Effect of Wood-Ash as Partial Replacement For Cement on The Performance of Concrete

Ishita Rajak[1], Anubhav Rai[2]
[1]Dept of Civil
[2]HOD, Dept of Civil
[1, 2] GGITS, Jabalpur (M.P), India

Abstract- *In this paper "Effect of Wood-Ash as Partial Replacement to Cement on Performance of Concrete" has been proposed for the partial replacement of cement weight with wood ash. Portland cement is used as a binder in concrete, but it leads to the emission of a vast amount of greenhouse gases.*

For this work, many concrete blocks by M30 grade of concrete were prepared. Ordinary Portland Cement 43 grade was adopted throughout in carrying out the present investigation. The size of each cubeare 150x 150x 150 mm. The days of curing were selected as 7 days, 14 days and 28 days respectively. The percentage of WA was taken as 5%, 10% and 15% as the partial replacement of cement.

Various tests were carried out on the materials. For cement the physical tests were conducted as a consistency test and compressive strength. And for cement chemical tests were conducted as Insoluble residue, magnesia, sulphuric Anhydride, Loss of ignition,

Keywords: Wood Ash, Sustainability, Cement replacement, Strength parameters, Economic

I. INTRODUCTION

The construction industry heavily relies on Portland cement, a material whose production significantly contributes to global carbon dioxide emissions and environmental degradation. As the demand for sustainable building practices grows, researchers and engineers are increasingly exploring the use of industrial and agricultural by-products as partial replacements for cement. One such promising material is Wood Ash, a residue generated from the combustion of wood in power plants, fireplaces, and other biomass systems.

This paper shows the investigation the effect of wood ash as a partial replacement of cement in concrete mixes, specifically at replacement levels of 5%, 10%, 15% and 20% by weight of cement. The primary focus of the study is to evaluate the compressive strength of the resulting concrete at different curing periods. In addition, the research assesses workability and other mechanical properties to determine the viability and optimal percentage of wood ash replacement.

Objectives of this research-

This research aims to investigate the effect of wood ash as a partial replacement for cement on the performance of M30 grade concrete. The key objectives include:

- To study the physical and chemical characteristics of wood ash.
- To design and prepare M30 concrete mixes with varying wood ash replacement levels at 0%, 5%, 10%, 15%, and 20% by weight of cement.
- To determine the compressive strength of concrete at 7-, 14-, and 28-days curing periods.

II. LITERATURE REVIEW

Sheetal Verma (2023)- Compressive strength of 40mm cubes at 0% replacement of WWA is 24.07 N/mm2 at 7 days of curing and 28.13 N/mm2 at 28 days of curing while at 10% replacement of WWA, the compressive strength is 17.28 N/mm2 at 7 days of curing and 20.67 at 28 days of curing. It is clear from results that at replacement of 10%, compressive strength decreased by 26.52% in comparison to control mortar. The Flexural strength results show that `there is a significant decrease in flexural strength at up to 10% replacement level of wood ash. At 0% replacement of cement by WWA, the flexural strength is 7.1 N/mm2 and at 10% replacement, strength is 5.82N/mm^2 . **Buthainah Nawaf AL-Kharabsheh (2022)-** The chemical composition of WA is similar to that of ordinary cement. Therefore, it can be used as a cement substitute in concrete. The setting time of concrete increased with the substitution of WA due to pozzolanic activity. The workability of concrete declined with the substitution of WA due to the larger surface area and irregular particles of WA. Strength and durability of concrete enhanced with WA due to combined pozzolanic activity and micro filling effects of WA. However, higher dose results decreased in strength and durability of concrete due to a lack of flowability which more pores in hardened concrete. **Er.**

Navdeep Singh & Harpreet Singh (2022) – The study is based on the use of sawdust as a partial replacement material for cement in concrete for property modification. Lightweight of the sawdust ash in comparison to cement, the concrete ultimately becomes lighter weight. The grade of concrete designed M30 and concrete cubes measuring 150mm ×150mm×150mm, cast and their compressive strength, flexural strength and spilt tensile strength are evaluated respectively after 7 and 28 days. **Nina M. Sigvardsen (2021)-** presented in this paper two representative WAs originating from combustion of wood chips by grate combustion (WA1) and circulating fluidised bed combustion (WA2) of wood chips were investigated. The difference in main reaction products was attributed primarily to the content of aluminium in 100%WA2, facilitating ettringite formation and the free CaO content in 100%WA1 facilitating precipitation of portlandite and subsequent formation of gypsum. **Kunamineni Vijay (2020)-** presented in this paper that wood ash has been added to concrete by 10%, 15%, and 20% by weight of cement. The addition of wood ash in concrete improves the strength of concrete. There is an 8.24% maximum improvement in strength of concrete was identified by the utilization of 15% of wood ash as replacement to cement. The water absorption test results show that the utilization of wood ash slightly diminishes the durability of concrete.

III. METHODOLOGY

1. **Cement (Ordinary Portland Cement)-** Portland Cement (OPC) is one of the most widely used cement around the Ordinary world.
   OPC 43: Ordinary Portland Cement grade 43 with a compressive strength of 43 N/mm^2 at 28 days is known as OPC 43. It's used for high-strength concrete work.
2. **Wood ash-** Wood ash is the powder form of raw material. It's the combustion of wood, such as the burning of wood. Wood ash contains a variety of minerals, including potassium, phosphorus, and trace minerals. Here using the Wood Ash, which are passing through a 90-micron sieve. When Started testing with cement and wood ash 10%, 15% and 20%.

Wood ash absorbed a significant amount of water, resulting in consistencies of 10%, 15%, 20%, 35 ml, 36 ml, and 37 ml. First, 10% wood ash was added to a 300 g sample and mixed for 1 minute using a trowel.

Normal Consistency	**Wood Ash Consistency**			
	5%	10%	15%	20%
30	33	35.5	36	36

Table-1

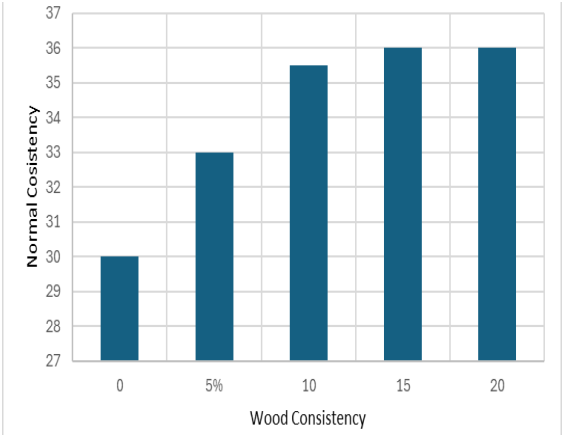


Fig-1
Graph-1 Consistency)

Chemical Constituents	**Values**	**Chemical Constituents**	**Values**
SiO2	31.00	SO3	7.04
Al2O3	7.03	Na2O	1.80
Fe2O3	1.12	K2O	10.05
CaO	31	CaCO3	-
MgO	3.84	LOI	3.68

Table-2 (**Chemical Properties of Wood Ash)**

3. Water

Water is reasonably free from suspended solids, organic matter, inorganic matter and dissolved salts. It affects the properties of the concrete, especially setting time, hardening, strength, and durability.

4. Aggregates

Aggregates can be defined as crushed stone or other materials (Coarse and Fine Aggregate) used in concrete. They typically make up about 70–80% of the total volume of concrete, providing its main body. They help reduce shrinkage, improve overall stability, and significantly influence the cost of the concrete mix. These studies were conducted on the basis of the guidelines provided in IS: 383.

IV. EXPERIMENTAL WORK

CONCRETE MIX PROPORTION-

A. Stipulation for proportioning:

a) Grade designation
b) Types of cement
c) Types of wood ash
d) Maximum nominal size of aggregates
e) Maximum cement content
f) Maximum water-cement ratio
h) Exposure condition
i) Method of concrete placing
j) Degree of supervision
k) Types of aggregate
l) Maximum cement content
m) Chemical admixture

B. Test data for material:

Cement use		**Water absorption-**	
Specific gravity of cement	3.18	Coarse aggregate	0.65
Specific gravity of wood ash	2.3	Fine aggregates	1.83
Specific gravity of-		**Free surface moisture**	
Coarse aggregates	2.81	Coarse –	Nil
Fine aggregate –	2.56	Fine –	Nil

Table-x (Test data for material)

C. Target strength for mix proportion:

f'ck = fck +1.65 s
where, f'ck = target mean compressive strength at 28 days in N/nn2.
fck = characteristic compressive strength at 28 days in N/mm2, and
s = standard deviation N/mm2.
Target mean strength = 30+1.65*5 = 38.25 N/mm2

The higher value is to be adopted. Therefore, target strength will be 38.25 N/mm² as 38.25 N/mm² > 36.5 N/mm².

D. Selection of water cement ratio:

From Table 5 IS; 456, maximum water cement ratio.
The free water cement ratio required for the target strength 38.25 N/mm².
Water cement ratio – 0.40 < 0.45 hence OK.

E. Selection of water content

- From IS 10262:2019 Table 4, for 20 mm aggregate, water = **186 kg/m³**
- If using superplasticizer → reduce by 18%

Water = 186 × 0.82 = 152.5Kg/m3≈ 160 Kg/m^3

F. Calculation of cement content

Water cement ratio = 0.40
Cement content = 152.5/0.40 = 381.25Kg/m^3
Minimum cement for Durability = 320Kg/m^3
Adopted cement = 382Kg/m^3

Mix calculation

The mix calculation per unit volume of concrete shall be as follow

a. Volume of concrete = 1 m3

b. Volume of cement = mass of cement /specific gravity of cement × 1/1000

= (382/3.15) *(1/1000)
=0.1213m3

c. Volume of water = (Mass of water / specific gravity of water) * (1/1000)

= 152/1 * 1/1000
= 0.1525 m^3

d. Volume of chemical admixture = mass of chemical admixture /specific gravity of admixture * 1/100

= 3.82/1.145 x 1000 = 0.003m^3

e. Volume of all in aggregate = [a-(b+c+d)]

= 1-(0.1213+0.1525+0.0033)
= 0.723 m^3

f. Mass of coarse aggregates = e x volume of coarse aggregate x specific gravity of coarse x 1000

= 0.470×2.81×1000
= 1320.7kg

g. Mass of fine aggregate = e x volume of fine aggregates x specific gravity of fine aggregate x 1000

= 0.253×2.56×1000
= 647.58 kg

G. Mix proportion for trial number 1 5% wood ash

a. Cement = 382kg
b. Water = 152.5 litre
c. Fine aggregates = 670 kg
d. Coarse aggregates =1270 kg
e. Chemical admixture = 3.82

Add Wood Ash percentage		Material Quantity
5%	Cement	382×0.95=362.9Kg
	WA	382×0.05=19.1Kg
10%	Cement	382×0.90=343.8Kg
	WA	382×0.10=38.2Kg
15%	Cement	382×0.85=324.7Kg
	WA	382×0.15=57.3Kg
20%	Cement	382×0.80=305.6Kg
	[1] WA	[2] 382×0.20=76.4Kg

Table- Wood Ash percentage & Material Quantity

S.No.	Mix Design codes	Slump cone test in mm
1.	A-1 (5% Wood Ash)	88
2.	A-2 (10% Wood Ash)	75
3.	A-3 (15% Wood Ash)	70
1.	A-4 (20% Wood Ash)	61

Table- Workability of various concrete mixes design for slump cone test as follow

RESULT AND DISCUSSION

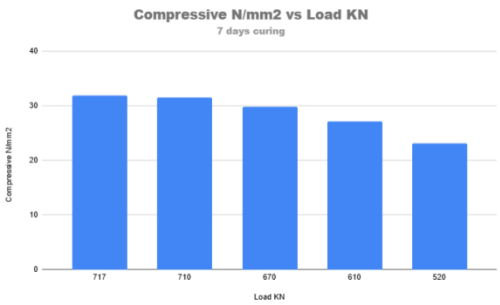
The various compressive strength results presented, including different values obtained by partial replacement of cement at 0%, 5%, 10%, 15% and 20% respectively are based on laboratory testing of standard 150 mm concrete cubes for M30 grade concrete under controlled conditions.

These results indicate the concrete's strength development after 7 days, 14 days and 28 days of curing, which is the standard benchmark for concrete performance. However, actual strength may vary due to differences in materials, curing methods, environmental conditions, and testing accuracy.

After 7 Days curing of M30 grade of concrete of Wood Ash with replacement as cement are mentioned in the below table-

S. No.	Size of cube mm	Percentage of WA	Area mm	Load KN	Compressive N/mm2
1	150x150x150	0%	22500	717	31.86
2	150x150x150	5%	22500	710	31.55
3	150x150x150	10%	22500	670	29.77
4	150x150x150	15%	22500	610	27.11
5	150x150x150	20%	22500	520	23.11

Table-2

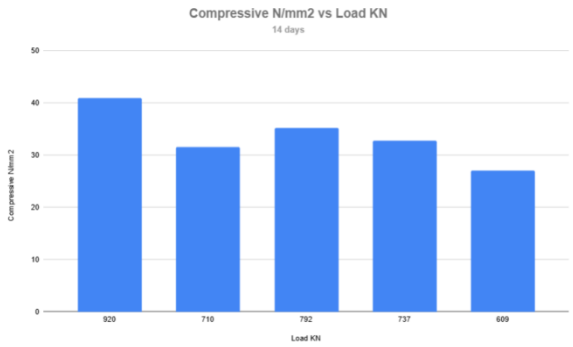


Graph-2

The compressive strength values presented at 7 days of curing based on laboratory testing of standard 150 mm concrete cubes where 0%, 5%, 10%, 15% and 20% of cement was replaced by wood ash in M30 grade concrete. In this graph the compressive strength is slightly decreasing as the partial replacement of the cement with increase of wood ash percentage.

14 Days curing of M30 grade of concrete 0%, 5%, 10%, 15% and 20% of Wood Ash with replacement as

S.No.	Size of cube mm	Percentage of WA	Area mm	Load KN	Compressive N/mm2
1	150x150x150	0%	22500	920	40.88
2	150x150x150	5%	22500	710	31.55
3	150x150x150	10%	22500	792	35.2
4	150x150x150	15%	22500	737	32.75
5	150x150x150	20%	22500	609	27.06



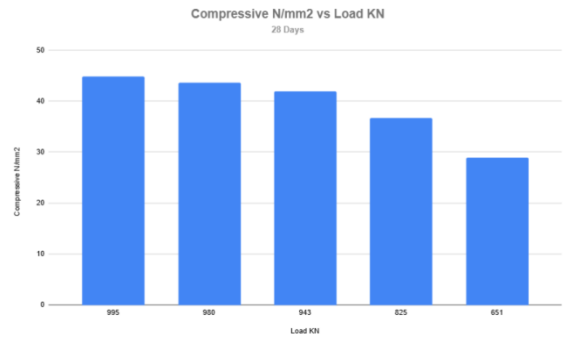
Graph-3

The compressive strength values presented at 14 days of curing based on laboratory testing of standard 150 mm concrete cubes where 0%, 5%, 10%, 15% and 20% of cement was replaced by wood ash in M30 grade concrete. In this graph the compressive strength is slightly decreasing as the partial replacement of the cement with increase of wood ash percentage.

28 Days curing of M30 grade of concrete 0%, 5%, 10%, 15% and 20% of Wood Ash with replacement as cement below table-

S.No.	Size of cube mm	Percentage of WA	Area mm	Load KN	Compressive N/mm2
1	150x150x150	0%	22500	995	44.86
2	150x150x150	5%	22500	980	43.55
3	150x150x150	10%	22500	943	41.91
4	150x150x150	15%	22500	825	36.66
5	150x150x150	20%	22500	651	28.93

Table-4



Graph-4

The compressive strength values presented at 28 days of curing based on laboratory testing of standard 150 mm concrete cubes where 0%, 5%, 10%, 15% and 20% of cement was replaced by wood ash in M30 grade concrete. In this graph the compressive strength is slightly decreasing as the partial replacement of the cement with increase of wood ash percentage.

- 5–10% wood ash can maintain or slightly improve strength at all ages.
- Strength gain slows with higher wood ash content, particularly at early stages (7 and 14 days).
- Pozzolanic reaction in wood ash continues beyond 28 days, so long-term strength (like at 56 or 90 days) may improve, especially with curing.

V. CONCLUSION

The use of wood ash as a partial replacement for cement in M30 grade concrete offers a promising pathway toward sustainable and eco-friendly construction.

- Compressive strength of the cubes with 5% and 10% improved after 7,14 and 28 days for wood ash.
- After conducting the test, we can conclude that wood ash can be used to create M30 grade of concrete but with the increase of wood ash in the concrete decreases the strength of concrete. Wood ash use in concrete is not recommended at higher percentages as it tends to decrease the strength properties of concrete
- At lower replacement levels (5–10%), the workability of fresh concrete is only slightly affected, and the compressive strength at 28 days remains close to that of the control mix.

VI. FUTURE SCOPE OF THIS STUDY

- Durability characteristics such as sulphate resistance, chloride permeability, and alkali-silica reactivity can improve at moderate replacement levels, provided the wood ash used is well-burned and properly processed (low LOI, fine particles).
- Additionally, the use of wood ash contributes to waste management and reduces the carbon footprint of concrete production.
- Cities like Guntur, Bhilai and Bhimavaram have explored and tested M30 grade concrete with wood ash in academic and practical settings, validating its potential for general RCC structures, pavements, and infrastructure in moderately aggressive environments.

REFERENCES

[1] Responding to failure: An introduction to forensic structural engineering- by RJ Heywood, Brady Heywood Pty Ltd, Brisbane, Queensland.

[2] Utilization of wood ash in concrete manufacturing- by Rafat Siddique, Resources, Conservation and Recycling, Elsevier.
[3] Characteristics of Wood ASH/OPC Concrete-by M. Abdullahi, Leonardo Electronic Journal of Practices and Technologies ISSN 1583-1078 .
[4] The Effect of Wood Ash as a Partial Cement Replacement Material for Making Wood-Cement Panels- by Viet-Anh Vu, Alain Cloutier, Benoit Bissonnette, Pierre Blanchet and Josée Duchesne, Materials 2019,
[5] A Comparative Study on Strength of Concrete Using Wood Ash as Partial Replacement of Cement-by Zubaid Hamid and Suhail Rafiq, IOP Conference Series: Materials Science and Engineering.
[6] The incorporation of wood waste ash as a partial cement replacement material for making structural grade concrete: An overview by- Swaptik Chowdhury, Mihir Mishra, Om Suganya, Ain Shams Engineering Journal, Volume 6, Issue 2, June 2015.
[7] Reaction mechanisms of wood ash for use as a partial cement replacement by- Nina M. Sigvardsen a, Mette R. Geiker b, Lisbeth M. Ottosen, Construction and Building MaterialsVolume 286, 7 June 2021.
[8] Partial Replacement of Cement with Wood Ash by- Amrutha Sebastian, Anju Sambath Manapurath, Devika Balachandran, Dona Maria Sebastian and Dona Philip, IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 11 | May 2016.
[9] Wood ash used as partly sand and/or cement replacement in mortar by- Lisbeth M. Ottosen, Esben Østergaard Hansen, Pernille Erland Jensen, Gunvor Marie Kirkelund, Per Goltermann, International Journal of Sustainable Development and Planning, Volume 11.
[10] 9.Impact of production parameters on physicochemical characteristics of wood ash for possible utilisation in cement-based material by- Nina M. Sigvardsen, Gunvor M. Kirkelund , Pernille E. Jensen, Mette R. Geiker, Lisbeth M. Ottosen, Resources, Conservation and Recycling, Volume 145, June 2019.
[11] Effect of Wood-Ash as Partial Replacement to Cement on Performance of Concrete by- Kunamineni Vijay, Korrakuti Hari Babu, Yarlagadda Vidya Indrasena, Community Based Research and Innovations in Civil Engineering 2020.
[12] The Influence of Wood Ash on Different Cement Mortar Mixes by- Eethar T. Dawooda ,Alya'a A. Al-Attarb and Omar S. Zinad, 2nd International Conference on Materials Engineering & Science (IConMEAS 2019).
[13] The Present State of the Use of Waste Wood Ash as an Eco-Efficient Construction Material: A Review by- Rebeca Martínez-García, Advanced Engineering Cementitious Composites and Concrete Sustainability), 2022.
[14] A Review on Strength and Durability Properties of Wooden Ash Based Concrete by- Buthainah Nawaf AL-Kharabsheh, Mohamed MoafakArbili, Ali Majdi, Jawad Ahmad, Ahmed Farouk Deifalla and A. Hakamy, New Advances in Cement and Concrete Research 2022.
[15] Compressive Strength and Leaching Behavior of Mortars Using Cement and Wood Ash Gabriele Fava, Tarun R. Naik, Giacomo Moriconi, SCMT3, 2011.