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Partial Substitution of Cement by Wood Ash in Cement Production

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Abstract: With increasing industry the economic by merchandise wastes area unit being accumulated to an oversized extent leading to environmental and economic issues involving their disposal of land filling. Wood ash is that residue made from the combustion of wood and its product (chips, sawdust, bark) for power generation or different uses. The utilization of Wood Ash (WA) in cement concrete combine can create it value effective and environment-friendly disposal of the merchandise. Cement is associate degree energy in depth industrial artifact and leads to the emission of a large amount of greenhouse gases. By reducing the demand for cement, natural reserves of rock are often preserved, energy is often saved and pollution due to CO_2 is often reduced. Utilization of wood ash as a partial substitution for cement is one among the promising strategies to extend the strength and thermal insulation for cement blocks. The effective parameters which includes split tensile strength, compressive strength and flexural strength) of concrete with blended WA cement are evaluated.

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

I. INTRODUCTION

In the recent years, growing consciousness regarding international surroundings and increasing energy security has led to increasing demand for renewable energy resources and to diversify current strategies of energy production. Among these resources, biomass (forestry and agricultural wastes) may be a promising supply of renewable energy. Within the current trends of energy production, power plants that run from biomass have low operational price and have continuous provider of renewable fuel. It's thought-about that these energy resources are the carbon dioxide neutral energy resource once the consumption rate of the fuel is under the expansion rate [1]. Also, the usage of wastes generated from the biomass industries (sawdust, woodchips, wood bark, saw mill scraps and onerous chips) as fuel offer the way for his or her safe and economical disposal.

Concrete that is being widely utilized in the construction trade has unlimited opportunities for innovative applications style and construction techniques. Factors like strength, workability, and durability of the standard concrete are endlessly being changed to create it a lot of appropriate for a fixed construction purpose. This has become more realistic because of the advancement of technology. Many studies have been carried out to spot substitutes for fine aggregates [2, 3] and for cement [3] in producing the concrete product that will enhance the properties whereas reducing the price. Rice husk ash [4], coconut shell and wood ash [5] may well be used as a partial replacement of cement. Ash is that the inorganic noncombustible a part of fuel left when complete combustion, and contains the majority of the mineral fraction of the first biomass.

Currently, the biomass ash is employed in many producing processes like cement clinker production, production of bricks, binding material for soil stabilization and additionally as a raw material for the assembly of artificial aggregates, fertilizers or liming agents [6].

In the present scenario, infrastructure industries creating a huge consumption of cement and concrete. There is urgent need to reuse and recovery of the natural source as well as materials from industrial waste for sustainable development.

Consumption of natural resources can be reduced due to advancement in concrete technology. It will help in reduces

the environmental pollution. Cement can be replaced by supplementary cementations materials so that the use of cementations clinker is reduced. The main aim is to take care of the performance of building material composite exploitation the utmost use of waste

At present, the biomass ash produced from timber factories and power plants is disposed of using the land filling technique which accounts for 70% [8] ash generated and some part remains uncontrolled i.e., 20% [7]. Besides this, the costs for disposal keep increasing day by day. so it is higher to include that waste within the bound manufacturing technique. However before utilizing it has to be treated well because it contains bound contaminants and compounds of C and N. Due to the presence of higher contaminants these need not to be treated in an open environment. The use of Wood Ash (WA) as a replacement for fine aggregate can be useful due to following reasons.

(i) The process of production of cement is responsible for about 6–8% of the global carbon emissions Bu using this martial as the replacement. It will reduce carbon emissions.
(ii) The problem of land pollution can be minimized by dumping of WA.
(iii) Serious respiratory diseases are caused by the very fine particle of WA.

Many authors have studied the use of waste material in concrete and their suitability. As the cement business at this time is on a booming rise the demand for cement is increasing however the price ought to stay traditional. Hence, utilizing the wood ash by economical means that solves a twofold drawback at their disposal still as providing associate economical replacer for cement. A number of tests are carried by researchers which show positive effects of wood ash in cement. Hence using these wastes will be beneficial economically and environmentally.

The ultimate aim of this study is to research the impact of wood ash on completely different major properties of concrete." The study focuses on the characteristics of wood ash/ sawdust and the properties incurred due to the replacement of cement with wood ash. The main objectives are:

(i) To observe the mechanical strength (compressive and tensile strength) of concrete along with the wood ash as the partial replacement for cement.
(ii) To observe the carbonation and drying shrinkage.
(iii) To observe the effect on bulk density.

I. MATERIALS AND METHODS

Wood ash: wood ash was made available from wood furnishing factory Phagwara Punjab. The wood ash was obtained by combustion of craft waste and different agricultural wastes like rotten wood.

Aggregates: Foundry sand having grain size of 4.75 mm along with specific gravity as 2.6. The coarse aggregates used were crushed gravel of size about 10 mm and specific gravity of 2.6. The grain size or particle size distribution was according to ASTM C33/ C33M-08 (**Figure 1**).

Figure 1: Typical foundry sand.

Cement: Ordinary Portland cement was used having particle size of 3.9 µm, specific gravity of 3.01. The physical and chemical analysis properties are provided in **Table 1**.

Constituents	%Value
Chemical Properties	
SiO2	20.5
Al2O3	4.58
Fe2O3	3.18
CaO	63.53
MgO	4.67
Loss on Ignition	3.21
Physical properties	
Specific Gravity	2.9
Mean Size	24µm

Table 1

Methods

Selection of mix proportion: The target compressive strength for M20 mix was calculated according to IS: 10262 2009 [9] as 28.6 N/mm^2 for 28 days. The water-cement ratio, fine aggregate content and coarse aggregate content was accordingly then carried as per the mentioned IS code [9]. Thus mix proportion obtained was:

Cement content = 412.9 kg/m^3

Fine Aggregate Content = 540 kg/m^3

Coarse Aggregate Content = 1179 kg/m^3

Preparation of mix: Preparation of control mix (M20 Design mix Considered) was done first for which the trial mix having water-cement ratio of 0.44 was prepared. Mix was checked for workability (to obtain consistent mix) and Slump Cone Tests to validate the results. Control specimen was casted for 7 days, 28 days and 56 days having foundry sand were casted.

Secondly the preparation of mix for same 0.44 water cement ratio was done along with wood ash in different proportions of 5%, 10%, 15%, 20% and 25% by weight of OPC. The specimens were casted for 7days, 28 days and 56 days. Cubes of 150 mm × 150 mm × 150 mm were casted to check compressive strength. Cylindrical Specimens were casted to check Split Tensile strength and Beams of dimensions 300 mm × 10 mm were casted to check flexural strength. A minimum of 3 specimens were casted for a single test to analyses. Whole procedure was carried at room temperature. Compacting of concrete was carried with the help of vibrating machine.

Curing of blocks

Curing of all specimens was done after 2 days.Tests were carried for compressive strength, split tensile strength, flexural strength, workability, water absorption, carbonation, drying shrinkage and for acid attacks like H_2SO_4 and HCL.

II. RESULTS AND DISCUSSION

Compressive strength

The replacement percentage was 5%, 10%, 15% & 20% by weight of cement. Tests were conducted on 7 days, 28 days and 56 days using the digitalized CTM (compression Testing Machine), so the accumulation of errors can be said to be minimum in this research. The results are provided in **Table 2**.

% age of wood ash added	7 days	28 days
0	18.39	32.41
5	16.16	25.25
10	16.69	26.32
15	17.32	28.14
20	16.34	27.14

Table 2: Compressive strength (N/mm^2) test result (wood ash as partial replacement of cement.

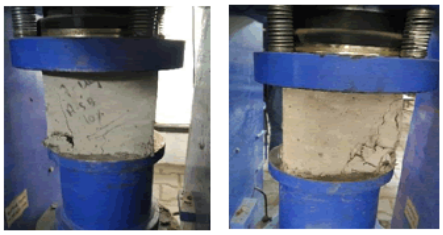
The conclusions drawn based on the results are:

(i) The compressive strength of the control mixes for 7 days, 28 days and 56 days obtained were 18 N/mm2, 32 N/mm2, and 36 N/mm2 respectively.

(ii) With the utilization of wood ash, there was a rise in the compressive strength however that increase wasn't up to the control specimens. The compressive strengths obtained for various days are given in Table 3:

(iii) The Optimum results were obtained at 14.5% replacement.

(iv) There was an increase in the ductile behavior of concrete for wood ash replacement when tested under CTM. The time required to break the wood ash specimen was long enough as compared to break the control specimen, as the development of cracks started increasing slowly under the same rate of loading (Figures 2 and 3).



(a) (b)

Figure 2: Compressive strength testing.

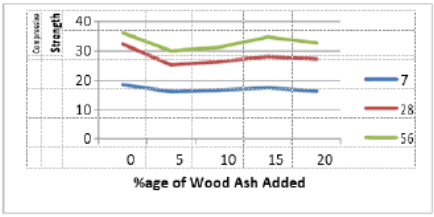


Figure 3: Comparison of compressive strength along wood ash percentage.

Rajamma et al. [1] observed the effects of wood ash on the compressive strength of concrete blocks. Wood ash was used to replace cement in percentages 10%, 20% and 30% by weight of cement, the optimum and significant results were shown on 10% of replacement exhibited higher 28 days strength. But with the replacement of 20% and 30% of by weight of cement, the 28days strength was insignificant and much reduced.

Udoeyo et al. [10] observed the compressive strength of concrete with replacements of 5%, 10%, 15% up to 30% and 30 by weight of cement).

Abdullia et al. [11] observed the compressive strength for 10%, 15%, 20% and 25%. The optimum results were

observed at 15%. But the curing was done for 7 days, 14 days and 21 days. This showed the variation in results.

Split tensile strength

The procedure was carried according to IS: 5816-199 [16]. The split tensile strength of the concrete with wood ash increased. The enhancement in split tensile strength was because of proper binding and insignificant surface area of binding particles (**Table 3**). But the increase was not higher than the control mix. We can say almost same results were obtained for 15% as the control specimen (**Figures 4 and 5**).

%age of wood ash	Split tensile strength at 7days (N/mm^2)	Split tensile strength at 28 days (N/mm^2)	Split tensile strength at 56 days (N/mm^2)
0	2.35	3.60	4.22
5	1.33	2.49	3.16
10	1.88	2.81	3.81
15	2.07	3.25	4.08
20	1.83	2.78	4.01

Table 3: Split tensile strength test (wood ash as partial replacement of cement).

Figure 4: Failure of control specimen.

Figure 5: Failure of specimen along with wood ash.

(i) The average split tensile strength achieved by the control specimens for 7 days, 28 days and 56 days was 2.35 N/mm^2, 3.60 $N/ mm^2$and 4.22 N/mm^2 respectively.

(ii) The strength of concrete along with the wood ash varied accordingly given in Table 4. The Optimum results were obtained on 15% replacement.

(iii) Increase in the split tensile strength is because of the enhanced quality of cement paste due to addition of wood ash.

(iv) The failure for control specimen was brittle which resulted its splitting into two equal halves whereas when wood ash was incorporated the failure observed was not sudden but quite uniform upon load condition as given in **Figure 6**.

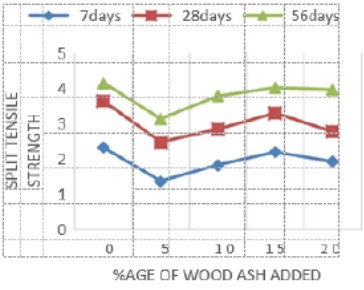


Figure 6: Comparison of split tensile strength along wood ash percentage.

Flexural strength

Beams were cast having dimensions of 305 mm × 10 mm × 10 mm to check flexural strength as per IS: 516 – 1959 [15]. The vibration of the mix was done on vibrating machine according to IS recommendations. A system of 2 point loading was used with CTM to test the specimens. It was observed that there was an increase in the flexural strength specimens with wood ash but not greater than control specimens. Optimum results were obtained at 10% replacement (**Figure 7**). The results are given in **Table 5**.

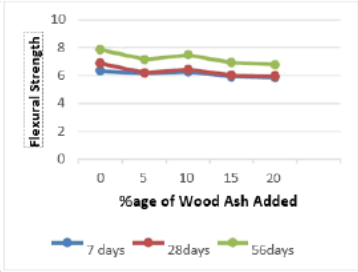


Figure 7: Comparison of flexural strength along wood ash percentage.

%Age of wood ash	Flexural strength at 7 days(N/mm^2)	Flexural strength at 28 days (N/mm^2)	Flexural strength at 56 days (N/mm^2)
0	6.28	6.77	7.80
5	6.13	6.16	7.12
10	6.24	6.39	7.56
15	5.84	5.98	6.81
20	5.79	5.87	6.75

Table 5: Flexural strength test.

Water absorption

An increase in water absorption was observed maximum for 15% at 28 days which indicates that rate of pozzolonic reaction is much higher at 15% replacement. Beyond 15% replacement, the water absorption significantly decreased.

Udoey et al. [5, 14]] According to this study the t-test carried showed certain results using wood ash as replacement of cement in the level of 5%, 10% and 25%, there was increase in water absorption for 28 days which was observed as significant. But the water absorption values up till 9% were observed significant which produced positive results both with a without wood ash.

Soundness

The soundness of concrete mix was studied and observed to be increase while increasing the wood ash % age. Similar results were obtained from other studies when the replacements were done from 5% to 30%. At 30% concrete obtained produced much soundness. Thus, in short, soundness increases in direct proportions of increased wood ash incorporation [17, 18].

Carbonation

The carbonation results along with the wood ash as a partial replacement when the water-cement ratio of 0.50 was observed to decrease, providing optimum results at 5% of replacement. From other researchers, similar results were observed. The tests for carbonation showed that with 5% incorporation of wood ash in cement resulted in a reduction in depth of carbonation. With the 12%, 16% and 20% the reduction in depth was insignificant [19].

Bulk density

According to a study [11-13], bulk density was observed to decrease with increasing % age of wood ash as a replacement for cement. Much more significant results were obtained at 39% replacement.

Reduction in bulk density at 39% was 2279 kg per cub. Meter and at 0% was 2487 kg per cub meter. This shows that wood ash observed is of low specific gravity.

Drying shrinkage

Naike et al. [10] observed the shrinkage in concrete with wood ash. Replacement was done for 5%, 8% & 10% by weight of cement as a binder. The following results were obtained:

(i) Shrinkage of concrete cube was 0.0089% at 7 days and 0.055% at 232 days.

(ii) At 5% replacement of cement with wood ash shrinkage was 0.014% at 7 days and 0.025% at 232 days.

(iii) At 8% replacement of cement with wood ash shrinkage was 0.016% at 7 days and 0.012% at 232 days.

(iv) At 14% replacement of cement with wood ash shrinkage was 0.0055% at 7 days and 0.044% at 232 days.

VI. CONCLUSION

The detailed study in this paper leads to the conclusion that wood ash may vary in quantity and quality because of many factors like temperature, type of wood or biomass, combustion type, etc. So it is quite necessary to analyze the wood ash before using. The wood ash has the potential ability to replace the cement partially in cement block manufacturing industry. The strength parameters obtained were quite better than the attaining target of M20. The results for compressive strength were much significant. The optimum level of replacement with wood ash produced positive results. The incorporation of wood ash resulted in increase in the water absorption. Bulk density of concrete was observed to decrease with the increasing % age of wood ash. Incorporation of wood ash made concrete ductile enough. It means that concrete was able to bear loads for longer time as the failure was not sudden. Incorporation of wood ash concrete resulted in increase in mass at initial stages when immersed in acids. Incorporation of wood ash increased the standard of paste thereby increasing each split strength and flexural strength of concrete.

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