A BRIEF STUDY ON THE STRENGTH PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH WOOD ASH & NATURAL SAND WITH 100% CRUSHED STONE SAND

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Abstract

Concrete is a construction material composed of portland cement and water combined with sand, gravel, crushed stone or other inert material like slag.Wood ash is a byproduct produced from the thermal power plants and many industries. It is causing many environmental problems. Several researches had been carried out to incorporate wood ash as a cement replacing material in the production of greener concentrate material and also as a sustainable means of disposable wood ash. Results of the researches have indicated that the wood ash can be effectively used as a cement replacement material for the production of the structural grade concrete of acceptable strength and durability properties.

In this research initial, an attempt has been made to use wood ash as a replacement to cement in varying percentage sand natural sand is replaced with 100% crusher stone sand. The materials used in this work were powdered wood ash sourced locally from a bakery in Anathapuramu. The wood ash was passed through IS SIEVE 90 micron size.

The study presents the behavior of wood ash replaced concrete. Analysis of wood ash, sieve analysis and specific gravity of wood ash and aggregate were conducted. A M_{20} grade mix concrete is proposed with mix proportions of 1:1.45:3.19 with water cement ratio of 0.50. Wood ash replacement is done in 0, 5, 10, 15, 20 and 25% to cement and in place of natural fine aggregate crushed stone sand has been used in the present study. 150×150×150 mm cubes and 150 mm diameter and 300mm height cylinders were cast and tested to determine the cube compressive strength and split tensile strength at 7 and 28 days curing periods respectively.Since wood ash indicates slightly pozzolanic, water demand increases as the ash content increases and the setting time of the paste increases as the ash content increases. It may be seen from this research initial that the optimum percentage replacement of cement by wood ash may be considered as 10%.

Keywords: *Wood Ash, Pozzolan, Crushed Stone Sand*

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1. INTRODUCTION

Concrete is the versatile construction material that is widely used in structural works. Infrastructural development around the world created demand for construction material. It is a composite material comprising cement aggregate, water and admixtures. However the current concrete construction practice is considered unsustainable because it consumes huge quantities of stone, sand drinking water and cement. The essential part of concrete is of course aggregate. Cement which is being produced at enormous quantities to satisfy the ever increasing demand for concrete has a huge environmental impact. Cement production is not only energy consuming , is also responsible for a considerable part of manmade carbon dioxide emission which , along with other green house gases lead to global warming . From this point of view, cement is not a environmental- friendly material. So it should be industry's top priority to reduce energy consumption and emissions to the air during concrete manufacture. Approximately 62% of all carbon dioxide emission originates in the calcination process and the remaining 38% is related to fuel combustion. Because of the consumption of natural resources like lime stone etc, we cannot go on producing more and more cement. There is a need to economize the use of cement. One of the practical solution is to optimize the use of cement is by replacing cement with pozzolanic waste material like wood ash.

2. WOOD ASH

Wood ash is the residue remaining after the combustion of wood and wood products (chips, saw dust, etc.) Wood and wood products are generally used for energy production at pulp and paper mills, saw mills and wood-product manufacturing facilities or for heat generation. On the average, the burning of wood results in about 6-10% of ash. When ash is produced in combustion systems, the temperature of combustion and cleanliness of the fuel wood, the collection location and the process can also have profound effects on the nature of the ash material. As a

result of the oxidation process during combustion the generated wood ash retains the overall composition of the mineral nutrients contained in the waste wood with the exception of nitrogen compounds, which are mainly released in the gas phase.

3. MATERIALS

3.1 Cement

Ordinary Portland Cement (OPC) of 53 grade Coramandal brand conforming to ISI standards has been procured and various tests have been carried out according to IS 8112-1989. From them it is found that

- Specific gravity of cement is 3.15
- Initial and final setting times of cement are 36 minutes and 580 minutes respectively.
- Fineness of cement is 7%.

3.2 Wood Ash

Wood ash has been collected from different bakeries. The collected wood ash is cleaned and sieved through 90 microns sieve. Various tests have been conducted on wood ash and following results are found out,

- Specific gravity of wood ash is 2.56
- Bulk density of wood ash is 1400-1700 kg/m^3.

3.3 Fine Aggregate

Crushed stone sand from the nearby quarry is used as fine aggregate in this project and is found to be conformed to Zone-3 of table 4 of IS: 383-1970. The specific gravity of crushed stone sand is 2.64.

3.4 Coarse Aggregate

Machine crushed granite aggregate conforming to IS: 383-1970 consisting of 20mm maximum size of aggregates has been used in the present work. It has been tested for physical and mechanical properties. The results are as follows.
Specific Gravity of coarse aggregate is 2.67
Water absorption of coarse aggregate is 0.5%

3.5 Water

Potable water available in the laboratory is used for the purpose of mixing and curing of concrete.

4. MIX DESIGN OF CONCRETE

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the objective of producing concrete of certain minimum strength and durability as economically as possible.

The design of concrete mix is not a simple task on account of widely varying properties of the constituent materials, the condition that prevail at the work and the condition that are present.

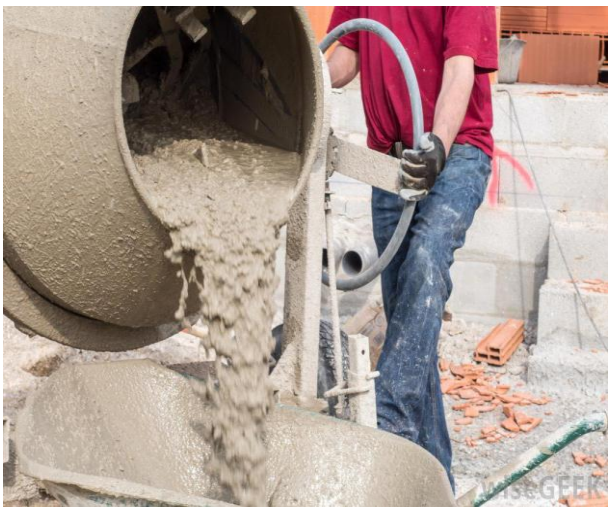
Design of concrete mix requires complete knowledge of various properties of the constituent materials, the complications, in case of changes on these conditions at the site. The design of concrete mix needs not only the knowledge of material properties of concrete in plastic condition, but also needs wider knowledge and experience of concreting. Even then, the proportion of the materials of the concrete found out at the laboratory requires modifications and readjustments to suit the field conditions.
In the present investigation M_{20} grade of concrete is considered. The mix of concrete is designed as per the guidelines given in IS 10262; the mix proportions are 1:1.45:3.19with water cement ratio 0.50.

5. EXPERIMENTAL INVESTIGATION

In the present experimental investigation cement is partially replaced by wood ash in varying percentages of 0%, 5%, 10%, 15%, 20% & 25%. Crushed atone sand completely replaces the natural sand. A total of 6 mixes has been planned with above variations to study the fresh properties of concrete such as density and slump. Hardened properties of concrete studied are the cube compressive strength and split tensile strength. A total of 72 specimens were cast out of which 36 were cubes of 150mm×150mm×150mm× and remaining 36 were cylinders of 150mm ø and 300mm height. An average of 3 specimens were taken to present the 7 days and 28 days strength of various concrete mix with 100% crushed stone sand.

5.1 Mixing of Concrete

Initially the ingredients cement and sand are mixed, to which wood ash is added and the mixture is thoroughly mixed. After some time, coarse aggregate are added and thoroughly mixed. Water is measured exactly, then it is added to the dry mix and it is thoroughly mixed until a mixture of uniform color and consistency is achieved which is then ready for casting. Prior to casting of specimens, workability is measured in accordance with the code IS: 1199-1959 and determined by slump and compaction factor tests. The mixing equipment is presented in plate below.



A view of the mixing of concrete

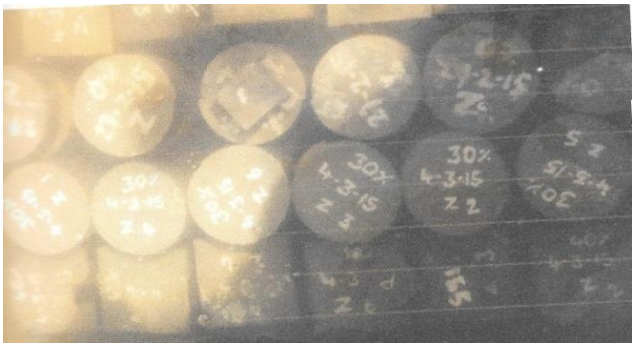
5.2 Casting of Specimens

After the completion of workability tests, the concrete is placed in the standard metallic moulds in three layers and has been compacted each time by tamping rod. Before placing the concrete inside faces of the mould are coated with the machine oil for easy removal afterwards. The concrete in moulds have been vibrated for 30 seconds using the table vibrator and the surfaces of the specimens have been finished smoothly. The cast specimens are shown in plate.

A view of cast cubes& cylinders

5.3 Curing Procedure

After the casting of the specimens, the moulds are kept for air curing for one day and the specimens are removed from the moulds after 24 hours of casting. Marking has been done on the specimens to identify the percentage of wood ash replaced. Then they are placed in water tank for curing. All the specimens have been cured for desired age. Specimens in curing tank are shown in plate.



A view of specimens in curing tank

Details of Tests Conducted

- Cube compressive strength of concrete.
- Cylindrical split tensile strength of concrete.

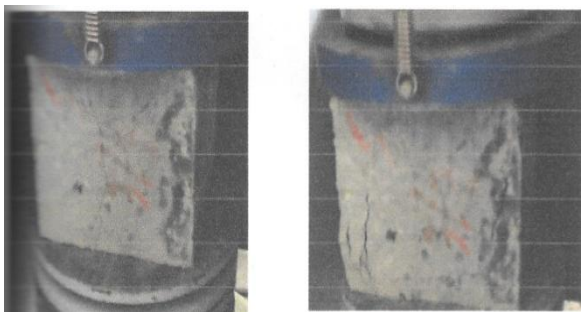
5.4 Testing of Cubes for Compressive Strength

Concrete cubes of sizes 150mm X 150mm X 150mm were tested for crushing strength. Compression test is done in a compression testing machine confirming to IS: 516-1959. All the concrete specimens were tested in a 2000 KN capacity Compression Testing Machine (CTM). The experimental arrangement is shown in plate. Crushing strength of concrete was determined by applying load at the rate of 140 kg/sq.cm/min till the specimen fails. The maximum load applied on the specimen was recorded. The test set-up for cube compressive strength of concrete is presented in figure below. Crushing strength is the ratio of failure load to the area of cross section of specimen.

The cube compressive strength can be calculated as follows:
If f_c is the cube compressive strength, then

$$f_c = P/A \text{ N/mm}^2$$

where, P= Ultimate Load in N,
A= Cross Sectional Area of the cube in mm^2



VIEW OF COMPRESSION TESTING OF CUBE

5.5 Testing Of Cylinders for Split Tensile Strength

Split tensile strength test was conducted on cylinders of 150mm X 300mm diameter and height. The test specimens were placed between two platens with two pieces of 3mm thick and approximately 25mm wide plywood strips on the top and bottom of the specimens.

The split tensile strength test was conducted in the same machine on which the compressive strength test was performed. The specimens were tested for 7 and 28 days. This test is conducted in a 2000KN capacity Compression Testing Machine by placing the cylinder specimen, so that its axis is horizontal to the plates of the test machine. Narrow strips of packing materials i.e., plywood is placed between the plates and the cylinder to receive compressive stress. The load was applied uniformly at a constant rate until failure by splitting along the vertical axis takes place. Load at which the specimens failed is recorded and the split tensile stress is obtained using the formula based on IS: 5816-1970. The splitting of cylinder is shown in plate below.

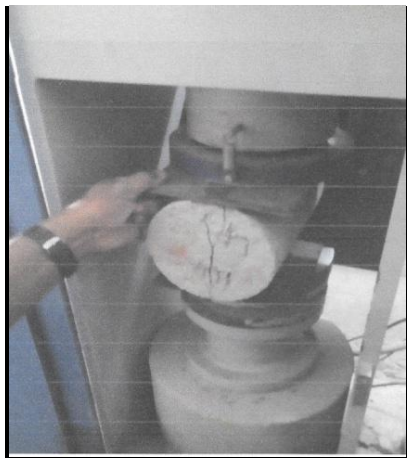
The following formula is used to find out the Split tensile strength of cylinder

$$f_t = 2P / \pi DL$$

Where
P = Compressive load on the cylinder in Newton
L = Length of the cylinder in mm
D = Diameter of the cylinder in mm

The results have been tabulated and graphical variations have been studied.

View of failure of cylindrical specimen



View of failure of cylindrical specimen at 28 days

The identification of the specimens is as follows:

1. M_1 refers to nominal mix without replacement of wood ash
2. M_2 refers to 5% replacement of cement with wood ash
3. M_3 refers to 10% replacement of cement with wood ash
4. M_4 refers to 15% replacement of cement with wood ash
5. M_5 refers to 20% replacement of cement with wood ash
6. M_6 refers to 25% replacement of cement with wood ash

- Keeping fine aggregate and coarse aggregate and water cement ratio constant for all mixes.

6. RESULTS AND DISCUSSIONS

6.1 Density

The density of concrete for conventional mix is 2435.56 kg/m^3. Densities of concrete for the rest of the mixes were found to be less when compared to the conventional mix. For all the other wood ash replacements, the density of fresh concrete is found to decrease. This decrease of density of concrete may be attributed to the lower specific gravity of wood ash. The density variation of various mixes has been as presented in the table1 and fig.1.

Table 1: Density of Concrete for various mixes

S.NO	MIX	WEIGHT OF CUBE (kg)	DENSITY (kg/m3)	% OF INCREASE / DECREASE DENSITY
1	M1	8.22	2435.56	-------
2	M2	8.20	2429.63	-0.24
3	M3	8.14	2420.48	-0.61
4	M4	8.16	2417.78	-0.73
5	M5	8.12	2405.93	-1.22
6	M6	8.06	2388.15	-1.95

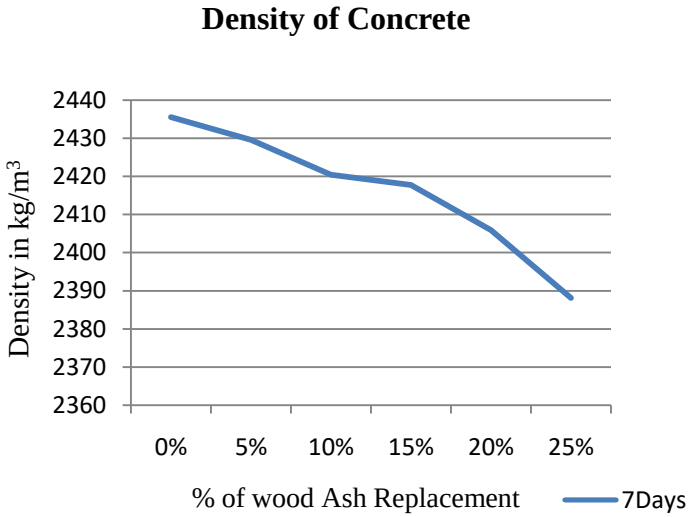


Fig. 1: Variation of density Vs % replacement of wood ash

6.2 Slump Cone Test

For various mixes, slump values of concrete was measured and are tabulated in the table 2. It is observed that for 5% mix the value was found to be increased compared to the other mixes and it was represented graphically in the figure 2.

From the table and fig. it may be seen that with 5% replacement of wood ash, there is slight increase in the slump value. With further increase in wood ash percentage, the slump was higher than control mix. For 25% wood ash mix the sump was as that of control mix.

Table 2: Slump values for various mixes

S.NO	MIX	% WOOD ASH	LOSS OF SLUMP (cm)
1	M1	0	3.0
2	M2	5	3.5
3	M3	10	3.4
4	M4	15	3.3
5	M5	20	3.2
6	M6	25	3.0

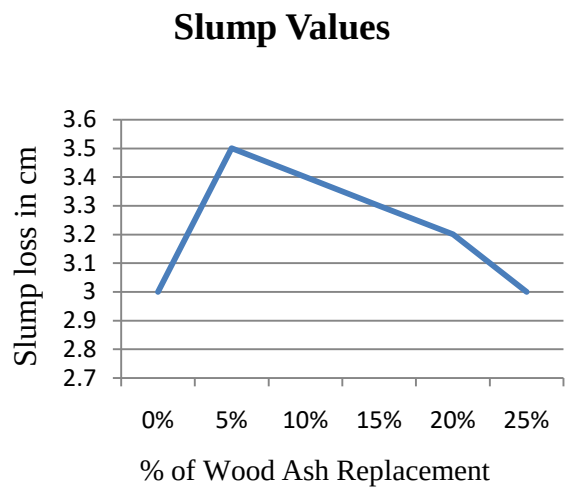


Fig 2: Variation of slump values Vs % replacement of wood ash

7. CUBE COMPRESSIVE STRENGTH

The 7 days and 28 days cube compressive test results with crushed stone sand and with various percentage replacement of cement by wood ash are presented in table 3. The graphical variations of compressive strength versus percentage replacements of cement with wood ash are represented in figure 3. From the table and figure it may be observed that there is decrement in cube compressive strength as the percentage of wood ash increases in concrete. The cube compressive strength at 7 days was found to be decreased with the increase in the percentages of replacement of cement with wood ash whereas 10% replacement of cement with wood ash gave strength of 23.36 N/mm^2 which is higher compared to other percentage replacements along with the conventional mix whose strength is 19.40 N/mm^2.

The cube compressive strength at 28 days was found to be decreased with increase in the percentages of replacement of cement with wood ash whereas 10% replacement of cement with wood ash gave strength of 41.77 N/mm^2 which is higher compared to other percentage replacement along with the conventional mix whose strength is 38.07 N/mm^2.

However, it may be observed that with 10% replacement of cement with wood ash at 7 days and 28 days cube compressive strength is found to be increased than the other mixes along with the conventional concrete when the mix is 10% replacement with wood ash compared to conventional concrete. Also it may be observed that the usage of 100% crushed stone sand and 25% wood ash replacement gave a 28days cube compressive strength of 27.40N/mm^2 which is slightly greater than the target mean strength.

Table 3

COMPRESSIVE STRENGTH DETAILS OF SPECIMENS IN N/mm^2		
% of Wood Ash	**7 Days**	**28 Days**
0%	19.40	38.07
5%	18.22	36.29
10%	22.36	41.77
15%	17.04	34.51
20%	16.44	32.15
25%	15.26	27.40

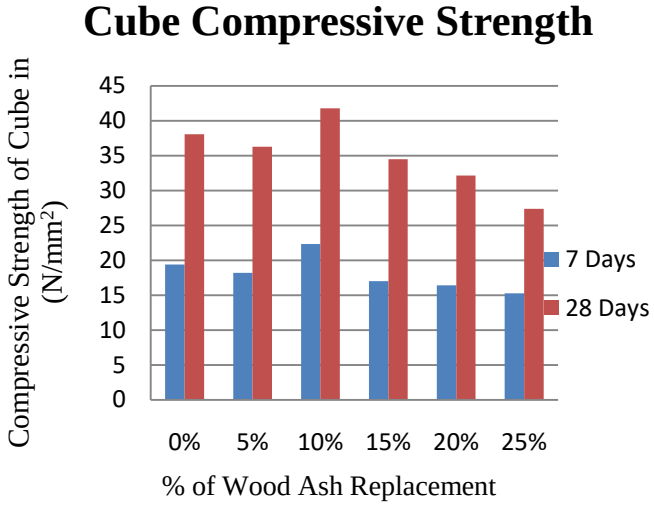


Fig 3: Variation of cube compressive strength Vs % replacement of wood ash

8. SPLIT TENSILE STRENGTH

The 7 days and 28 days split tensile strength test results with natural sand being completed replaced by crusher stone sand and with various percentage replacement of cement by wood ash are presented in table 4. The graphical variation of split tensile strength versus percentage replacement of cement with wood ash are represented in figure 4. From above table and figure it may be observed that there is decrement in split tensile strength with 0% to 25% replacement of cement with wood ash in concrete.

The split tensile strength at 7 days was found to be decreased with increase in the percentages of replacement of cement by wood ash whereas 10% replacement of cement with wood ash has given a strength of 2.17 N/mm^2 which is higher compared to other percentage replacements.

The split tensile strength at 28 days have been found to be decreased with the increase in the percentages of replacement of cement with wood ash whereas 10% replacement of cement with wood ash gave strength of 3.09 N/mm^2 which is slightly higher compared to other percentage replacements along with the conventional mix whose strength is found to be 2.85 N/mm^2.

Table 4

SPLIT TENSILE STRENGTH DETAILS OF SPECIMENS IN N/mm^2		
% of Wood Ash	**7 Days**	**28Days**
0%	2.24	2.85
5%	2.02	2.94
10%	2.17	3.09
15%	1.99	2.45
20%	1.81	2.17
25%	1.72	1.89

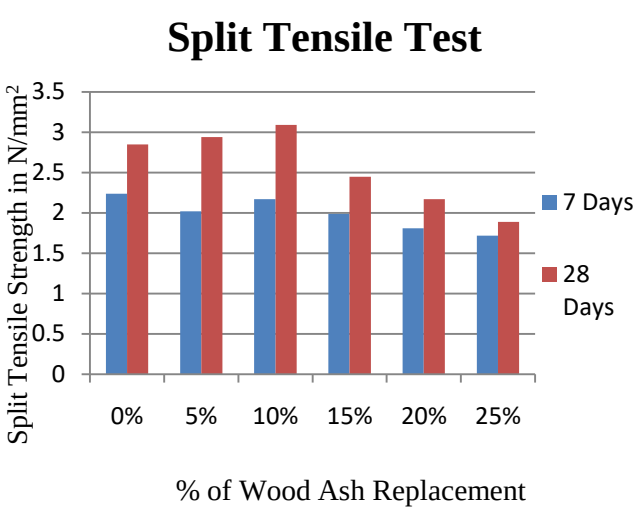


Fig 4: Variation of Split tensile strength Vs % Replacement of wood ash

9. CONCLUSION

- The use of wood ash as a partial replacement of cement provides us an alternative source to use the waste into a useful material. Also the attempt to use the plentily available crushed stone sand is found to obtain good results.
- The density of various mixes of the concrete has decreased when compared to the conventional mix. This is because of replacement of cement with wood ash, as the specific gravity of wood ash is less than cement.
- The slump value for conventional concrete with constant water cement ratio of 0.5 is 30mm but it has been increased due to the absorption of water by wood ash.
- Workability problems arises with this replacement mix.
- The cube compressive strength and split tensile strength of the mixes has decreased when compared to conventional mix.
- Here target mean strength is achieved for 10% replacement of cement with wood ash as the cube compressive strength is increased by 15.26% at 7days and 9.72% at 28 days.
- With 10% replacement of cement with wood ash the splittensile strength is increased by 8.42% at 28 days.

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