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Study on Strength Properties of Concrete by Replacing Sand with Wood Ash.

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ABSTRACT

Cementations materials have been used by mankind for construction from time immemorial. The every rising functional requirement of the structures and the capacity to resist aggressive elements has necessitated developing new cementations materials and concrete composites to meet the higher performance and durability criteria. The environmental factors and pressure of utilizing waste materials from industry have also been the major contributory factors in new developments in the field of concrete technology.

Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. The concrete has become so popular and indispensable because of its inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Its great versatility and relative economy in filling wide range of needs has made it very competitive building material.

With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable for a by situations. Added to this is the necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixtures is found to be an important alternative solution.

Hence an attempt has been made in the present investigation to evaluate the workability, compressive strength, split tensile strength and flexure strength on addition of wood waste ash (0 – 30%) along with crimped steel fibers (0-1%) in concrete. Wood ash is an admixture: a pozzolana. Wood ash is generated as a by-product of combustion in wood-fired power plants, paper mills, and other wood burning industries.

The scope of present research is

To study the workability in terms of compaction factor and vee bee time of wood waste ash based fiber reinforced concrete

To study the strength characteristics in terms of compressive, split tensile and flexure strengths of wood waste ash based fiber reinforced concrete

Standard cubes of 150 X 150 X 150 mm have been cast and tested for obtaining 28 days and 90 days compressive strength.

Standard cylinders of 150mm diameter and 300 mm height were cast and tested for Split tensile strength

Standard Beams of 500mmx100mmx100mm were cast and tested for Flexural strength

Results were analyzed to derive useful conclusions regarding the strength characteristics of wood waste ash fiber reinforced concrete. M_{20} concrete has been used as reference mix. The mix design is presented in Appendix-I.

Keywords: Concrete, compaction, conclusions, wood waste.

1.1 INTRODUCTION

India is the second largest producer of cement on the globe after China. In total, India manufactures 251.2 Million Tons of cement per year. The cement industry in India has received a great impetus from a number of infrastructure projects taken up by the Government of India like road networks and housing facilities. While the Indian cement industry enjoys a phenomenal phase of growth, experts reveal that it is poised towards a highly prosperous future over the very recent years. The annual demand for cement in India is consistently growing at 8-10%. NCAER has estimated after an extensive study that the demand for cement in the country is expected to increase to 244.82 million tons by 2012. At the same time, the demand will be at 311.37

million tones if the projections of the road and housing segments are met in reality countries the most remarkable break troughs have been achieved by the building material industries and their R&D laboratories.

An accepted fact is that these encouraging results on the use of admixtures are not penetrating into the user community and the entire research work is getting flocked in their organizations. With the result, the very purpose of research work is becoming questionable. Along with and R&D units, the policy makers and consultants should take more interest in handling these issues directly keeping not only the techno-economics in view but also national obligations.

2.1 WOOD WASTE ASH

Wood Waste Ash (WWA) is the residue generated due to combustion of wood and wood products (chips, saw dust, bark, etc.). It is the inorganic and organic residue remaining after the combustion of wood or unbleached wood fiber. The physical and chemical properties of wood ash vary significantly depending on many factors. The physical and chemical of wood ash, which determining its beneficial uses, are dependent upon the species of the wood ash the combustion methods that include combustion temperature, efficiency of the boiler, and supplementary fuels used.

Typically, wood ash contains carbon in the range of 5-30% (Campbell, 2009). The major elements of wood ash include calcium (7-30%), potassium (3-4%), magnesium (1-2%), manganese (0.3-1.3%), phosphorus (0.3-1.4%) and sodium, (0.2-0.5%). Density of wood ash decreases with increasing carbon content. The chemical and physical properties depend upon the type of wood, combustion temperature, etc.

Typically wood burnt for fuel at pulp and paper mills and wood products industries may consist of saw dust, wood chips, bark and saw mill scraps, hard chips rejected from pulping, excess screenings such as sheaves and primary residuals without mixed secondary residuals. Physical and chemical properties of wood ash are important in determining their beneficial uses. These properties are influenced by species of tree, tree growing regions and conditions, method and manner of combustion including temperature, other fuel used with wood fuel, and method of wood ash collection. Further quality variation in the wood ash properties occur when wood is co-fired with other supplementary fuels such as coal, coke, gas and the relative quantity of wood versus such other fuels.

2.1.1 Physical Properties:

Etiegni and Campbell (2010) studied the effect of combustion temperature on yield and chemical properties of wood ash. For this investigation, lodge-pole pine saw dust collected from a saw-mill was combusted in an electric furnace at different temperatures for 6–9 hours or until the ash weight became constant. The results showed that wood ash yield decreased by 45% when combustion temperature were increased from about 550–1100°C. The average article size of the wood ash was found to be 230μm. The concentration of potassium, sodium, zinc, and carbonate decreased while concentrations of other metal ions remained constant or increased with increasing temperature. The pH of wood ash was found to vary between 9 and 13.5.

Naik TR (2011) determined the physical and chemical properties of wood ashes derived from different mills. Scanning Electron Microscopy (SEM) was used to determine shape of wood ash particles. The SEM micrographs showed wood ashes as a heterogeneous mixture of particles of varying sizes, which were generally angular in shape. The wood ash consisted of cellular particles, which were unburned, or partially burned wood or bark particles. The average moisture content values for the wood ash studied were about 13% for wood ash and 22% for bottom ash. The average amount of wood ash passing sieve No.200 (75μm) was 50%. The average amount of wood ash retained on sieve No. 325 (45μm) was about 31% for wood ash. Test results for unit weight or bulk density (ASTM C 29) exhibited average density values of 490 kg/m^3 for wood ash and 827 kg/m^3 for bottom ash. Wood ash had an average specific gravity value of 2.48. Specific gravity for bottom ash showed an average of 1.65. The average saturated surface dry (SSD) moisture content values were 10.3% for wood ash and 7.5% for bottom ash. The average cement activity index at the age of 28 days for wood ash was about 66% of the control. The average water requirement for wood ash exhibited a value of 116%. Autoclave expansion tests for wood ash exhibited a low average expansion value of 0.2%.

Naik TR, Kraus RN (2012) evaluated the wood ashes from five different sources for possible use in making controlled low-strength materials (CLSM). They used wood ashes from five different sources in Wisconsin (USA) and were designated as W1, W2, W3, W4, and W5. ASTM standards do not exist for wood ash. Each source of wood ash exhibited different physical properties. Fineness of the wood ash (% retained on 45μm sieve) varied from 23 to 90%. SourceW1 andW5 met the ASTM requirement for fineness (34% maximum), while sourcesW2, W3 andW4 exceeded the ASTM limit. The strength activity index of the wood ash is a comparison of the compressive strength development of 50mm mortar cubes that have 20% (by mass) replacement of cement with wood ash, with compressive strength of standard cement mortar. Wood ashes W1 and W3 met the strength activity index requirement of ASTM (75% minimum at either 7 or 28 days), while wood ashes W2, W4 and W5 did not meet the requirement. However, sources W1 and W3 satisfied the requirement for natural Pozzolana. The higher water requirement indicated that for concrete and CLSM containing wood ash, more water would be required to produce same slump or flow as compared with the control mixture. Unit weight values of the wood ashes W1, W2, W4, and W5 were 545, 412, 509, and 162 kg/m^3, respectively. These unit weights are significantly less than the unit weight of a typical ASTM Class C or Class F wood ash (approximately 100 to 1300 kg/m^3). SourceW3 had a unit weight of 1376 kg/m^3. Specific gravity of wood ash sources ranged from 2.26 to 2.60. Specific gravity of wood ash source W1 and W5 was lower than that of a typical coal wood ash (approximately 2.40–2.60).

Udoeyo FF, Inyang H, Young DT, Oparadu, EE (2013) reported the physical properties of waste wood ash (WWA), used as additive in concrete. They used wood waste collected from a dump site at the timber market in Uyo, Akwa Ibom State of Nigeria. The waste was subjected to a temperature of

1000°C in an oven to incinerate it into ash before it was used as an additive in concrete. The WWA had a specific gravity of 2.43, a moisture content of 1.81%, and a pH value of 10.48. The average loss on ignition of the ash was found to be 10.46.

Abdullahi (2014) determined the properties of wood ash to be used as partial replacement of cement. The wood ash used was powdery, amorphous solid, sourced locally, from a bakery. The wood ash was passed through BS sieve 0.075mm size. The specific gravity of wood ash was found to be 2.13. The bulk density of wood ash was found to be 760 kg/m^3.

2.1.2 Chemical Properties:

Etiegni (2008) and Etiegni and Campbell (2009) obtained X-ray diffraction data to determine the presence of various compounds in dry and wet ash, which was then dried for 24 hours. The major oxides detected in the wood ash were lime (CaO), calcite ($CaCO_3$), portlandite ($Ca(OH)_2$) and calcium silicate (Ca_2SiO_4). The authors reported that swelling of wood ash occurred due to the possible hydration of silicates and lime present in the ash.

Naik TR, Kraus RN (2007) studied the chemical composition of wood ashes from five different sources for their possible use in making Controlled Low-Strength Materials (CLSM). ASTM standards do not exist for wood ash. The nearest ASTM standard (ASTM C 618, 1994) available is for coal ash and volcanic ash, was used for analysis of its properties. All wood ashes did not meet all the chemical requirements of ASTM C 618, particularly for the amount of carbon as shown by LOI test results. The LOI obtained for the wood ashes ranged from 6.7 to 58.1%. These high LOI ashes probably will present some difficulties when developing air-entrained concrete mixtures. The high carbon content tends to reduce the amount of air entrained in the concrete mixture and thus requires higher dosages of air-entraining admixtures. However, the higher carbon contents of the wood ashes should not affect the performance of these ashes in CLSM. Wood ash W-2 showed a very low value of $SiO_2 + Al_2O_3 + Fe_2O_3$ (23.4% most likely due to its high LOI).

Udoeyo FF, Inyang H, Young DT, Oparadu, EE (2008) reported the chemical composition of waste wood ash (WWA). The results of Nylon

a. Polyester similar to the steel fiber, whereas the low modulus synthetic macrofiber experienced much higher creep.

b. **Plastic Shrinkage Cracking** — Wongtanakitcharoen and Naaman (2010) evaluated the plastic shrinkage cracking characteristics of concrete containing PP, polyvinyl alcohol (PVA), high-density polyethylene (HDPE), carbon, and metallic fibers during the first 24 hours after mixing. Testing parameters cover several fiber properties, including diameter, length, cross section, form, bond strength, and elastic modulus that were

days compressive strength. Standard cylinders of size 150mm x 300mm were cast and tested for 28days and 90days split tensile strength. Also standard beams of size 500mm x100mm x 100mm were cast and were tested for 28 days and 90 days flexural strength

3. OBJECTIVES

The specific objectives of the present investigations are as listed below.

→ To conduct feasibility study of producing wood waste ash concrete using Crimped Steel Fibers

→ To evaluate the workability characteristics in terms of compaction factor and vee bee time on addition of wood waste ash (0-30%) along with crimped steel fibers (0-2%)

→ To The workability of WWAFRC (Wood Waste ash fibre reinforced concrete) mixes has been measured by conducting Compaction factor test and Vee Bee time test. The values of compaction factors and vee bee times obtained from present investigation are presented in Table 4.7 and Table 4.8 respectively.

The variations of workability on addition of wood waste ash are presented in Figures 5.1(A) & 5.1 (B) respectively.

Table 5.1.1 : Workability in terms of Compaction Factor

S.No	% of fibre	Flexural Strength (Mpa)			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	5.15	5.45	5.61	4.32
2	1%	6.23	6.51	6.79	5.17
3	2%	6.72	6.99	7.28	5.68

Figure 5.4(A): 28 Days Flexural Strength Vs % of Wood Waste Ash

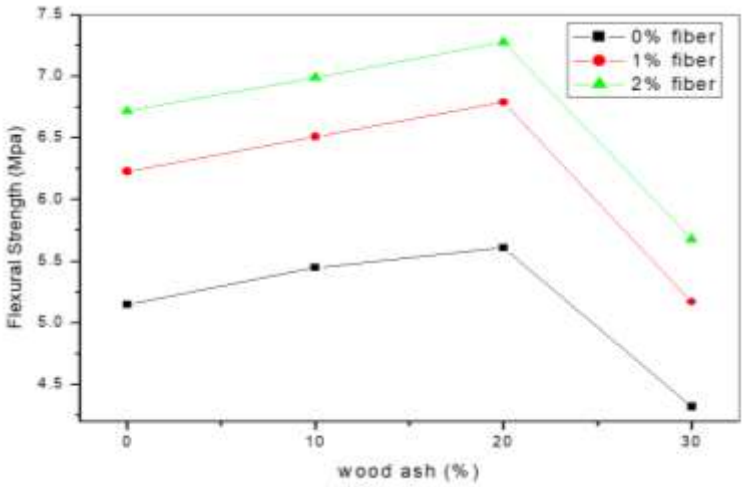
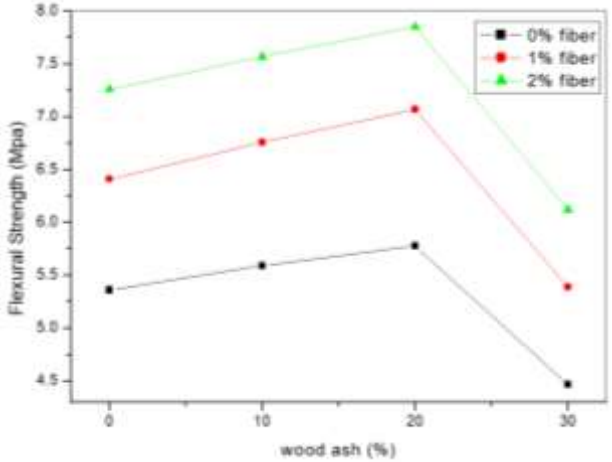


Table 5.4.2 : 90 days Flexural Strength values in N/mm^2

S. No	% of fiber	Flexural Strength (Mpa)			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	5.36	5.59	5.78	4.47
2	1%	6.41	6.76	7.07	5.39
3	2%	7.26	7.57	7.85	6.12

Figure 5.4(B): 90 Days Flexural Strength Vs % of Wood Waste Ash



From Figure 5.4(A) it can be observed that the 28 days flexural strength increases with the increase in the percentage of wood waste ash up to 20% addition level. On 20% addition of wood waste ash there is increase of flexural strength by 8.93% over plain concrete. At 10% level, the flexural strength has increased by 5.83%. But at 30% level, the split tensile strength has decreased by 16.11%. Similar trends were observed even in case of FRC (Fiber reinforced concrete) mixes on addition of wood waste ash. For example: at 0.75% of fiber volume and on addition of 20% wood waste ash the flexural strength has increased by 8.33% over plain FRC. On 10% addition of wood waste ash there is increase in the flexural strength by 4.01%. But at 30% level, the flexural strength has decreased by 15.47%. Hence 20% addition of wood waste ash is taken as the optimum content. Thus, the effect of addition of wood waste ash is very similar for both plain concrete as well as fiber reinforced concrete. From figure 5.4(B), similar trends were observed even at 90 days age.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Results were analyzed to derive useful conclusions regarding the strength characteristics of wood waste ash fiber reinforced concrete (WWAFRC). M_{20} concrete has been used as reference mix.

The following conclusions may be drawn from the study on strength characteristics of wood waste ash fibre reinforced concrete properties.

- → The workability of concrete measured from compaction factor degree, as the percentage of wood waste ash and steel fibre increases in mix compaction factor decreases. Hence it can be concluded that with the increase in the wood waste ash content and fiber content workability decreases.
- → The workability of concrete measured from vee-bee degree, as the percentage of wood waste ash and steel fibre increases in mix the vee bee time increases. Hence it can be concluded that with the increase in the wood waste ash content and fiber content workability decreases.
- → From the experimental results, the optimum percentage recommended is 1% steel fiber volume with 20% addition of in wood waste ash achieving maximum benefits in compressive strengths, split tensile strengths and flexural strengths at any age for the characteristics of wood waste ash fibre reinforced concrete.
- → The compressive strength of WWAFRC mixes at 28 days increased with the addition of wood waste ash up to 20% level when compared to that of plain concrete. Hence for normal concreting works we can go up to 20% addition level of wood waste ash. The maximum percentage increase over plain concrete is 22.50% and the percentage increase ranges from 11.25 to 22.50% over plain mix. Similar trends were observed even at 90 days age. The maximum percentage increase over plain concrete is 26.33% and the percentage increase ranges from 11.83 to 26.33% over plain mix.
- → The split tensile strength of WWAFRC mixes at 28 days increased with the addition of wood waste ash up to 20% level when compared to that of plain concrete. The maximum percentage increase over plain concrete is 43.47% and the percentage increase ranges from 8.92 to 43.47% over nominal mix. Similar trends were observed even at 90 days age. The maximum percentage increase over plain concrete is 49% and the percentage increase ranges from 7.54 to 49% over nominal mix.
- → The flexural strength of WWAFRC mixes at 28 days increased with the addition of wood waste ash up to 20% level when compared to that of plain concrete. The maximum percentage increase over plain concrete is 41.36% and the percentage increase ranges from 8.93 to 41.36% over normal mix. Similar trends were observed even at 90 days age. The maximum percentage increase over plain concrete is 46.45% and the percentage increase ranges from 7.83 to 46.45% over normal mix.

4.2 RECOMMENDATIONS FOR FUTURE INVESTIGATIONS

- → Studies on different lengths, proportions and aspect ratios of steel fibers may be carried out.
- → Studies on the different proportions of wood waste ash may be carried out.
- → Mathematical / Empirical models can be developed for the Stress/Strain behavior of strength characteristics on wood waste ash fibre reinforced concrete.