"BEHAVIOR OF CONCRETE WITH INCORPORATION OF WOOD ASH AS PARTIAL REPLACEMENT OF CEMENT"

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Abstract: Wood ash is denouement from combustion of wood in various industries like thermal power generation plant, paper and pulp plants, boilers, bakeries etc. Wood being renewable resource for energy is widely being used from past times as a source for energy production and thus resulting in wood ash production. This study consists of incorporation of wood ash as partial replacement of cement in concrete. Uncontrolled burning of kikker wood (Kashmiri version of MESQUITE TREE) in baker's oven to form wood ash is used as partial replacement of cement in concrete thereby changing its behaviour. Wood ash is quite similar to fly ash and rise husk ash. In this study concrete mix M-30 is used as control specimen and replacement of cement with wood ash is done at 10%, 15%, 20%, and 25%. The behavior of concrete is observed in terms of workability, water absorption capacity, compressive strength and splitting tensile strength.

Key Words: Wood Ash (WA), Compressive strength, splitting tensile strength

I Introduction:

The brisk pace of urbanization drives the cement requirement to multiple folds in the past few decades. The rapid advancement in science and technology has initiated a global emphasis on sustainable, greener cleaner and environment friendly techniques and development in all fields. The quantum jump in production of cement results in release of alarming level of CO_2 into the atmosphere and has made it one of the main sources of pollution. So the challenge is to restrict and bring down the CO_2 levels. The need for sustainable development has given way for utilising waste and other industrial by-products in construction industry. Like Fly-Ash and Rice Husk Ash, Wood Ash has been found to have potential to be used in construction industry.

Wood ash concrete is a type of concrete that has wood ash blended as partial replacement for cement. On an average burning of wood, 6–10% of ash is produced by the weight of wood burnt and its composition can be highly variable depending on geographical location, type of wood and burning processes [1]. The most prevailing method for disposal of the ash is land filling which accounts for 70% of the ash generated, rest being either used as soil supplement (20%) or other miscellaneous jobs (10%) [2]. So utilization of such an industrial by product and agricultural waste ashes solves a greater problem of their disposal as well providing a viable alternative for cement substitutes in concrete[3].

Knowledge about wood ash in terms of its physical and chemical properties is important in order to utilise it of its benefits.

Researchers have conducted tests which showed promising results that wood ash can be suitably used to replace cement partially in concrete production [4][5]. Hence, incorporating wood in concrete is advantageous not only in the environmental point of view but also in producing low cost construction output, thus leading to a sustainable relationship. But a lot more is to be done by conducting the in depth study of the behaviour of the concrete in general and cement in particular so as to obtain the most optimum outcome.

II OBJECTIVES AND LIMITATIONS OF THE STUDY

Objectives: This study highlights the change in behavior of concrete with partial replacement of cement with wood ash at various percentages (ie.10%, 15%, 20% and 25%). The objectives are as under:

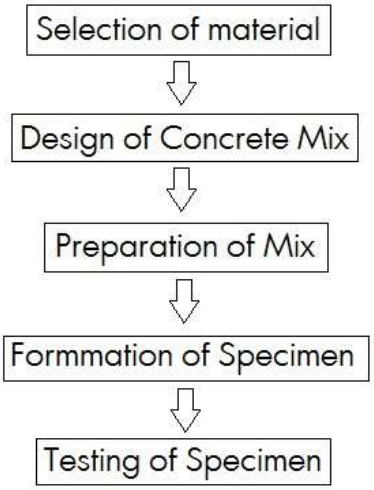
1) To study the effect on slump and thus workability of fresh concrete.
2) To do analysis of water absorption capacity.
3) To study the mechanical strength of concrete (compressive strength and tensile strength)
4) To compare above results and obtain the most optimum outcome.

Limitations:

- The wood ash is of varied quality as the wood was burned in uncontrolled manner.
- There is difference between the grain size of cement and wood ash this likely may not give precise results.
- The quality and properties of wood ash also depend upon type of wood source, geographical location etc.

III GENERAL METHODOLOGY

The general methodology followed in this study is illustrated in following flow chart below:



Flow chart 1 Showing General Methodology

IV Material used and experimental method:

1) Materials:

The materials used during the course of analysis have been tabulated below along with their properties and source [6]:

Table 1 Showing Materials Used and Their Properties

S.No:	Name of Ingredient	Type Used	Specific Gravity	Source
1	Cement	Ordinary Portland Cement of 43 GRADE	3.15	Ultratech OPC

2	Sand	Sand of Zone II	2.65	Baramullah J&K
3	Coarse Aggregate CA	CA 10 mm	2.71	Lassipora J&K
4		CA 20 mm	2.72	Lassipora J&K
5	Wood Ash WA	Wood Ash was made available from a bakery manufacturing unit (Shalimar Bakers) in Srinagar, J&K by uncontrolled burning of Kikker wood.		
6	Water	Regular tap water available was used.		

2) Method:

2.1 Selection of mix Proportion: The Concrete mix M30 was selected for the study. The target compressive strength and other parameters for M30 were calculated in accordance to IS: 10262 2009.

STEPS INVOLVED IN DESIGN OF CONCRETE M30 AS PER IS-10262-2009 [7] **AND IS-456-2000** [8] **ARE AS UNDER:**

A) CALCULATION OF TARGET MEN STRENGTH:

[Target Mean Strength = Characteristic Strength + 1.6 x Standard Deviation]*

Target Mean Strength = 30 + 1.6 x 5 = 38.25 Mpa

B) SELECTION OF WATER-CEMENT RATIO:

- W/C = 0.45 (Max)
- Minimum Cement = 360 Kg/cum

C) SELECTION OF WATER CONTENT:

Maximum water content = 186 litre (for 25to50 mm slump range)
For 20mm aggregate

Estimated water content for 100mm slump = 186 + 6/100 x 186 = 197litre.

D) CALCULATION OF CEMENT CONTENT:

Water-Cement Ratio = 0.45
Cement content = 197/0.45 = 438 Kg/m^3 (438 Kg/m^3 > 360 Kg/m^3) hence OK

E) PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:

Now from code book volume of coarse aggregate with regard to the 20mm size aggregate and the fine aggregate (of zone II) = 0.62 for W/C of 0.5

So, 0.5 – 0.45 = 0.05

As W/C of 0.5 is lowered by 0.05 the volume of coarse aggregate is increased by 0.01

Therefore corrected proportion of volume of coarse aggregate for W/C of 0.45= 0.62 + 0.01 = 0.63 i.e., says 63%

Which means volume of fine aggregate will be = 1 – 0.63 = 0.37 i.e., 37%

F) MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows:

i) Volume of concrete = $1m^3$

ii) Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

$= \frac{438}{3.15} \times \frac{1}{1000} = 0.139\ m^3$

iii) Volume of water = $\frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$

$= \frac{197}{1} \times \frac{1}{1000} = 0.197\ m^3$

iv) Volume of all in aggregate = [i – (ii + iii)]
= [1 – (0.139 + 0.197)]
= [1 – 0.336]
= 0.664 m^3 mm^2

v) Mass of coarse aggregate = [iv x volume of coarse aggregate x sp. gravity Of coarse aggregate x 1000]
= [0.664 x 0.63 x 2.7 x 1000]
= 1129 Kg

vi) Mass of fine aggregate = [iv x volume of fine aggregate x sp. gravity of Fine aggregate x 1000]
= [0.664 x 0.37 x 2.7 x 1000]
= 663 Kg

G) MIX PRAPORTION FOR CONTROL SPECIMEN AT 0% OF WA

Table 2 Showing Mix Proportion for control Specimen

MATERIAL	QUANTITY
Cement	438 Kg
Water	197 litre
20mm	677 Kg
10mm	452 Kg
Sand	663Kg

H) MIX PROPORTION FOR SPECIMEN AT 10%, 15%, 20% AND 25% OF WA

Table 3 Showing Mix Proportion At Various percentages of Wood Ash

MATERIAL	QUANTITY IN Kg AT			
	10%WA	15%WA	20%WA	25%WA
Cement	394.2	372.3	350.4	328.5
Wood Ash	43.8	65.7	87.6	109.5
20mm	677			
10mm	452			
Sand	663			
water	197			

2.2 PREPARATION OF MIX AND CASTING OF CUBES

Firstly control specimen was prepared with its respective proportion. Moisture correction was also done and water content for water-cement ratio of 4.5 was adjusted accordingly. The mix was checked for workability. The control specimen was casted for 7, 28 and 56 days. Similarly mix was prepared for 10%, 15%, 20% and 25% of wood Ash (WA).

The cubes of 150mm x 150mm x 150mm were casted to check compressive strength and cylinder specimen were casted to check split tensile strength.

2.3 CURING AND TESTING OF BLOCKS

The casted blocks were cured after 24hrs in the curing tank. The compressive strength and tensile strength was checked after 7, 28 and 56 days of curing.

V RESULTS AND DISCUSSION

1) Slump Value: The slump value was evaluated and thus workability of freshly mixed concrete was checked using slump cone test. The evaluation was done following IS 1199-1959 standards and procedures [9] at various percentages of Wood Ash. The slump values recorded are tabulated below:

Table 4 Showing slum Values at Various Percentages of Wood Ash

Wood Ash %age	0%	10%	15%	20%	25%
Slump in mm	76	54	36	17	8

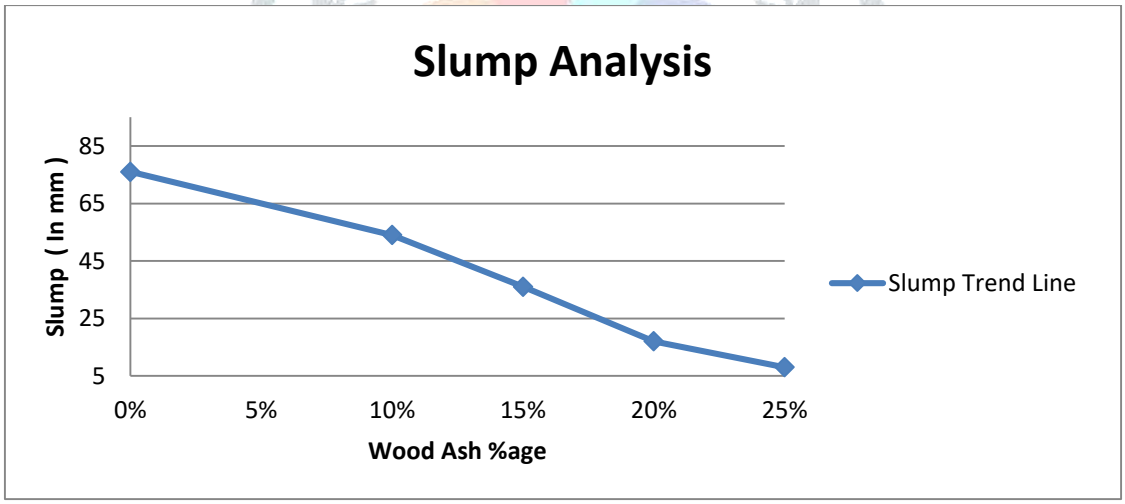


Figure 1 Graphical Illustration of Slum at Various Percentages of WA

The observations drawn from above results are as under:

- It was recorded that slump declined with increase in wood ash content (figure 1).
- The slump for controlled specimen was 76 mm later with addition of wood ash at 10%to25% the slum was found further declining from 54 mm to 8 mm.
- The decrease in slump may be attributed to high organic content of ash [10].

2) Water Absorption Capacity: In order to determine water absorption capacity of concrete blocks, dry weight of blocks was first recorded after de-moulding and later wet weight of same blocks was noted after submerging them for 24hrs. The water absorption was determined using following formula:

$$\%\text{age of Water Absorbed} = \frac{\text{AVG. WET WEIGHT} - \text{AVG .DRY WEIGHT}}{\text{AVG. DRY WEIGHT}} X100$$

The water absorption capacity of specimen is given in table 5:

Table 5 Showing Percentage of Water Absorbed By Specimen

Percentage of Wood Ash	Avg. Dry Wt. of cube (gm)	Avg. Wet Wt. of cube (gm)	Percentage of Water Absorbed
0%	8163	8198	0.43%
10%	8143	8193	0.62%
15%	8210	8272	0.76%
20%	8138	8213	0.92%
25%	8096	8182	1.06%

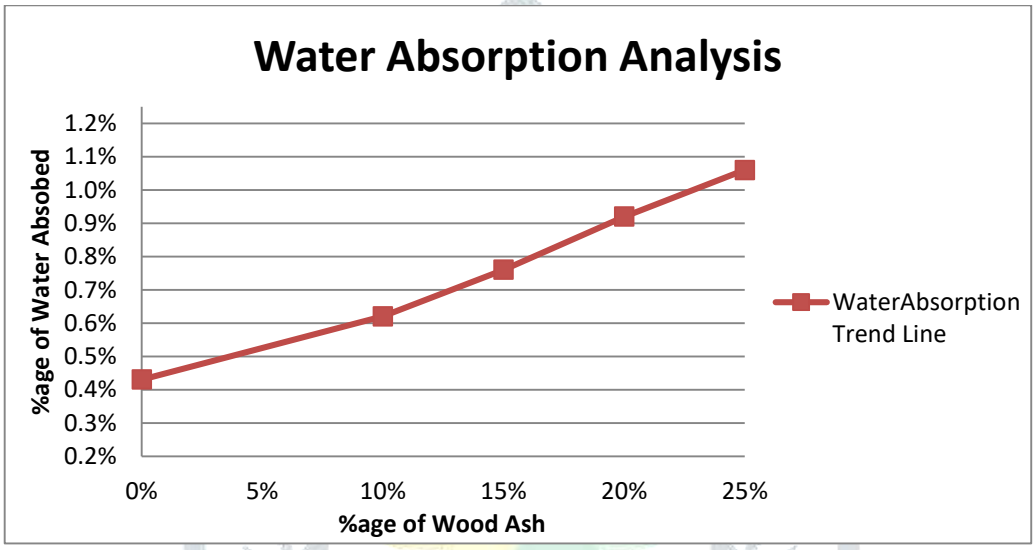


Figure 2 Graphical Illustration of Water Absorption at Various Percentages of WA

The observations drawn from above results are as under:

- From the above records and illustration in figure 2 it is evident that with increase in wood ash content to the control mix the water absorption capacity also increased
- The water absorption capacity of control mix was 0.43% and with addition of wood ash the water absorption to 0.62% at 5%WA to 1.06% at 25%WA.
- The determined values are far below accepted 10% in concreting [10]

3) Compressive Strength: The compressive strength of control mix and wood ash concrete (WAC) was checked after 7, 28 and 56 days of curing using Digitalized Compressive Testing Machine (CTM). The results of same have been tabulated below:

Table 6 Showing Compressive Strength at Various Percentages of Wood Ash

PERCENTAGE OF WOOD ASH ADDED	COMPRESSIVE STRENGTH In N/mm^2 AFTER		
	7 DAYS	28 DAYS	56 DAYS
0%	25.68	39.32	41.92
10%	24.15	34.12	38.01
15%	23.02	33.93	34.29

20%	22.21	32.23	33.27
25%	21.97	30.98	31.94

The observations drawn from above results are as under:

- The Compressive strength after 28 days of curing for control specimen was 39.32 N/mm^2 and that of wood ash concrete at 10%, 15%, 20% and 25% of wood ash was 34.12 N/mm^2,33.93 N/mm^2 ,32.23 N/mm^2 , 30.98 N/mm^2 respectively
- It is observed from figure 3 that wood ash concrete with increase in wood ash content show declining trend in compressive strength when compared to the control mix. Although wood ash concrete gains strength but not at par with the control mix.
- Also it is evident from the analysis that in later ages i.e. 56 days in this study, there is further prominent increase in compressive strength upto desirable level but only upto 20% WA with maximum strength of 38.09 N/mm^2 at 10% .
- This strength gain at later ages may be attributed to the pozollanic nature of wood ash [10].
- The characteristic compressive strength was easily achieved upto 20% Wood Ash content.

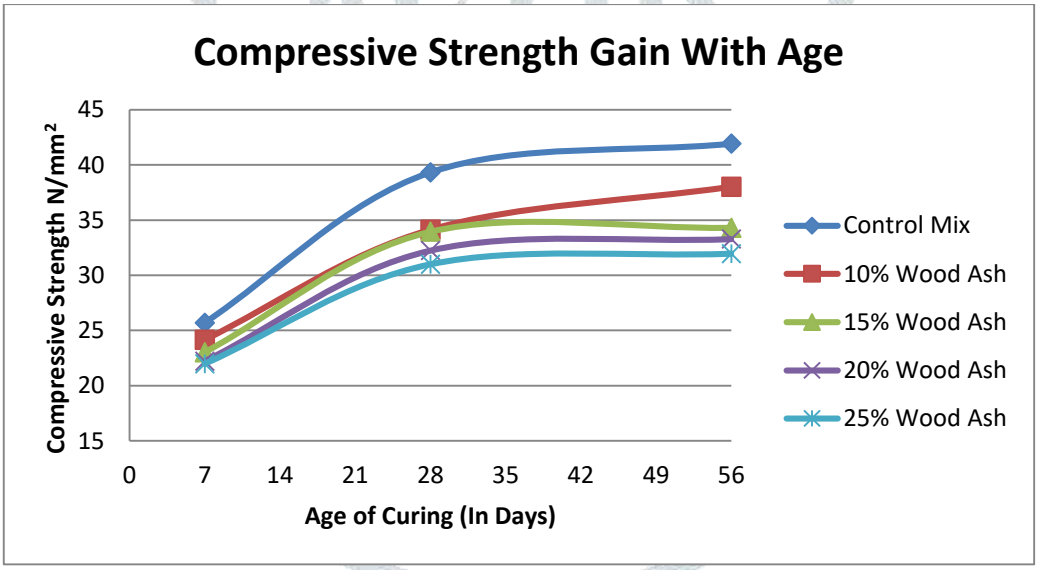


Figure 3 Graphical Illustration of Compressive Strength at Various Percentages of WA

4) Splitting Tensile Strength: The split tensile strength of the specimen was determined following the guidelines as per IS 5816-1999[11]. The outcomes are recorded are shown in table 7.

Formula used:

Splitting tensile strength = $\frac{2P}{\pi x D X L}$

Where, P =Compressive load at failure, L= Length of cylinder and D= Diameter of cylinder

Table 7 Showing Splitting Tensile Strength at Various Percentages of Wood Ash

PERCENTAGE OF WOOD ASH ADDED	SPLIT TENSILE STRENGTH In N/mm^2 AFTER		
	7 DAYS	28 DAYS	56 DAYS
0%	2.54	3.89	4.15
10%	2.48	3.57	3.91

15%	2.41	3.42	3.83
20%	2.29	3.37	3.68
25%	2.18	3.26	3.47

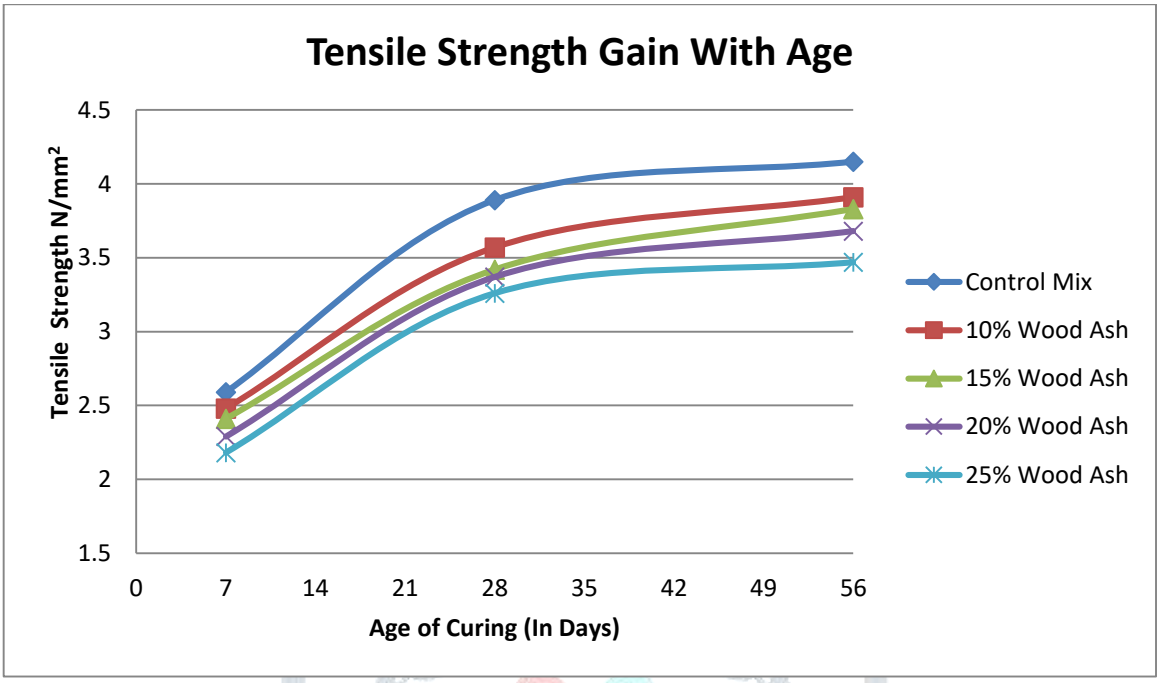


Figure 4 Graphical Illustration of Splitting Tensile Strength at Various Percentages of WA

The observations drawn from above results are as under:

- The splitting tensile strength after 28 days of curing for control specimen was 3.89 N/mm^2 and that of wood ash concrete at 10%, 15%, 20% and 25% of wood ash was 3.57 N/mm^2, 3.42 N/mm^2 , 3.37 N/mm^2 , 3.26 N/mm^2 respectively
- It is evident from the above illustration that the trend lines for splitting tensile strength are mostly similar to that of compressive strength.
- So there is decrease in splitting tensile strength with increase in wood ash content

VI CONCLUSION AND FUTURE SCOPE

Conclusion: This study emphasis the need for sustainable means of development and thus exploring the attainability and conceivability of using Wood Ash as partial replacement of cement in concrete. Some important conclusions drawn from the study are as under:

- The properties of wood ash is dependent on many factors like mode of burning wood, temperature at the time of burning, source and type of wood burnt etc. This may alter the desired outcomes.
- There in difference in grain size of wood ash and cement this may again alter the desired outcomes.
- It was concluded that with increase in wood ash content the slump of freshly mixed concrete decreased thus decreasing workability.
- Incorporation of wood ash as partial replacement of cement in concrete increased the water absorption capacity of concrete cubes.

- There was decrease in compressive strength and splitting tensile strength of concrete specimen with increase in wood ash content but in later ages the strength gain showed positive trend upto 20% replacement at 56th day. This may be attributed to pozollanic reactions that may be active.

Future Scope: Many studies have been done in order to check the possibility of Wood Ash as a partial replacement material to cement but a lot more needs to be done to attain this goal. The limitations in the present study like varied wood ash properties, difference in grain size of wood ash and cement, uncontrolled means of achieving wood ash needs to be eliminated in order to get more precise results. Also the wood ash being of pozollanic nature has possibility of giving positive results and becoming a sustainable material for construction industry.

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