ISSN (online): 2349-784X

Partial Replacement of Cement with Wood Ash

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Abstract

With increasing industrialization, the industrial by products (wastes) are being accumulated to a large extent, leading to environmental and economic concerns related to their disposal (land filling). Wood ash is the residue produced from the incineration of wood and its products (chips, saw dust, bark) for power generation or other uses. The use of Wood Ash (WA) in cement concrete mix will make it cost effective and environment friendly disposal of the product. Cement is an energy extensive industrial commodity and leads to the emission of a vast amount of greenhouse gases. 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. Utilization of wood ash as a partial substitution for cement is one of the promising method to increase the strength and thermal insulation for cement blocks. The strength parameters (compressive strength, split tensile strength and flexural strength) of concrete with blended WA cement are evaluated.

Keywords: Wood ash, cement replacement, environment friendly, strength parameters, economic

I. Introduction

In the recent years, growing consciousness about global environment and increasing energy security has led to increasing demand for renewable energy resources and to diversify current methods of energy production. Among these resources, biomass (forestry and agricultural wastes) is a promising source of renewable energy. In the current trends of energy production, power plants which run from biomass have low operational cost and have continuous supply of renewable fuel. It is considered that these energy resources will be the CO_2 neutral energy resource when the consumption rate of the fuel is lower than the growth rate. Also, the usage of wastes generated from the biomass industries (sawdust, woodchips, wood bark, saw mill scraps and hard chips) as fuel offer a way for their safe and efficient disposal.

Wood wastes are commonly preferred as fuels over other herbaceous and agricultural wastes as their incineration produces comparably less fly ash and other residual material. A major problem arising from the usage of forest and timber waste product as fuel is related to the ash produced in significant amount after the combustion of such wastes. It is commonly observed that the hardwood produces more ash than softwood and the bark and leaves generally produce more ash as compared to the inner part of the trees.

The characteristics of the ash depend upon biomass characteristics (herbaceous material, wood or bark), combustion technology (fixed bed or fluidized bed) and the location where ash is collected. As wood ash primarily consists of fine particulate matter which can easily get air borne by winds, it is a potential hazard as it may cause respiratory health problems to the dwellers near the dump site or can cause groundwater contamination by leaching toxic elements in the water. As the disposal cost of the ashes are rising and volume of ash is increasing, a sustainable ash management which integrate the ash within the natural cycles needs to be employed. Extensive research is being conducted on industrial by products and other agricultural material ash like wood ash which can be used as cement replacement in concrete. Due to current boom in construction industry, cement demand has escalated which is the main constituent in concrete. Also, the cement industry is one of the primary sources which release large amounts of major consumer of natural resources like aggregate and has high power and energy demand for its operation. So utilization of such by product and agricultural wastes ashes solves a twofold problem of their disposal as well providing a viable alternative for cement substitutes in concrete. Hence, incorporating the usage of wood ash as replacement for cement in blended cement is beneficial for the environmental point of view as well as producing low cost construction entity thus leading to a sustainable relationship.

Rice husk ash and fly ash, are major players which already proven to be effective mineral admixtures to cement at various percentages. 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 land filled 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. Chemical analysis of wood ash shows that it has pozzolanic property, and using it as a partial replacement to cement may be one of the best application in the current environment scenario.

II. Scope and Objective

In the recent years, there has been increasing demand for renewable energy resources. Among these resources, biomass (forestry and agricultural wastes) is a promising source of renewable energy. The usage of wastes generated from the biomass industries (sawdust, woodchips, wood bark, saw mill scraps and hard chips) as fuel offer a way for their safe and efficient disposal. The thermal combustion greatly reduces the mass and the volume of the waste thus providing an environmentally safe and economically efficient way to manage the solid waste. The most prevailing method for disposal of the ash is land filling. Wood ash consists of particulate matter which may cause respiratory diseases and groundwater contamination. A sustainable ash management which integrates the ash within the natural cycle needs to be employed in the coming year.

The objective of this project is to find the compressive strength, split tensile strength and workability of concrete with blended wood ash cement. The water-to-binder ratio will be taken as 0.45 and three different replacement percentages of wood ash (3%,5%, 8%) will be tested.

III. Methodology

A. Component Materials

Component materials for concrete mixtures were:

- Portland Pozzolona cement(PPC)
- fine aggregate
- coarse aggregate
- wood ash
- water

1) Cement

In this work, Portland Pozzolona Cement of Shankarhas been used. It was procured from a single source and stored as per IS: 4032 – 1977. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 1489-1991(part 1)

The various physical properties of cement were found out and are tabulated in Table.3.1.

2) Coarse and fine Aggregates

The fine aggregate used was locally available m-sand without any organic impurities and conforming to IS: 383 – 1970 [Methods of physical tests for hydraulic cement]. The coarse aggregate chosen for SCC was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self-compacting concrete was between 10mm to 16mm.The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 – 1963 [Methods of test for aggregate for concrete] and is shown in table 3.2 and table 3.4. The aggregates were surface dried before use.

3) Water

Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS :3025 – 1964 part22, part 23 and IS : 456 – 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 – 2000.

4) Wood ash (WA)

Three different proportions of concrete mix (WA replacement of 3%, 5%,8% by weight of cement) including the control mixture were prepared with water to binder ratio of 0.45. The specific gravity of WA was found to be less than that of cement. Specific gravity of wood ash is 2.37 conforming to BS 5628-1: 2005. The suitable range of specific gravity of wood ash is 1.6 to 2.8.

Table - 3.1
Physical Properties of Wood Ash

S.No	*Property*	*Wood Ash*
1	*Specific gravity*	*2.37*
2	*Water absorption*	*5%*
3	*Nature*	*Pozzolanic*

IV. Results

A. Control Specimen

The results obtained are tabulated in Table 6.1.

Target strength: 31.6 N/mm

Table - 4.1
Results of Control Specimen

Tests on concrete	*7-day strength (N/mm^2)*	*28-day strength (N/mm^2)*	*Splitting Tensile strength (N/mm^2)*	*Compressive strength of cylinder (N/mm^2)*	*Flexural strength (N/mm^2)*
Streg th	*16.7*	*25.8*	*3.51*	*23.2*	*3.72*

B. Cube Test Results

Samples with 3%, 5% and 8% replacement of cement with wood ash were casted. The cubes were casted as per the procedure specified in IS 516:1959 and IS 456:2000. The strength of 3 samples were tested at 7 and 28 days using compression testing machine. The compressive strength values were compared with that of conventional concrete mix of M25.
Following the mix design specified inIS: 10262 (1982), samples were casted. The obtained results are shown in fig 3.

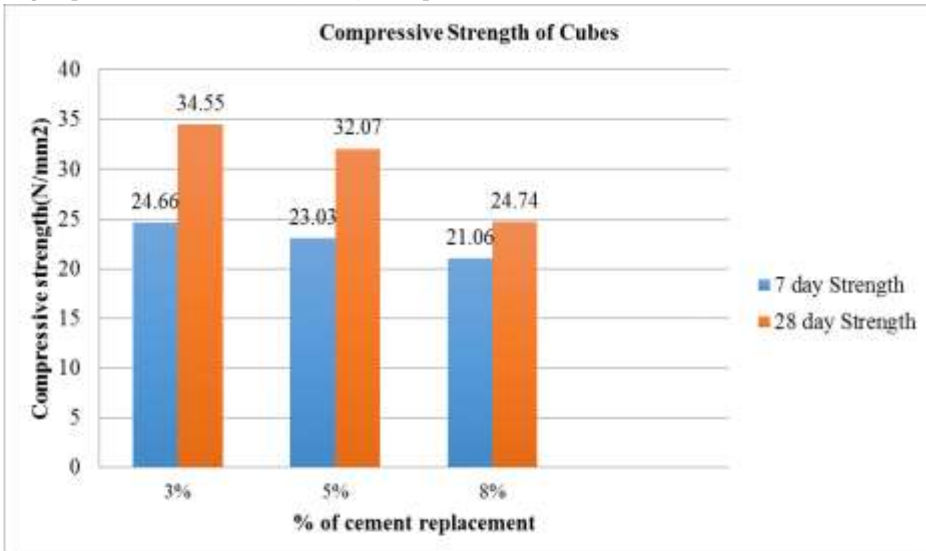

Fig. 3: Compressive Strength of Cubes

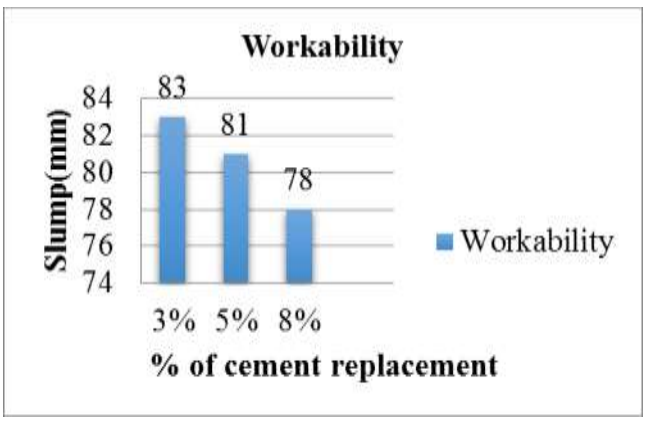

Fig. 4: Workability

The 7 day compressive strength of a standard M25 concrete was obtained as 16.7N/mm^{2}and the 28 day compressive strength was obtained as 25.8N/mm^2.From the above results, it is observed that the 7-day strength of 3%, 5% and 8% is greater than the expected strength of 16.7N/mm^2.The 28 day compressive strength of cube with 8% of cement replacement is only 24.74N/mm^2 which is lesser than 25.8N/mm^2.Therefore, it is observed that the cement can be safely replaced with wood ash up to 5%.
From fig 4, it can be gathered that the workability of concrete decreases with increase in percentage of wood ash. This is because, the water absorption of wood ash is greater than that of cement.

C. Cylinder Test Results

1) Compressive strength of cylinder test results

The cylinders were casted as per the design mix specified in IS: 10262 (1982). The obtained results are shown in fig.5..

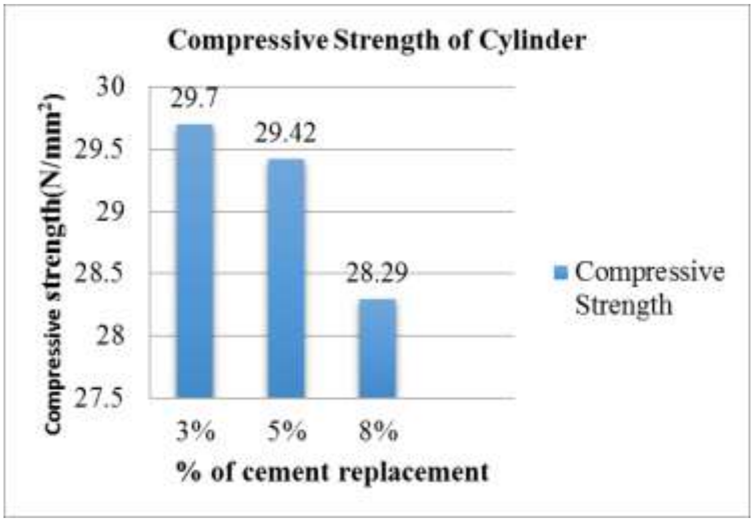

Fig. 5: Compressive Strength of Cylinder

The 28-day compressive strength of cylinder of the control sample was obtained as 23.2N/mm^2. Even though the strength has decreased with increase in % of ash, all the three replacements of cement with wood ash are greater than the 28-day compressive strength of control sample. The maximum strength was obtained for 3% replacement which is 29.7N/mm^2.

2) Split tensile strength of cylinder test cylinders

The cylinders were casted as per the design mix specified in IS: 10262 (1982). The obtained results are shown in graph

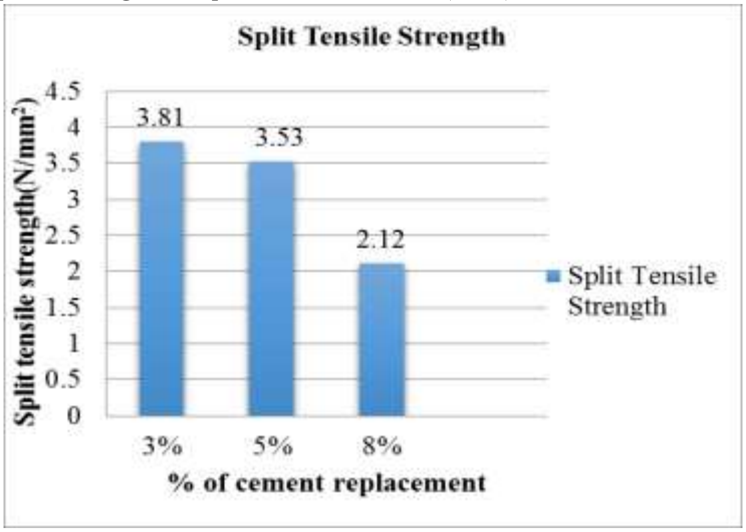

Fig. 6: Split Tensile Strength of Cylinder

The target split tensile strength is given by 0.7 times square root of f_{ck}which is 3.5N/mm^2.Thesplit tensile strength (28 day) of cylinder for the control specimen was obtained as 3.51N/mm^2. The cylinders with 3% and 5% replacement of cement with wood ash have obtained a greater split tensile strength than 3.51N/mm^2. However, 8% replacement did not satisfy this requirement. The maximum strength was obtained for 3% replacement which is 3.81N/mm^2.

D. Beam Test Results

The beams were casted as per the design mix specified in IS: 10262 (1982).The results obtained are shown in fig 7.

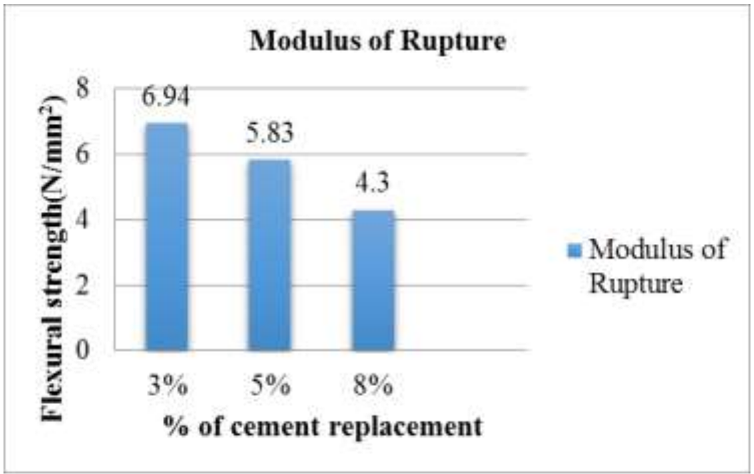

Fig. 7: Modulus of Rupture

The target flexural strength (28 day) of standard M25 beam is 3.5N/mm^2.The flexural strength of control sample was obtained as3.72N/mm^2.All the three percentages of replacement of cement with wood ash satisfied the flexural strength requirement. The maximum value of 6.94N/mm^2 was obtained with 3% replacement.

V. CONCLUSION

The 7-day compressive strength of cube with all the three percentages of replacement satisfied the strength requirement. The 28-day compressive strength of cube with 8% replacement of cement with wood ash was found less than the standard strength of a control specimen. The 28-day compressive strength of cylinder was obtained satisfactory for all the three percentages of replacement of cement with wood ash. But the strength decreases in the increase in wood ash content. The split tensile strength of 8% replacement of cement with wood ash was found less than the standard value. The 28-day flexural strength of beam for all the three percentages of cement with wood ash was found to be satisfactory. 3% and 5% replacement of cement with wood ash satisfied all the strength requirements. But, 5% replacement will be more economic. Hence, 5% replacement of cement with wood ash for PPC is suggested. Workability is found to decrease with increase in the replacement. This is because the water absorption of wood ash is greater than that of cement. The presence of much finer particles and hence, larger surface area per particles make wood ash pozzolanic material. Wood ash contains amorphous silica making it fit as cement replacing material due to its high pozzolanic activity. The strength parameters decrease slightly with increase in wood ash content in the concrete when compared to control specimen. However, the strength obtained is still higher than the target strength. Also the strength increases with age due to pozzolanic reactions. Thus, use of wood ash in concrete helps to transform it from an environmental concern to a useful resource for the production of a highly effective alternative cementing material.

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