AN EXPERIMENTAL INVESTIGATION OF CONCRETE BY USING PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH ASH AND WASTE CEMENT PELLETS

A.Ganeshkumar[1], S.Bharath[2], A.Kalidoss[3], R.Kaushik[4], K.Vignesh[5]

[1]Assistant Professor, [2,3,4,5]UG Scholar
Department of Civil Engineering, Sri Ramakrishna College Engineering
Perambalur-621 113.

***Abstract*: For construction, one of the most important materials is concrete. Concrete is preferred because of its Low cost, High strength, Thermal & fire resistance, Availability, Durability, Diversity etc.To check the compressive and flexure strength, concrete cubes reinforced with Wood Ash pellets have been tested by changing the percentage. The cement and wood ash proportions of 25:75, 27.5:72.5, 30:70, 32.5:67.5 and 35:65 were tried with a suitable water cement ratio 0.4 to get the ash aggregates .Aggregate is most widely used in reinforced concrete construction. Wood ash is generated as residual from combustion done in boilers at pulp and paper mill, since wood is a renewable resource for energy and an environmentally friendly material. There is an increased requirement of using waste wood for the purpose of energy production thus leading to formation of more wood ash waste. Uncontrolled burning of saw dust to form wood ash is used as a partial replacement of aggregate, thereby changing its physical and chemical properties. In this project, artificial wood ash aggregates were used in concrete and its effect on strength of concrete was studied. The particle size distribution, specific gravity, bulk density and impact test on aggregate were conducted. The conventional and artificial ash aggregates concrete cubes, cylinders and beam specimens were cast. All the specimens were cured in curing tank. Compressive and Extramural strength tests were conducted on these normal and artificial ash aggregates concrete specimens. The results were tabulated. Based on the results obtained, conclusions and suggestions were made Usually M20 concrete is used for most of the constructional works, hence in this project M20 concrete is taken.**

Index terms: Wood Ash, Waste Cement, Compressive, Flexural Strength and Split tensile strength

1. INTRODUCTION

Apart from historical evidences about demand of renewable energy in the present mode missing world, in the era of urbanization now the demand for renewable energy resources have further increased. A part these resources is made by biomass resources including forestry and agricultural wastes. Forestry and agricultural biomass are considered as efficient and favourable sources of fuel for energy production as their availability is in abundance and are cheap. In the current period of energy production, power plants which run from biomass have low operational cost and have continuous supply of renewable fuel. The wastes generated from the biomass industries like sawdust, wood chips, wood bark, and hard chips can be used as fuel offer a better way for their safe and efficient disposal. The true residual solid wastes of these agricultural components are produced by thermal incineration which is environmentally safe and much economic. These wood ash wastes can be obtained in abundance from industries which require wood as their fuel for operating their boiler units. The technologies available for production of wood ash in bulk are the fluidized bed and grate furnaces. In grate furnaces biomass wastes are incinerated under high temperatures resulting in vitalization of organic complex compounds.

1.1 MATERIALS USED

The following materials were used for preparing the test specimens

i. Ordinary Portland cement 43grade confirming to IS:8112-1989
ii. Wood ash
iii. Water
iv. Coarse aggregate
v. Fine aggregate: M-SAND

1.2 WOOD ASH

Wood ash is the powdery residue remaining after the combustion of wood,such as burning wood in a fireplace,on fire, 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. wood ash was made available from wood furnishing factory Phagwara Punjab. The wood ash was obtained by incineration of carpentry was together agricultural wastes like rotten wood.

1.3 ADVANTAGES OF ASH

Ash contains phosphorus, potassium, calcium, boron and other elements that growing plants need to be healthy and strong. Ash is very alkaline and raises pH levels.

1.4 COMPOSITION OF ASH

Conducted regarding the chemical composition of wood ash, with widely varying results. Calcium carbonate ($CaCO_3$) is the major constituent at temperatures below 750°C (small fire place). At temperatures above 750°C (big furnance) calcium oxide (CaO) is the major constituent.

1.5 OBJECTIVES OF THE PROJECT

The objectives of this study are as listed below:

- To study the properties of wood ash
- To study the Compressive strength.
- To study the Extramural strength.
- To study the split tensile strength

1.6 SCOPE OF WORK

Scope of this work is to provide more economic and efficient concrete for the construction. The waste wood ash from the thermal power plant and industries can be converted in useful manner. To reduce the quantity of cement in concrete to minimize the greenhouse gases producing from cement manufacturing industries. This study conducted to evaluate the performance of concrete in corporation of wood ash as partial replacement in concrete. It will provide an economic and environmental safe construction.

2. REVIEW OF LITERATURE

Pranav S.Dhakulkar et. Al studied the properties of concrete with cement replaced with Wood Ash .The Wood Ash has been chemically and physically characterized and partially replaced in the ratio of 5%,10%, 15%, 20% and 25% by weight of cement concrete. The experiment was carried out by using M25 mix with 0.5water cement ratio. The incorporation of wood ash as partial replacement of cement decreases the slump of concrete. Workability of the concrete is decreases with increase in wood ash content. The strength properties such as compressive strength, split tensile strength and flexural strength at the age of 7, 14, 28 days are evaluated and studied. The test result indicates that the strength of concrete increase up to 15% of Wood Ash replacement with cement. [1]

Amrutha Sebastian et.al studied the mechanical properties of Wood Ash concrete replaced in the ratios3%, 5% and 8% by weight of Portland Pozzolanic cement (PPC).The strength properties such as compressive strength, split tensile strength and flexural strength at the age of 7 and 28 days are evaluated and studied. The 7^{th}day compressive strength of all three percentages satisfied the requirement.3%and5% replacement of Wood Ash by weight of cement satisfied all the strength requirement.But,5% replacement is more economic. The workability is found to decrease with increase the Wood Ash content. The Wood Ash is pozzolanic in nature. So, it used as partial replacement with cement. [2]

Barathan et.al in this study investigated the replacement of cement with Wood Ash. They partially replaced the cement with wood ash in the ratios 10%,20% and 30% by weight of Ordinary Portland cement.The experiment was carried out by using M35 mix with 0.45water cement ratio.The samples were hydrated from one to four weeks.The hydrated samples were subjected to FTIR,SEM micro graph sand study the compressive strength analysis. The compressive strength increases with increase in curing period. The 20% Wood Ash shows higher degree of hydration and compressive strength. Thus, the optimum replacement percentage of wood ash is 20 % for construction industry.[3]

Akeem Ayinde Raheem used Wood Ash from bread bakery to replace 5% - 25% by weight of the cement in concrete. 1:2:4 mix ratio was used with water to binder ratio maintained a 0.5.The workability of concrete increases as the Wood Ash content increases. The mechanical strength of specimens were determined at curing ages 3, 7, 28, 56, 90 and 120 days. Only up to 10% wood ash replacement is suitable for structural concrete. During hydration reaction calcium hydroxide from Wood Ash will react and produce calcium silicate gel. This will improve the strength of concrete. [4]

Raghu et.al used Mesquite Wood Ash to replace cement in concrete. Mesquite Wood Ash is a by-product obtained by the combustion of wood in the wood-fired power plants, hotels, etc. The main aim of this project is to minimize the cost of project and reduce the wastage of Wood Ash.In this study the Wood Ash is replaced to cement in concrete by 0%, 5%, 10%, 15% 20% and 25%.The mechanical properties and durability properties are determined at different curing period and were compared to M-30 mix of concrete. The specimens were casted and cured for 3,7and 28days.The mechanical strength properties are increased up to 15% of replacement of Wood Ash by cement. The 15% replaced Wood Ash shows lower values of acid attack and water absorption. [5]

3. MATERIALS USED AND THEIR PROPERTIES

The materials used for this study are given below,

- Ordinary Portland cement (43 grade)
- Sand (zone 2 as per IS 383:1970)
- Coarse aggregate (as per IS 383:1970)
- Wood ash

3.1 CEMENT

Ordinary Portland cement of 43 grades available in local market is used in the experiment. The cement used has been tested for various properties and test result are shown in the table

Table 1: Physical properties of OPC 43 grade

S. No	Property of cement	Values
1	Grade of cement	OPC43
2	Fineness of cement	3%
3	Specific gravity	3.13
4	Consistency	30%
5	Initial setting time	29 minutes
6	Final setting time	597 minutes

Table 2: Chemical composition of cement

s.no	constituent	Percentage (%)
1	Calcium oxide	60
2	Silica	22
3	Al2O3	5
4	Magnesium	1
5	Calcium sulphate	4

3.2 FINE AGGREGATE

Aggregate which is passed through 4.75 IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the M- sand is used as fine aggregate. Important thing to be considered is that fine aggregates should be free from coagulated lumps. Grading of natural sand or crushed stone i.e. fine aggregates shall be such that not more than 5 percent shall exceed 5 mm in size, not more than 10% shall IS sieve No. 150 not less than 45% or more than 85% shall pass IS sieve No. 1.18 mm and not less than 25% or more than 60% shall pass IS sieve No. 600 micron

Table 3: Properties of fine aggregate

Particulars	Test values
Fineness modulus	6.12
Specific gravity	2.76

3.3 Wood Ash

Wood ash prepared from uncontrolled burning of wood obtained from the industry is studied for its suitability as partial replacement for cement in conventional concrete. The wood ash will adversely affect the workability of concrete. The water requirement increases with increasing wood ash content. It has high calcium oxide content. During the hydration reaction calcium oxide will react with cement and form C-S-H gel provide better strength to the concrete. Wood ash is a residue powder that left after the combustion of wood. Wood is generally used in industries for heat generation. The temperature of combustion have profound effect the ash properties. Wood ash was collected from Baliapattam Tile Works Ltd is shown in figure1.Wood ash prepared from uncontrolled burning of wood obtained from the industry is studied for its suitability as partial replacement for cement in conventional concrete.

Fig.1.1 Wood Ash

Table-4 Chemical composition of wood ash

S. No	Particulates	Percentages
1	CaO	47
2	SiO	37
3	MgO	8.7
4	Al_2O_3	5.3
5	Fe_2O_3	1.53
6	KO	1.2

3.4 COARSE AGGREGATE

Coarse aggregate for the works should be river gravel or crushed stone .It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregates should be cubical, or rounded shaped and should have granular or crystalline or smooth non-powdery surfaces. Aggregates should be properly screened and if necessary washed clean before use. Coarse aggregates containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per specifications. After 24-hrs immersion in water, a previously dried sample of the coarse aggregate should not gain in weight more than 5%. Aggregates should be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

Table 5: Properties of coarse aggregate

Particulars	Test values
Fineness modulus	6.56
Specific gravity	2.66

3.5 Water

Water is an important in gradient in concrete construction. The water participate in the hydration reaction with cement. The water is used for mixing the fresh concrete and curing the specimens. It should befree from impurities such as acids, oils, alkalis, silts and organic materials. The pH value of water shall not be less than 6.Mixing and curing with saline water shall not permitted.

4. MIX DESIGN

Mix design is a process of specifying the mixture of ingredients required to meet anticipated properties of fresh and hardened concrete. Concrete mix design is a well-established practice around the world. Adapting from developed countries, many developing countries have standardized their concrete mix design methods.

4.1 Procedure for mix design as per IS (10262 : 2009)

The following basic data are required for a concrete mix.

1. Characteristics compressive strength of concrete
2. Degree of workability desired
3. Max water cement ratio of coarse aggregate
4. Type of max size of coarse aggregate
5. Standard deviation-based on concrete control
6. Statistical constant-accepted
7. Grade of cement used

Target mean strength is determined by

i. **a. Fck= fck+ t x s**

ii. The water/cement ratio for the target mean strength is limited as per table 5 of (IS:456-2000)
iii. Appropriate water content per kg of concrete are selected as per table 2 of (IS 10262 : 2009)
iv. Adjustment in aggregate percentage and water content are made as per table 3 and by the clause 4.2 of (IS 10262 : 2009)
v. Collected water quantity is computed and hence from W/c ratio.
vi. The quantity of fine aggregate and coarse aggregate per unit volume of concrete can be calculated from.
vii. Volume of material = (Mass of material / specific gravity of material) X (1/1000)
viii. The mix proportions by weight are computed by keeping cement as one unit.

4.2 Data

Characteristic compressive strength required : 20 N /mm2
Maximum size of aggregate : 20 mm
Degree of workability : 0.90 compacting
Degree of quality control : Good
Type of exposure : Moderate
Specific gravity of cement : 3.15
Specific gravity of fine aggregate : 2.60
Specific gravity of coarse aggregate : 2.60
Water absorption fine aggregate : 1 Percent
Water absorption coarse aggregate : 0.5 Percent
Free (surface) moisture of aggregate : 2 Percent

4.3 Target mean strength of concrete:

For tolerance factor of 1 .65 and assumed standard deviation, the target mean strength for specified characteristics cube strength is,

Target mean strength, Fck = f_{ck}+ t x s

= 20 + 1.65 x 4
= 26.6 N/mm2

4.4 Selection of water/cement ratio:

The free water/cement ratio required for the target mean strength of is 0.50. This is lower than the maximum value of 0.55 prescribed for mild exposure in Table 5 of IS 456: 2000.

4.5 Selection of water and sand content:

For 20 mm nominal maximum size aggregate and sand conforming to grading zone II, water content per cubic meter of concrete = 186 kg and sand content as percentage to total aggregate by absolute volume = 35 percent.

4.6 Adjustment required if any:

For change in values in water/cement ratio, compacting factor and sand belonging to zone III, the following adjustment is required:

(i) For water content percent:

For decrease in water/cement ratio by (0.60-0.50)
that is 0.10 = 0%
For increase in compacting factor (0.90-0.80)
That is 0.60 = +3%
For sand conforming to zone III of Table 4 of
IS 383: 1970 = 0%
Total = 3%
Required water content = 186 + 3% of 186
= 186 + 2/100 x 186
= 186 + 5.5
= 191.6 kg/m^3 (or) lit/m^3 (or) 1/m^3

(ii) For sand in total aggregate:

For decrease in water/cement ratio
By (0.60 – 0.50) that is 0.10 = -2.0%
For increase in compacting factor
(0.90 – 0.80) that is 0.10 = 0%
For sand conforming to zone III of
Table 4 of IS: 383 – 1970 = -1.5%
Total = -3.5%
Therefore, required sand content as percentage of total aggregate by absolute volume = 35 – 3.5 = 31.5 percent.

4.7 Determination of cement content:

Water cement ratio = 0.50
Water = 191.6 litres
Cement = 191.6/0.50 = 383 kg/m^3
This cement content is adequate for mild exposure condition, according to Table 5 of IS 456:2000.

4.8 Determination of fine and coarse aggregate content:

For specified maximum size of aggregate of 20 mm, the amount of entrapped air in the concrete is 2 percent. Take this into account and applying equations below,

$V = [W + C/S_C + 1/P. f_a/S_{fa]} \times 1/1000$
$V = [W + C/S_c + 1/1\text{-}p. C_a/S_{ca}] \times 1/1000$
$0.98 = (191.6 + 383/3.15 + 1/0.315 \times f_a/2.60) \times 1/1000$
$F_a = 546$ kg/m^3 and
$0.98 = (191.6 + 383/3.15 + 1/1\text{-}0.315 \times C_a/2.60) \times 1/1000$
$C_a = 1188$ kg/m^3

4.9 Mix proportion:

From the above steps 1 to 6, the mix proportion then becomes:

Table 6: Mix proportion

Cement	Fine aggregate	Coarse aggregate	Water
383 kg	546 kg	1188 kg	191.60 kg
1	1.42	3.10	0.50

Actual quantities of material required:

Water

For water/cement ratio of 0.50 quantity
of water = 191.60 lit

Add extra quantity of water to be added for absorption in case of coarse aggregate, at 0.50 percent by mass,

0.50/100 x 1188 = +5.94 lit

Deduct quantity of water for free moisture present in sand, at 2 percent by mass

2/100 x 546 = -10.92 lit

Therefore, actual quantity of Water to be added = 186.62 lit

Fine aggregate

As per original calculation fine aggregate = 546 kg

Add 2 percent for free moisture = 10.92 kg

Actual quantity of sand required after allowing for mass of free moisture = 556.92 kg

Coarse aggregate

As per original calculation = 1188 kg

Deduct 0.50% for water absorption,

0.50/100 x 1188 = -5.94 kg

Total aggregate = 1182 kg

Fraction I (60%) = 60/100 x 1182 = 709.20 kg

Fraction II (40%) = 40/100 x 1182 = 472.80 kg

Actual quantities required for the mix without adjustment:

The mix 1: 1.42: 3.10: 0.50 (by mass), the mix quantity different materials are:

Cement : 383 kg

Sand : 546 kg

Coarse aggregate : 1188 kg (Fraction I = 712.80 kg)

(Fraction II = 475.20 kg)

Water : 191.60 kg

Actual quantities required for the mix with adjustment:

(Ratio: 1: 1.45: 3.08: 0.487)

Cement : 383 kg

Sand : 556.92 kg

Coarse aggregate: 1182 kg (Fraction I = 709.20 kg)

(Fraction II = 472.80 kg)

Water : 186.62 lit

5. TESTS CONDUCTED ON HARDENED CONCRETE

5.1 Compressive strength test

The compressive strength is one of the most important properties of hardened concrete. The test specimens in shape of size 150*150*150mm. Minimum of 3 cubes should be tested. Compression of tests are conducted at 7 days ,14 days and 28 days of the casting of specimens. After completion of curing,

$$fck = P/A \ (N/mm^2)$$

Were,

P = Load at which the specimen fails in Newton (N)

A = Area over which the load is applied in mm^2.

5.2 Split Tensile strength Test

Tensile strength is one of the most important fundamental properties of concrete. An accurate prediction of tensile strength of concrete will be mitigating cracking problems the split tensile strength was determined at the age of 7 days, 14 days and 28 days on cylinders of sizes 300mm*150mm as per IS specifications BIS516-1959. The magnitude of this tensile stress (acting in a direction perpendicular to the line of action of applied compression) is given by,

$$\text{Tensile stress} = {}^{2p}/_{\pi dl}$$

Were,

P = Applied load at failure in N,

L = length of cylinder in mm

d = Diameter of cylinder in mm

5.3 Flexural strength test on beam

The Flexural strength of concrete is also one of the important properties of concrete. Concrete specimens of 500 x 100 x 100 mm beam were cast with different proportions of concrete.

Formulae used:

$$F = 3PL/2bd^2 \ (N/mm^2)$$

Were,

F = Flexural strength of concrete in N/mm^2.

P = Failure load in Newton (N).

L = Effective span of the beam in mm.

B = Breadth of the beam in mm.
d = Depth of the beam in mm.

6. RESULTS AND DISCUSSION

6.1 GENERAL

In this experimental study of cement and wood ash proportions of 25:75, 27.5:72.5,30:70, 32.5:67.5 and 35:65. the test was conducted for 1:1.45:3.08 mix ratio and the results of tests conducted are discussed below.

6.2 COMPRESSIVE STRENGTH

The compressive strength test was carried out by a compression testing machine. Cube of size 150mm x150mmx 150mm is used for this test. The load applied on the specimen is140Kg/Cm²/minute till the specimen fails. The failure load obtained are tabulated and calculations are done as per IS: 506 -1959

6.2.1 Comparison of Compressive Strength Of Specimens For 7 ,14 & 28 Days

The results of variation of compressive strength test of cubes for 7, 14 & 28 days are compared in below tables and the variation of compressive strength of all mixes are clearly illustrated.

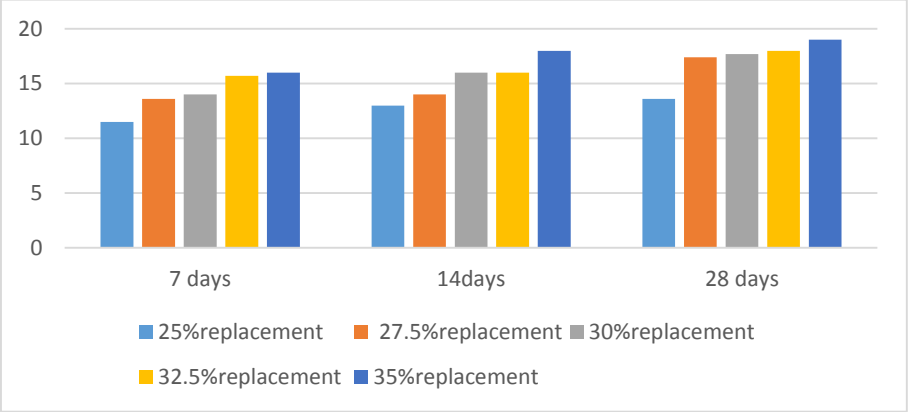

Chart-1:compressive strength at 7 ,14 &28 days

6.3 SPLIT TENSILE STRENGTH TEST

The compressive strength test result for the split tensile strength tests were conducted on concrete cylinder specimens of size 150mm dia X 300 mm height. The cylinder was tested after curing periods of 7 days, 14days and 28 days of testing is given. The chart-2 shows the average compression test results for each specimen.

6.3.1 Comparison of Split Tensile Strength of Specimens For 7 ,14 & 28 Days

The results of variation of split tensile strength test of cylinder for 7, 14 and 28 days are compared in below tables and the variation of split tensile strength of all mixes are clearly illustrated.

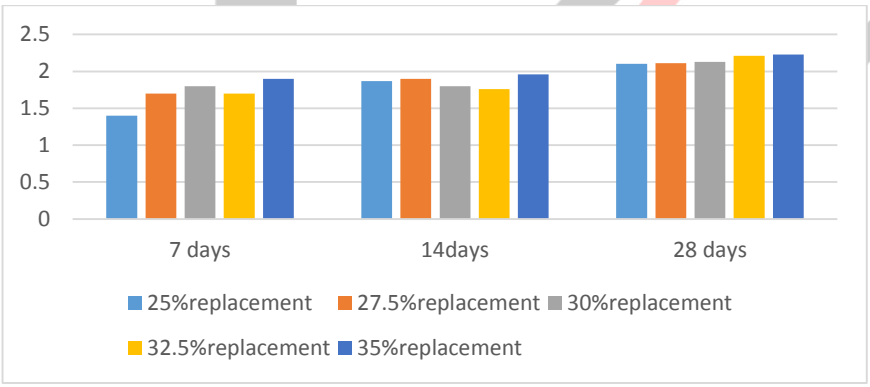

Chart-2: split tensile strength at 7.14 & 28 days

6.4 FLEXURAL STRENGTH TEST

Flexural strength of concrete for for different percentage of polypropylene fiber with partial replacement of Ash by coarse aggregate. The flexural tests were conducted on prismatic specimens of size 100mmX100mm x500mm. The prism was tested after curing periods of 7 days and 28 days.

6.4.1 Comparison of Split Tensile Strength of Specimens For 7 ,14 & 28 Days

The results of variation of flexural strength test of cylinder for 7, 14 and 28 days are compared in below tables and the variation of split tensile strength of all mixes are clearly illustrated.

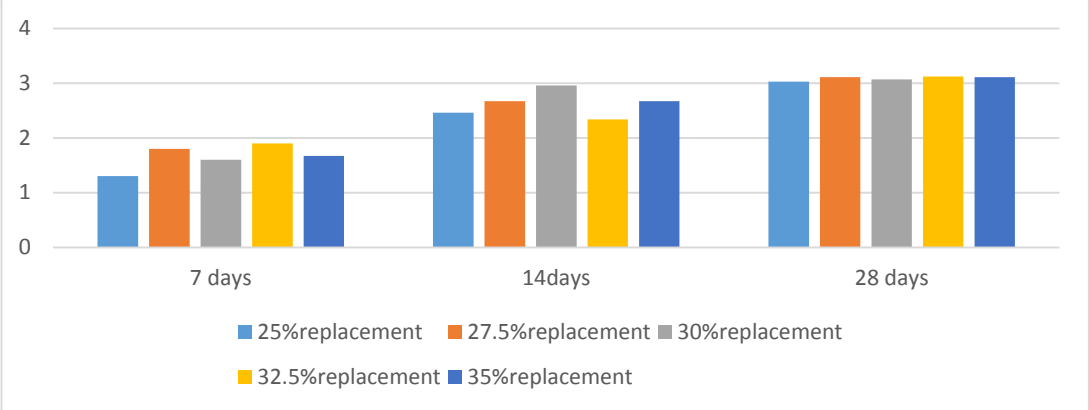

Chart-3: Flexural strength at 7 ,14 & 28 days

CONCLUSION

The experimental study leads to the following conclusions.

i. Replacement of cement with wood ash helps to reduce the environmental pollution.
ii. Detailed literature review on wood ash blended concrete is done.
iii. Physical properties of materials are tested and verified with the IS code specifications.
iv. M20 grade wood ash blended concrete is designed.
v. Tests on specimens were conducted.

While comparing the compression strength, the ash aggregate concrete with aggregate made from cement ash proportion 35:65 showed high compressive strength than control concrete at all ages of concrete. The increase in compressive strength of ash aggregate concrete with cement ash proportion35:65 at 7 days increased by 8.96% over control concrete. The increase in compressive strength of ash aggregate concrete with cement ash proportion 35:65 at 14 days increased by 9.16% over control concrete. The increase in compressive strength of ash aggregate concrete with cement ash proportion 35:65 at 28 days increased by 15.75%over control concrete. High flexural strength was observed for ash aggregate concrete with cement ash proportion35:65 At 7 days increase in flexural strength of 4.76% over control concrete. At 28 days increase in flexural strength of 2.13% over control concrete.

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