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**International Journal of Research Publication and Reviews**

Journal homepage: www.ijrpr.com ISSN 2582-7421

# Partial Replacement of Ordinary Portland Cement with Wood Ash and Foundry Sand as Fine Aggregate

***Praveen Birla[1], Dr. B.P. Mudgal[2] , Dr. Manoj Sharma[2]***

**[1]M. Tech Students, IPS College of Technology and Management, Gwalior, M.P.**
**[2]Professor, IPS College of Technology and Management, Gwalior, MP**

**ABSTRACT**

Wood ash is generated as residual / waste from combustion done in boilers at mills, powerplants, and at different thermal power generating facilities. Since wood is a renewable source of energy and an environmentally friendly, there is an increased requirement of using waste or residual wood for the purpose of energy generation thus leading to formation of more wood ash waste. The study focuses on incorporation of wood ash in combination with ordinary Portland cement and foundry sand while using it for various structural works.

A critical study of sieve analysis, consistency and water absorption, setting time and slump testing of wood ash added to OPC will produce important results that will emphasize the research process. Save details. Uncontrolled burning of saw dust to form wood ash can be used as a partial replacement of OPC, thereby changing its physical and chemical properties. These properties are found somewhat similar to fly ash. The concrete mixes are replaced with the amorphous wood ash as an admixture of cement having grain size less than 75micron in proportions of5%, 10 %, 15%, 20%, 25% and 30% by weight of cement and can be tested for compressive strength and carbonation. In this study a review of numerous technical papers will be done to analyze and compare the properties of conventional cement concrete with wood ash concrete. All the properties of wood ash cement are compared with OPC for the purpose of reviewing the application and feasibility of using woo dash in structural works.

**Keywords:** Compressive Strength, Carbonation, 2point load System, Flexural Strength, Split Tensile Strength, HCWA, cement replacement

## INTRODUCTION

In the present years, the concern of our technology, efficiency issues have forced us for an increased demand for renewable energy and their sources to meet the growing energy problems. Biomass resources (including forest wastes and agricultural wastes) and powerplants comprising a part of these are an efficient source of renewable energy. These sources are economic i.e. have low operational costs. A part from historical evidences about demand of renewable energy int he present modernizing world, in the era of urbanizationnow the demand for renewable energy resources have further increased. Wood ash is produced by the combustion of wood in power plants, paper industries, wood Incinerating factories, etc. It is well known fact that wood or forestry waste is considered to be a potential source of energy. It has no hazards and thus is environmentallyfriendly material (proving zero harm to ecosystem). With all these facts to be known toeveryone that increasing energy demand can enhance the increased usage of forestry wasteproducts, thereby leading to increased waste production. As a result, the quantity of ashgenerated will be very high to get disposed. It will increase in quantity, thereby raising theissues of disposal. thus making large part of it available to be used in cement industries asmostof its chemical as wellas physical properties resembleflyash.As in research programs we mainly focus the economic criteria at first we can say that wood ash produced as waste if used as partial replacement for OPC (ordinary Portland Cement) will be beneficial in economic aspects. Apart from this it will be beneficial for environment in the way of disposing large wastes. This way of utilization will provide a better way to the waste management problem where they require high energy sources for disposing large quantities of wastes.

### *Objectives of The Study*

The study focuses on the characteristics of wood ash/ saw dust and the properties incurred due toreplacement of cement with wood ash. The main and final objectives of the conducted study is to get familiar with basic civil engineering site methods and understanding the importance of composites.

The objectives are;

**(a)** To study the mechanical strength (compressive& tensile strength) of concrete along with the wood ash as partial replacement for cement.

**(b)** To study the carbonation.

**(c)** To study the effect on bulk density.

**(d)** Tolearnhowtoconductexperimentsonconstituentelementstobeusedtopreparemix.

**(e)** To make concrete economical.

**(f)** To make concrete efficient

## LITERATURE REVIEW-

**T. R. Omodara* and E. Y. Aderibigbe (2014)** The effects of varying concentrations of wood ash on the growth of known strains of Bacillussubtil is were studied. Different concentrations of ash (0-5%w/v) were prepared in distilled water and filtered. The Ph of the filtrates that ranged between 9.6 and 9.8 were titrated, using 0.1M HCl (hydrochloric acid) to pH of 7.2. The ash filtrates were used to prepare nutrient agar and nutrient broth. The growth of five strains of Bacillus subtilis (8B,1A,2B,3A,5AandBC4333)on the ash incorporated nutrient agar were determined by pour-plate method at 35$^{o}$C.

**Prabagar Subramaniam, Kalya Subasinghe (2015)**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 present study focused to use wood ash as a partial replacement for cement material during sand cement block manufacturing. The concrete mixtures have been mixed with 10%, 15% 20% and 25% of wood ash as a partial replacement for cement with sand and tested for compressive strength, water absorption and heat release.

**Amrutha Sebastian &Anju Sambath Manapurath (2016)-** 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.

**Jonna Wiklund & Sigrun Dahlin, (2017) -** In the search for farming strategies working to sustain and improve soil fertility while also being affordable to farmers with limited resources, use of wood ash is sometimes discussed. Wood ash contains many important plant nutrients such as potassium (K) and phosphorus (P) and can be used as a fertilizer.

**Dora Neina, &Sibylle Faust (2020)**-Ample quantities of ashes generated from domestic biomass energy combustion in Ghanaian kitchens are currently disposed of despite their potential agricultural value. This study aimed to investigate the potential agricultural value of charcoal and firewood ashes in terms of differences in the chemical and mineralogical compositions, and to identify the suitability of aqua regia, $H_2SO_4$, vinegar and distilled water to extract plant nutrients.

**Haider M. Owaid(2021)** Large quantities of paper and wood waste are generated every day, the disposal of these waste products is a problem because it requires huge space for their disposal. The possibility of using these wastes can mitigate the environmental problems related to them. This study presents an investigation on the feasibility of inclusion of waste paper ash (WPA) or wood ash (WA) as replacement materials for fly ash (FA) class F in preparation geo polymer concrete (GC).

**RebecaMartínez-García, P. Jagadesh(2022)**-A main global challenge is finding an alternative material for cement, which is a major source of pollution to the environment because it emits greenhouse gases. Investigators play a significant role in global waste disposal by developing appropriate methods for its effective utilization.

**Ece Ezgi Teker Ercan, Lale Andreas (2023) ,**Different ecological binders have been used to minimize the negative effects of cement production and use on the environment. Wood ash is one of these alternative binders, and there has been increasing research related to this topic recently. The wood ash utilized in the literature primarily originates from power plants and local bakeries, and predominantly wood fly ash is used. This review paper examines the use of wood ash as an ecological binder in two different applications: as a cement replacement and as an alkali-activated material.

**ENVIRONMENTAL IMPACT OF WOOD ASH (WA)-** A main global challenge is finding an alternative material for cement, which is a major source of pollution to the environment because it emits greenhouse gases. Investigators play a significant role in global waste disposal by developing appropriate methods for its effective utilization.

**MATERIALS & PROPERTIES -**They are following materials used.

(1) **Wood**

(2) **Cement**

(3) **Aggregates**

Explain

(i) **WOOD** - As a material, wood has been in service since humans appeared on Earth. Today, in spite of technological advancement and competition from metals, plastics, cement, and other materials, wood maintains a place in most of its traditional roles, and its serviceability is expanding through new uses. In addition to well-known products such as lumber, furniture, and plywood, wood is the raw material for wood-based panels, pulp and paper, and many chemical products. Finally, wood is still an important fuel in much of the world.

**Wood-Ash-** Wood ash is the powdery residue remaining after the combustion of wood, such as burning wood in a fireplace, bonfire, or an industrial power plant. It is largely composed of calcium compounds along with other non-combustible trace elements present in the wood. It has been used for many purposes throughout history.

Figure No. 1 Wood Ash

**Chemical properties of wood ash** - Elemental analysis-Typically, wood ash contains the following major elements:

Carbon (C) - 5–30%., Calcium (Ca) - 7–33% ,Potassium (K) -3–4%,Magnesium (Mg) - 1–2%,Manganese (Mn) - 0.3–1.3% ,Phosphorus (P) -0.3–1.4%

,Sodium (Na) — 0.2–0.5%.**CEMENT-** cement, in general, adhesive substances of all kinds, but, in a narrower sense, the binding materials used in building and civil engineering construction. Cements of this kind are finely ground powders that, when mixed with water, set to a hard mass. Setting and hardening result from hydration, which is a chemical combination of the cement compounds with water that yields submicroscopic crystals or a gel-like material with a high surface area. Because of their hydrating properties, constructional cements, which will even set and harden under water, are often called hydraulic cements. The most important of these is portland cement.

**Portland cement** - Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-specialty grout. It was developed from other types of hydraulic lime in England in the early 19th century by Joseph Aspdin, and is usually made from limestone. It is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. Several types of portland cement are available.

**Chemical properties of Portland cement**

**Table 1 Chemical Properties of Portland cement**

| S.no. | Name of content | % |
|---|---|---|
| 1 | Lime (CaO) | 60 to 67% |
| 2 | Silica (SiO2) | 17 to 25% |
| 3 | Alumina (Al2O3) | 3 to 8% |
| 4 | Iron oxide (Fe2O3) | 0.5 to 6% |
| 5 | Magnesia (MgO) | 0.1 to 4% |
| 6 | Sulphur trioxide (SO3) | 1 to 3% |
| 7 | Soda and/or Potash (Na2O+K2O) | 0.5 to 1.3% |

**AGGREGATES -** Aggregates are raw materials that are produced from natural sources and extracted from pits and quarries, including gravel, crushed stone, and sand. When used with a binding medium, like water, cement, and asphalt, they are used to form compound materials, such as asphalt concrete and Portland cement concrete.

**Physical properties of aggregates-** Specific gravity

(i)Bulkage of aggregates , (ii) Voids (iii) Composition (iv) Size & Shape(v) Texture of aggregate

## METHEDOLOGY

This Chapter includes the whole experimental procedure and worked one for the research. A step wise procedure is briefly mentioned here to understand the whole concept here:

**Foundry Sand Tests**

**Silt Content Test:**

Silt Content= **8.1%**

Thus calculated silt content is correct as maximum permissible silt content is 10%

**Bulkage Test:**

% age bulking= **8.1%**

Thus calculated bulk age is correct as maximum permissible bulk age is 10%.

**Moisture Content Test:**

Moisture content = **1.12 %**

Thus the calculated moisture content is correct according to**.**

**Sieve Analysis of foundry sand Observation Table:**

**Table 2. Sieve Analysis of Foundry Sand**

| Sieve Size | Weight Retained in each Sieve | %age on each Sieve | Cumulative % age retained on each Sieve | % Passing on each Sieve | Standard Values Zone-IV as per IS383:1970 |
|---|---|---|---|---|---|
| 4.75mm | 0 | 0 | 0 | 100 | 95-100 |
| 2.36mm | 0 | 0 | 0 | 100 | 95-100 |
| 1.18mm | 0 | 0 | 0 | 100 | 90-100 |
| 600micron | 27gm | 5.20 | 5.20 | 94.8 | 80-100 |
| 300micron | 206gm | 40.20 | 45.4 | 54.6 | 15-50 |
| 150micron | 251m | 49.02 | 94.42 | 5.58 | 0-15 |
| 75micron | 16gm | 3.10 | 97.52 | 2.48 | - |
| Pan | 8gm | 1.50 | 99.40=100 | 0 | - |

**Coarse Aggregate Tests 1SpecificGravity:**

Specific Gravity =2.6 , Apparent Specific Gravity=2.81

**Water absorption Test**

Water Absorption =**1.2%**

**Cement Tests-**

Normal Consistency Test: Table No. 3

| %age of water added by wt. of cement | Water added in ml | Penetration observed from bottom |
|---|---|---|
| 25% | 125 | 27mm |
| 28% | 140 | 18mm |
| 29% | 145 | 11mm |
| 29.5% | 147.5 | 9mm |
| 30% | 150 | 6mm |
| 31% | 155 | 1mm |

## RESULTS-

**Fresh Properties of Concrete with Wood Ash as Replacer**

**Workability:** Adopting thaw/ratio of 0.47 the workability of the concreted decreased with the increasing wood ash content. At 10% replacement the consistency of freshly prepared concrete mix was consistent and nearly same as of concrete mix having 0%WA.Beyond10 % replacement workability decreased proportionally. A true slump was observed in all cases. **Table**

**Table 4 Settlement values in Slump Test with and without WA**

| %age of WA added | Settlement for Slum test (cm) |
|---|---|
| 0 | 12.60 |
| 5 | 9.50 |
| 10 | 11.30 |
| 15 | 10.00 |
| 20 | 9.00 |
| 25 | 7.00 |

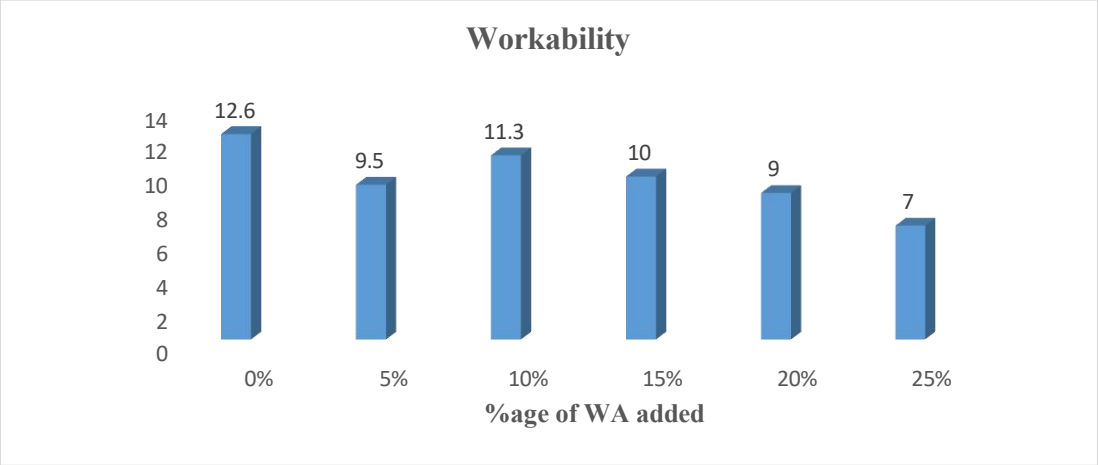


**Figure 2 no. Change in workability with WA**

**Hardened Properties of Concrete**

**Compressive strength:** The replacement percentage was 5%, 10%, 15%, 20% and 25%by weight of cement. Tests were conducted on 7 days, 28 days, 56 days and 90 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 4**

The conclusions drawn based on the results are:

(1) The compressive strength for the control mixes for 7days, 28days, 56days and 90daysobtainedwere18.95N/mm$^2$, 32.51 N/mm$^2$,36.03N/mm$^2$and38.86 N/mm$^2$ respectively.

**(2)** With the use of wood ash there was an increase in the compressive strength but that increase was not up to the control specimens. The compressive strengths obtained for respective days are given in **Table 4**

(3) The Optimum results were obtained at 15%replacement.

(4) There was 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 controls pecimen, as the development of cracks started increasing slowly under same rate of loading.

**Table 4 Values of CS for all days with and without WA**

| %age of woodash added | 7days | 28days | 56days | 90days |
|---|---|---|---|---|
| 0 | 18.95 | 32.51 | 36.03 | 38.86 |
| 5 | 16.43 | 30.22 | 33.68 | 36.17 |
| 10 | 17.08 | 31.11 | 34.95 | 36.93 |
| 15 | 17.85 | 31.86 | 35.76 | 37.62 |
| 20 | 16.96 | 30.61 | 34.18 | 37.04 |
| 25 | 16.31 | 30.14 | 33.91 | 36.57 |

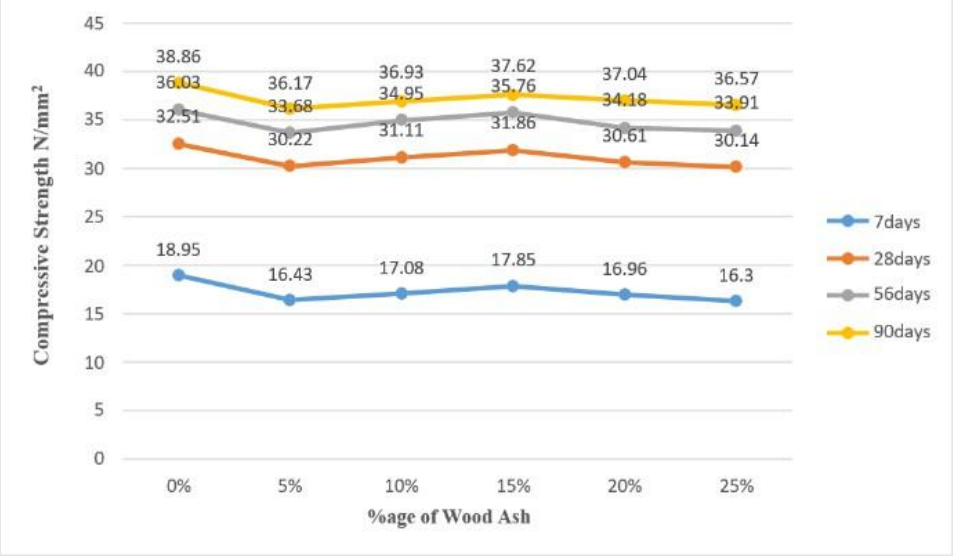


Figure no.3 Variation of compressive strength with addition of wood ash

## CONCLUSION

(i) 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. Wood ash containing higher silica content can be considered to be better to produce efficient results.

(ii) Workabilitywasconsistentat0.47ofwatercementratio.Noneedofanysuperplasticizerwas observed.

(iii) The strength parameters obtained were nearly equal to the target of M20. The results for compressive strength were much significant. The optimum level of replacement with wood ash produced positive results. At 15% replacement Optimum results were obtained. Thus to make our concrete economical only 15% replacement is recommended according to this study.

(iv) The incorporation of wood ash resulted in increase in the water absorption. This is because of the finer size of wood ash particles which demand water to maintain wet state.

(v) Setting Time was observed to decrease as the mix when prepared got stiffer in lesser time.

(vi) 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.

(vii) Incorporation of wood ash enhanced the quality of paste, thereby increasing both split tensile strength and flexural strength of concrete.

(viii) An increase in flexural strength was observed at 10% replacement. The increase was not up to the level of control specimen.

(viii) Depth of carbonation decreased with the addition of wood ash. Optimum results were obtained at 5% replacement both for7days and28days.

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