b) 1d, (c) 1w, and (d) 4w

The micrograph of 20% WA sample hydrated for 4 week show denser structure. The ettringite needles were replaced by voluminous

CSH structure which indicates the higher degree of hydration. This observation was well in line with the compressive strength observations.

#### IV. CONCLUSION

The wood ash exhibits an appreciable amount of pozzolanic properties. The water requirement increases with the increase with WA addition. The 20% WA sample shows higher degree of hydration and compressive strength than OPC. The optimum replacement percentage of WA is therefore 20% for construction industry

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