Partial Replacement of Ordinary Portland Cement with Wood Ash and Foundry Sand as fine aggregate

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by

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Transforming Education Transforming India

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DECLARATION

I, Amir Shafi Batt student of Lovely Professional University Punjab bearing Registration Number as 11209505, hereby declare that this thesis report entitled "Partial Replacement of Ordinary Portland Cement with Wood Ash and Foundry Sand as fine aggregate**"** submitted in the partial fulfilment of the requirements for the award of degree of Master of Civil Engineering, in the School of Civil Engineering is my own work and involves genuine and guided work under the guidance of Mr. Anshul Garg. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Date: **AMIR SHAFI BATT**

Place:

CERTIFICATE

Certified that this project report entitled "Partial Replacement of Ordinary Portland Cement with Wood Ash and Foundry Sand as fine aggregate" submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara , carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

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ABSTRACT

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Wood ash is generated as residual/waste from combustion done in boilers at mills, power plants, 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 review study in sieve analysis, consistency, water absorption, setting time and slump tests of wood ash added to OPC will produce significant results to emphasize the detailed study process. 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 of 5%, 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 wood ash in structural works.

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

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CHAPTER 1

INTRODUCTION

1.1 Present Scenario:

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 power plants comprising a part of these are an efficient source of renewable energy. These sources are economic i.e. have low operational costs **[1]**. Apart from historical evidences about demand of renewable energy in the present modernizing world, in the era of urbanization now the demand for renewable energy resources have further increased. A part of these resources is made by biomass resources including forestry and agricultural wastes. Forestry and agricultural biomasses are considered as efficient and favorable 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.

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 environmentally friendly material (proving zero harm to ecosystem). With all these facts to be known to everyone that increasing energy demand can enhance the increased usage of forestry waste products, thereby leading to increased waste production **[2]**. As a result, the quantity of ash generated will be very high to get disposed. It will increase in quantity, thereby raising the issues of disposal. Thus making large part of it available to be used in cement industries as most of its chemical as well as physical properties resemble fly ash.

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. At present wood ash is mostly disposed over lands to increase soil alkalinity acting a soil supplement. Besides, this at present wood ash is used in flexible pavement construction for roads and highways as a filler material to fill down the voids created in fine aggregate to obtain better compaction and well prepared subgrade.

CHAPTER 2

Literature Review

2.1 Physical properties of wood ash

Tarun et al.[3] reported the various types of constituents in a sample of wood ash obtained from a known source like: carbon between 5% to 30%, calcium between 5% to 30%, potassium between 3% to 4%, magnesium between 1% to 2%, phosphorus between 0.3% to 1.4% and sodium between 0.2% to 0.5%.

Pascale Coatanlem et al. [4] in their research process examined the durability/lifespan of a wood fiber light-weight concrete. The prepared specimens were stored in a dry and humid environment. After that flexural strength and compressive strength were measured. In a further study process the microstructure of prepared samples was examined by using SEM analysis. The research process showed that material properties can be enhanced when wood chippings are saturated with sodium silicate solution. It will help in the formation of excess CSH gel, thus bonds between chippings and cement paste get much stronger.

Felix et al. [5] in their study showed that wood waste ash (WWA) obtained from pretreating of timber was incorporated in the percentages of 0%, 5%, 10%, 15%, 20%, 25%, and 30% by weight of OPC/binder into a concrete mix with respective proportion of 1:2:4 and 0.56 water cement ratio. The water absorption and different strengths of matrix and specimen respectively were studied by carrying out various tests for them. The earlier tests for flexural strengths and compressive strength for wood waste ash (WWA) concrete show the results which range between 3.65 to 5.57 N/mm and 212.83 to 28.66 N/mm2, respectively, where 30% of addition of wood ash gives the lowest value. By plotting the comparison with the normal mix or control mix both the strengths for WWA were between 62 and 91% and 65 and 98%, respectively, of the former.

Abdullahi et al. (2005) [6] has studied the behavior of wood when used as partial replacer for OPC concrete. The study carried for Chemical analysis of wood ash including the study for bulk density, specific gravity and sieve analysis of wood ash and further studies for setting time, consistency of mix with wood ash and slump test of the fresh paste were carried out to analyze and determine efficiency of concrete making. The results obtained at the end showed that the wood ash is slightly pozzolanic. There was an increase in water demand as the wood ash content kept increasing. Besides that, the setting time of fresh paste also increases with increased wood ash content.

Naik et al. [7] studied the physical as well as the chemical properties of waste wood ash obtained from different mills. Waste wood ash sample taken was observed to be having different sized particles generally angular in shape i.e. a heterogeneous mixture was obtained.

The mixture obtained involved partially burnt or unburnt wood and chippings. To obtain required fineness, average amount of waste wood ash sieved from 75micron sieve was seen to be 50% and the percentage of waste wood ash retained on 45micron sieve was seen to be 31%.

Udoeyo et al. [8] carried out the research on waste wood ash to study its physical properties), used as partial replacement for ordinary Portland cement (OPC). The study revealed that WWA had moisture content of 1.81%, specific gravity of 2.43, the average loss on ignition was 10.46 and a pH value of 10.48.

Rajamma et al. [9] studied the waste wood ash for its specific gravity. The source obtained for that was taken from a forestry biomass which was incinerated in a power plant. The observation revealed finer particles which were having an average diameter of about 50micron. The particle shape or grain shape of wood ash particles was observed to be angular with extensive surface porosity which can be proved by SEM analysis.

Naik et al. [10] researched on different sources of wood ash. Five different sources were chosen for the study process, designated as W1, W2, W3, W4 & W5. The results for specific gravity varied from 2.26 to 2.60 for all the sources of wood ash. Besides that, the tests for fineness done with 45micron sieve (retained) were between 23% and 90%. Some of the Physical properties for different sources of waste wood ashes are given in **Table 1:**

Table 1 Physical Properties of waste WA [10]

Test	W1	W2	W3	W4	W5
Retained on no. 325 sieve	23	60	90	40	12
Strength activity index with Portland cement					
3 days	88	38	102.0	53.8	112.3
7DAYS	84	39	83.3	59.3	72.0
28DAYS	88	34	78.7	59.4	67.0
Water requirement, % of control	115	155	115	126	130
Autoclave expansion, %	0.2	0.5	-0.6	-0.22	0.12
Specific gravity	2.26	2.41	2.60	2.26	2.33

Table 1 Physical Properties of waste WA [10]

2.2 Fresh Properties of Concrete

2.2.1 Workability: Raheem et al. (2013) [13] The results of the compacting factor and the slump test indicating the workability of the waste wood ash concrete are given in **Table 2**. According to the obtained results in the below table we can observe that at first when OPC replacement by wood ash is done for 10% slump decreases, and then increases as we increase wood ash content and a similar phenomenon was observed for the compacting factor. This showed that concrete mix containing wood ash beyond 10% replacement has more workability, as the quantity of wood ash increases which means that less water is required to make the concrete workable. This lower water demand is because of finer particles of wood ash with filling role in concrete mix.

Table 2 Slump and Compacting Factor of WA Concrete

Percentage of Wood ash replacement (%)	Slump (mm)	Compacting Factor
0	110	0.98
5	85	0.97
10	45	0.96
15	100	0.98
20	140	0.98
25	170	0.98

Raheem et al. (2012) [13] carried out the research on saw dust ash (SDA) for studying the slump and compacting factor. The results for taken sample of SDA for compacting factor and the slump indicating the workability are shown in **Table 3**. The obtained results in the below table show us that as the SDA content increases, the slum value decreases. Besides this for the increased content of SDA the compacting factor also decreases. The conclusion from these observations makes it quite clear that workability of concrete mix decreases as the %age of SDA increases. It means that larger amount of water is required to make the concrete mixes more workable. This was why in this research process these reasons led to increase the water cement ratio from 0.5 to 0.6 for 20% & 25% substitution i.e. partial replacement of OPC with SDA, since the concrete paste was becoming much stiffer. The increased demand for water as we increase the SDA content is because of the reason that SDA contains more amount of silica. This phenomenon is quite similar to pozzolan cement concrete where more addition of water is required during hydration reaction when we go for the silica-lime reaction.

Table 3 Slump and compacting factor values of SDA Concrete [13]

Percentage SDA replacement (%)	Slump (mm)	Compacting factor

0	110	0.94
5	100	0.94
10	100	0.93
15	95	0.92
20	95	0.91

2.2.2 Heat Release: Subramaniam et al. [2] studied the wood ash concrete for the variation in heat release when OPC was replaced by different %ages for 7 days, 14 days and 21 days which are given in **Figure 1**. From the research process it was observed that there was reduction in heat release from 7 days of curing time to 14 days, thereby decreasing the surface temperature. However further curing showed increase in heat release for all sample blocks **(Figure 1a & 1b)**. The lower surface temp. difference in S3 and S4 after 21 days indicates the slow release of heat by both sample blocks **(Figure 1c)**.

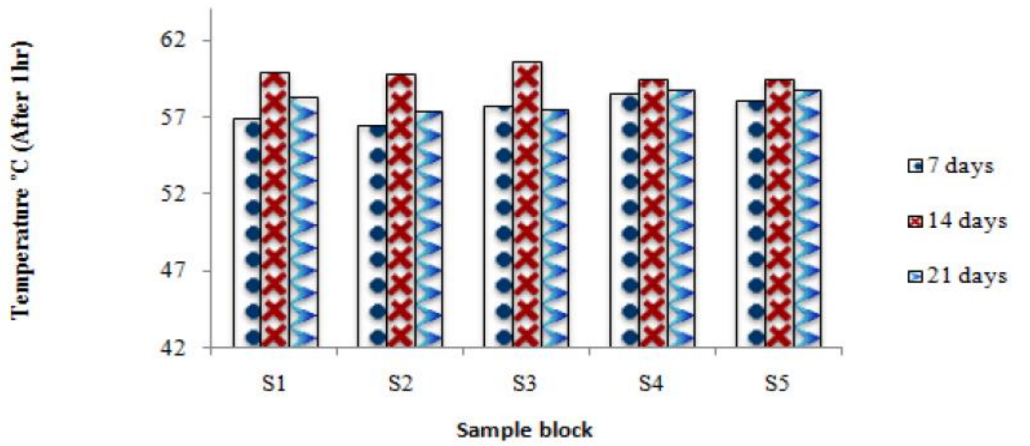

Figure 1 Surface temperature after 1 hour

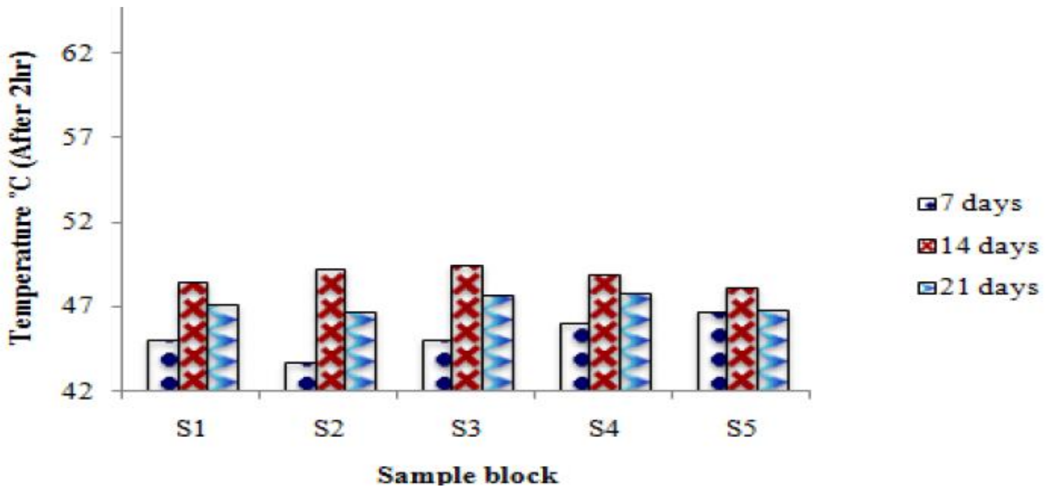

Figure 2 Surface temperature after 2 hours

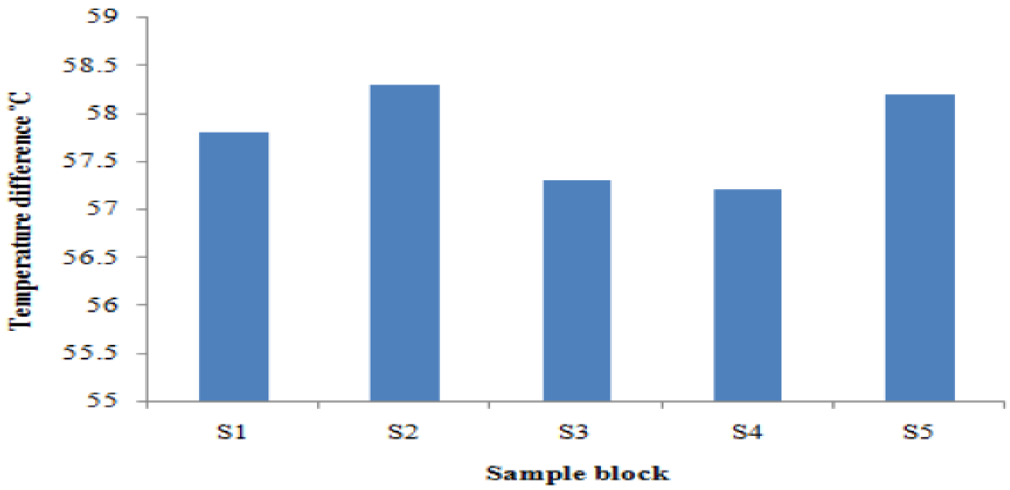

Figure 3 Temperature difference b/w initial and after 2 hours at 21 day of curing period

2.3 Hardened Properties of Concrete

2.3.1 Compressive Strength: Naik et al. [12] A comparative study for checking the compressive strength of concrete mix containing wood ash as a replacer for OPC was done for 365 days. OPC was replaced for different percentages of wood ash like 5%, 8% and 12% by its total weight used.

1. The study revealed the results that compressive strength of control mixture with the wood ash for 28 days was 34 MPa and for 365 days was 44 MPA.

2. The study revealed that there was increase in strength development of the concrete paste/mix when replacement of OPC was done by 15% wood ash. This was because for 15% replacement pozzolonoc activity became much faster.

Subramaniam et al. [2] carried out research for the compressive strength of cement cubes/blocks measured at different curing periods. The results are shown in **Table 4.** From the table it can be observed that compressive strength value increases with the curing time **(Figure 2).** The results reveal significant difference in compressive strengths between sample cubes/ blocks at all ages of curing periods (7days of curing provides: $p < 0.001$, 14days of curing provides: $p < 0.001$ & 21days of curing provides: $p = 0.003$). It can also be observed from the results obtained that for S5, the compressive strength was lower than the control specimen/ block S1 i.e. normal mix at all curing stages. The optimum observation for compressive strength can be seen to be obtained at 15% replacement for OPC after 21days of curing.

Table 4 The average compressive strength of blocks [2]

Wood Ash Content (%)	Strength (N/mm^2)		
	7Days	14days	21days
0	1.9592	2.4338	3.1033
10	2.2939	2.2477	2.6142
15	2.1917	2.5074	3.6631
20	1.9736	2.6200	2.8046
25	1.1974	1.1974	1.4052

Raheem et al. (2013) [13] conducted the research study for the compressive strength of concrete blocks that were tested for 3, 7, 28, 56, 90 and 120 days. The results are shown in Figure 3. The analysis of the below figure shows that there is increase in the compressive strength with the curing time/period but decreases as keep increasing the wood ash content above the optimum percentage. The r 7 days concrete blocks showed higher strengths 5% and 10% wood ash content results for compressive strength for 3 days indicated an increase at 5% wood ash content. For

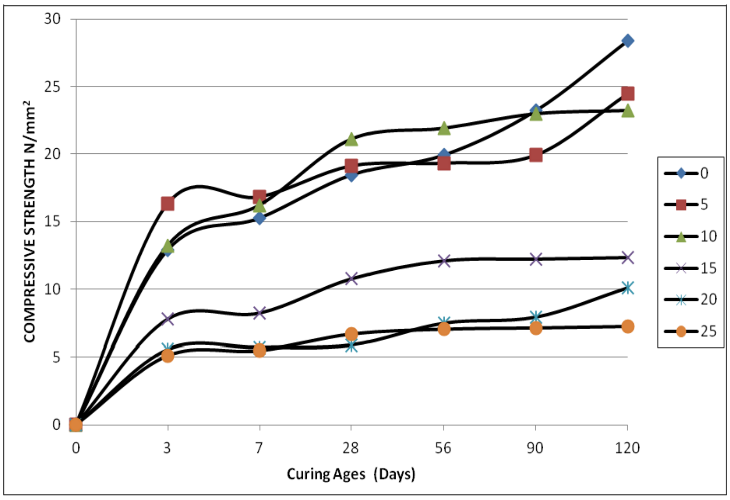

Figure 4 Effect of curing age on the compressive strength of concrete

2.3.2 Flexural Strength: Cheah et al (2010) [14] Carried out the research for flexural strengths mortar mixes with OPC that was replaced with high calcium wood ash (HCWA) as shown in Table 5. For the 3days age the there was an increase in the flexural strength at 5% replacement of OPC with wood ash, while the other replacement results up to 25% indicated the same strengths with no considerable changes at all. This is because of the fine particle size of wood ash with high calcium content, which is capable of filling the voids b/w cement particles & aggregate cement zone. The paste so produced is called as micro filler paste helps densifying the cement paste matrix because of which there is an increase in the flexural strength of HCWA mortar. On 7days prolonged curing, the higher hydration rate of Ordinary Portland cement (OPC) as compared to HCWA offset the micro-filler effect of HCWA because of which we can observe larger variations for flexural strengths of normal mortar mix and HCWA mortar mix. In a detailed study conducted for 28 days the behavior for flexural strengths both for OPC mortars and HCWA mortars for 10%, 15% & 20% was analyzed. The study conducted was mainly focused on pozzolonic reaction. With the increased curing period up till 90 days for both OPC mortars and HCWA mortars there was convergence in flexural strength. On that age the optimum results for the increased flexural strength were obtained at 10% replacement of OPC with HCWA by weight of total binder.

Naik et al. [12] carried out an investigation for flexural strength when wood ash used as partial replacer. The replacement was done for 5%, 8% and 12% by total weight of ordinary Portland cement. The results revealed in that study for flexural strength are shown in **Fig.4.** It showed us that:

1. The normal mix or control specimen achieved flexural strength at 28 days as 401 MPa and & at 365 days as 4.4 Mpa.
2. The flexural strength of mixes with wood ash as partial replacer for 28 days varied from 3.9 to 4.4 MPa and for 365 days varied from 4.3 and 5.3 MPa.
3. From the results obtained in this study it is quite clear that there is an optimum increase for flexural strength when waste wood-fly ash content increases.

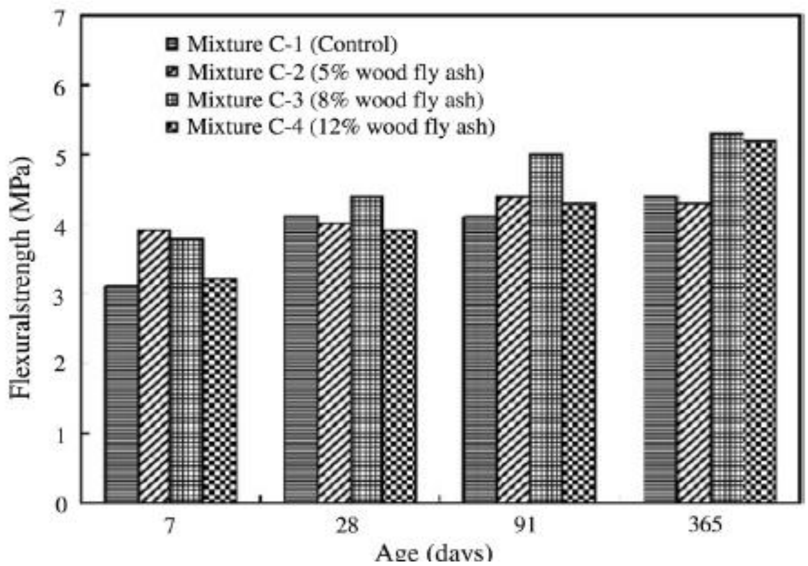

Figure 5 Flexural strength of concrete mixtures incorporating wood fly ash [12]

Rajamma et al. [14] carried out the research study for checking the flexural strength change in the concrete mixes in which wood fly ash was used as partial-replacer for OPC. The wood fly-ash was obtained from two sources viz- wood biomass power mills. For checking the flexural strength mortar bars were casted with replacement of OPC done with wood fly ash with different percentages of 0% at first denoting the control specimen then with further replacements of 10%, 20% and 30% by weight of total OPC used. The results obtained from this study showed that there is decrease in flexural-strength with the increasing content of wood fly ash. Specimen having replacement percentages of 10%, 20% and 30% revealed the range of flexural-strength varying in between 60.6 to 71%, 59.6 to 61.7% and 45 to 48.6%, of the control specimen/normal mix respectively. Thus, from the study it can be concluded that:

1. The increase of flexural strength was observed at 20% replacement with wood fly ash which can be considered as an optimum percentage yielding maximum results.
2. With the increase of wood fly ash beyond 20% it was observed that flexural strength decreases rapidly.

2.3.3 Split Tensile Strength: **Naik et al. [12]** carried out the research for studying the behavior of splitting tensile strength of specimens casted when wood ash obtained from waste wood or biomass was used as partial replacer for OPC. The replacement was done in the percentages of 5%, 8% and 10% by weight of OPC used**.** From the study it was concluded that:

1. The splitting-tensile strength for control specimens or normal mixes obtained at 28 days was 3.8 MPa and at 365 days was 4.3 MPa.
2. The splitting-tensile strength for concrete specimens casted when waste wood-ash was used as partial replacement material for 28 days and 365 days was observed to be between 3.6 and 4.0 MPa and 4.2 and 5.1 MPa, respectively.

Udeyo and Dashibil [15] carried out the research for studying the behavior of splitting tensile strength at 7days of curing period and 28days of curing also. The replacement of OPC was done with saw dust ash. From the study it was observed that there is some decrease in splitting tensile strength when replacement percentages were increased but the decrease was lesser than the compressive strength when checked in this study.

Chowdhury et al. (2015) [6] Table 7 shows the split tensile strength of wood ash (WA) blended cement concrete for two different water–cement ratios. From the table it can be analyzed: there is decrease in the splitting tensile strength of concrete specimens when WA content was increased but the decreases was observed to be much lesser that the compressive strength when checked in this study process. This decrease in splitting tensile strength was seen for both the water cement ratios used. This results obtained are in same findings that **Udoeyo and Dashibil [15**] discovered from their studies who also observed same kind of results. This behavior of reduction of strength is because of poor or improper binding of wood ash particles with aggregates because of higher surface area of WA particles.

Table 5 Results of SVM prediction

Water to Cement ratio	**Replacement %age**	**Split tensile strength (N/mm^2) 28 days**
0.4	6	3.508
	16	2.7913

	9	2.76
0.45	6	3.298
	16	2.8335
	9	2.8828

2.4 Durability Properties

2.4.1 Carbonation: **Khan at al. (2002) [17]** carried out the research for studying the carbonation depth of various specimens of mortar mixes when high calcium wood ash HCWA was incorporated to replace OPC. The water cement ratio for 90 days as 0.35 taken is shown in the provided **Figure.** When replacement was done with 5% of HCWA it was observed the average depth of carbonation interface/zone decreases for mortar mixes casted as compared to control mixes/normal mix casted. When the replacement was done with 10% and 25% of HCWA it was observed that carbonation interface/zone depth varied proportionally with OPC replacement. The results obtained from this study are quite similar to other findings for carbonation behavior. The average carbonation interface/zones depth for the mortar-mixes containing HCWA used as replacer for OPC, replacement levels of 0% (normal mix), 5%, 10%, 15%, 20% and 25% were recorded as 1.56 mm, 1.01 mm, 2.38 mm, 2.41 mm, 3.18 mm and 3.74 mm respectively.

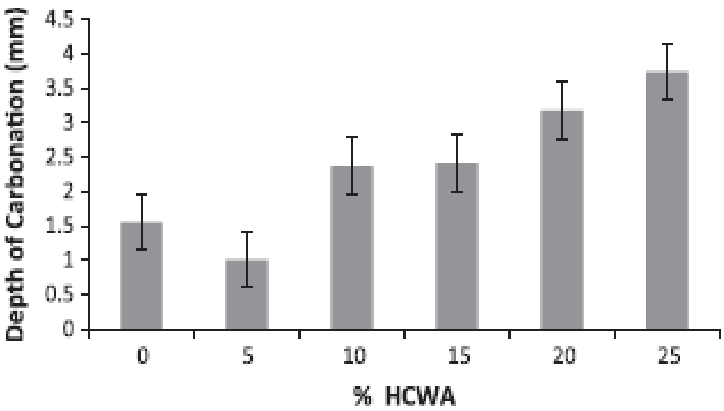

Figure 6 Average depth of carbonation when HCWA used as partial replacer

Neville et al. (1995) [18] carried out the research for carbonation when HCWA containing more amount of amorphous silica was used. It was observed that because of more silica there was the formation of enough CSH leaving less amount of: $Ca(OH)_2$ in the hardened mix. Thus, smaller amount of CO_2 was left behind for the reaction with $Ca(OH)_2$ to produce $CaCO_3$.

Further observations are shown by a study **[19]** which shows that the presence of higher content of Ca(OH)2 leads to more carbonation.

CHAPTER 3

RATIONALE AND SCOPE OF THE STUDY

3.1 Scope of the study

The scope of this study mainly focuses on to make our concrete economical with the help of wood ash when used as Replacement for OPC. The wide scope of this investigation work to be carried for longer duration of time with the incorporation of WA is to study the performance of WA concrete both for plain concrete and reinforced concrete. Apart from this a brief overview is to check the performance in harsh environments also. It seems WA concrete enhances workability and other strength parameters and further enhances the micro level cracking of specimen in transition zone, thereby increasing the ductility of concrete. This process can be studied with the help of measuring various strengths and carbonation results.

3.2 Objectives of The Study

The study focuses on the characteristics of wood ash/ saw dust and the properties incurred due to replacement 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. Besides this study mainly focuses to make concrete economical and efficient to be used. Apart from all these discussions this research help in understanding various site experiments.

The objectives are

(1) To study the mechanical strength (compressive & tensile strength) of concrete along with the wood ash as partial replacement for cement.
(2) To study the carbonation.
(3) To study the effect on bulk density.
(4) To learn how to conduct experiments on constituent elements to be used to prepare mix.
(5) To make concrete economical.
(6) To make concrete efficient.
(7) To enhance workability of concrete and its efficiency to get placed easily
(8) To increase the durability properties.
(9) To study the ductile behavior of concrete under extreme loads

CHAPTER 4

EQUIPMENT AND MATERIALS

4.1 Equipment

Compression: Trowels, Shovels, Mixer, Sieve Table, moulds, Vibrating Table, Compression Testing machine, etc

4.2 Materials

4.2.1 Cement: Ordinary Portland cement was used having particle size of 3.9µm, specific gravity of 3.01. The physical and chemical analysis properties are provided in **Table.**

Table 1 Chemical Properties of WA

Constituents (%age)		Values
Chemical Properties		
1	SiO_2	21.25
2	Al_2O_3	5.04
3	Fe_2O_3	3.24
4	CaO	63.61
5	MgO	4.56
6	Loss on Ignition	3.26

4.2.2 Wood ash: wood ash was made available from wood furnishing factory Phagwara Punjab. The wood ash was obtained by incineration of carpentry waste and other agricultural wastes like rotten wood.

4.2.3 Aggregates: Foundry sand having grain size of 4.75mm along with specific gravity as 2.6. The coarse aggregates used were crushed gravel of size about 10mm and specific gravity of 2.6. The grain size or particle size distribution was according to ASTM C33/ C33M-08.

Figure 1 Typical Foundry Sand used

CHAPTER 5

RESEARCH METHEDOLOGY

This Chapter includes the whole experimental procedure and work done for the research. A stepwise procedure is briefly mentioned here to understand the whole concept here:

5.1 Foundry Sand Tests

5.1.1 Silt Content Test:

Silt Content = **8.1%**

Thus calculated silt content is correct as maximum permissible silt content is 10% **[21]**

5.1.2 Bulkage Test:

%age bulking = **8.1%**

Thus calculated bulkage is correct as maximum permissible bulkage is 10% **[21]**

5.1.3 Moisture Content Test:

Moisture content = **1.12 %**

Thus the calculated moisture content is correct according to **[21].**

5.1.4 Sieve Analysis of foundry sand:

Observation Table:

Table 1 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	-

According to **IS: 383 – 1970 [22]** our analysis provides us **Grading Zone IV** which means that we can use this foundry sand as we are providing no reinforcement.

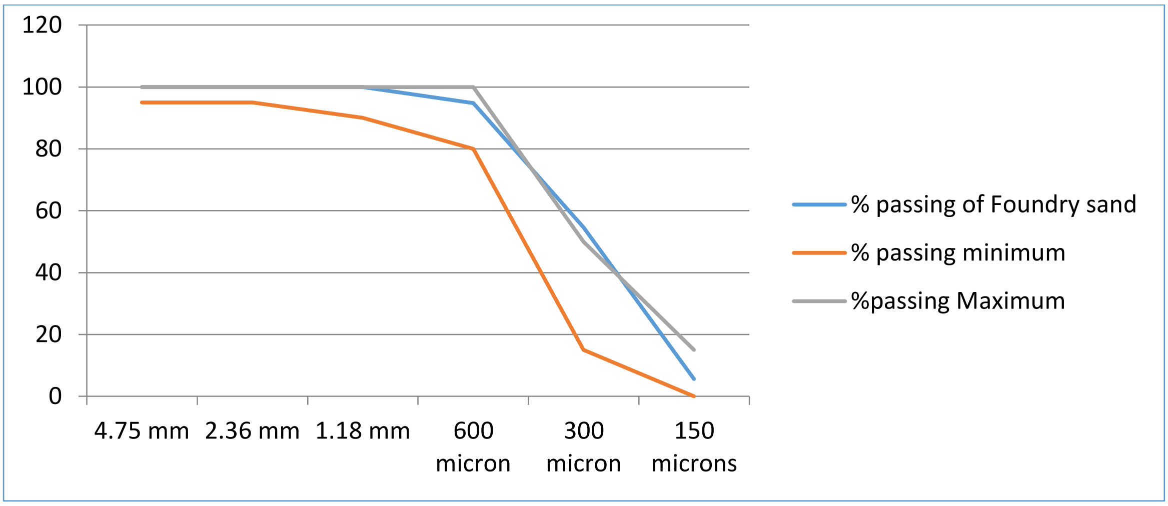

Figure 1 Graph between sieve sizes and % Finer (Compared to IS: 383- 1970) [22].

5.2 Coarse Aggregate Tests

5.2.1 Specific Gravity:

Specific Gravity = 2.6

Apparent Specific Gravity=2.81

5.2.2 Water absorption Test

Water Absorption = **1.2%** Which is according to **(IS : 2386 part 3 1963)[24]**

5.2.3 Impact Test

Table 2 Impact Test Value

Description	**Sample 1**	**Sample 2**

Total_weight of dry_sample taken **W1**	**336**	**336**
Weight_ of portion_passing_2.6 mm sieve **W2**	**62.1**	**59.4**
Agg Impact_Value = W2/W1 * 100	**18.4%**	**17.6%**

Thus, Aggregate_ Impact_ Value = (18.4 + 17.6) / 2= **18% (Satisfactory).**

Which is according to **(IS : 2386 part 4 1963).[24]**

5.2.4 Sieve Analysis of Coarse Aggregate

Table 3 Sieve analysis of Coarse Aggregates

IS Sieve Size	Wt. of Agg. Retained (gm)				%age of total wt. retained	Cumulative %age of total wt. retained	%age passing	Permissible values as per IS 383
	Determination No.							
	A	b	c	Average				
1	2	3	4	5	6	7	8	9
20mm	0	0	0	0	0	0	(100-0)%=100%	85 to 100%
16mm	52	46	44	47.3	47.3/1000 *100 = 4.73	0+4.73 = 4.73	100-4.73 = 95.2	-
12.5mm	536	454	492	494	49.40	4.73+49.40=54.13	45.87	-
10mm	320	408	396	374.7	37.47	91.60	8.40	0 to 20 %
4.75mm	86	82	60	76.0	7.60	99.20	0.80	0 t0 5%
Pan	6	10	8	8.0	0.80	100	0	

On comparing with **IS 383** we have aggregates corresponding to 20mm single size **[25].**

5.3 Cement Tests

5.3.1 Normal Consistency Test:

Observation Table

Table 4 Consistency test

%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

The normal consistency of cement is brought at 30% of water added by weight of cement which is accurate for OPC according to **IS 4031 Part 4 1988 [26].**

5.3.2 Fineness of cement:

% residue = **8 % < 10 %** which is satisfactory according to **IS 4031 part 1 [27].**

5.3.3 Initial Setting Time of Cement:

Observation Table:

Table 5 Initial Setting Time for Cement

Time Interval in minutes	Penetration observed from bottom in mm			Average Penetration in mm
	Sample 1	Sample 2	Sample 3	
00:00 to 04:00	0	0	0	0
04:00 to 10:00	0	0	0	0
10:00 to 20:00	0	1	0	0.33
20:00 to 30:00	3	4	1	2.67
30:00 to 40:00	**6**	**7**	**3**	**5.34**
40:00 to 50:00	8	9	5	7.34

On an average we record the initial setting time between 30 to 40 minutes which is satisfactory according to **IS 4031 Part 5 1988 [28].**

5.3.4 Soundness test of Cement:

Observation Table:

Table 6 Soundness test for cement

Description	**Sample 1**	**Sample 2**	**Sample 3**	**Average gap b/w indicators (should be less than 10mm as per IS specifications)**
Distance bb/w two indicators at first L1 (mm)	11	12	9	
Distance b/w two indicators after boiling L2 (mm)	15	15	14	
L2 – L1 (mm)	15-11=4	15-12= 3	14-9=5	**4mm**

The average expansion of indicators = **4mm** which is according to **IS: 8112-1989 for OPC (43) i.e. < 10mm [29]**

Table 7 Test results of all Materials Used

	Foundry Sand test Results	
S.NO.	**Name of Experiment**	**Results**
1	Silt Content	8.10%
2	Bulkage Test	8.10%
3	Moisture Content Test	1.12%
4	Sieve Analysis	Zone IV
	Coarse Aggregate Tests	
1	Specific Gravity	2.6

1	Apparent Specific Gravity	2.81
2	Water Absorption Test	1.20%
3	Impact Test	18%
4	Sieve Analysis	20mm Single graded agg.
	Cement Tests	
1	Consistency Test	30%
2	Fineness of Cement	8%
3	Initial Setting Time	30 to 40 minutes
4	Soundness of Cement	4mm
5	Specific Gravity	3.19

5.4 Preparation of trial mix for 7 days

This part was included to check the calculations done above to carry our research work precisely. In this part a clear check was done for observing water cement ratio. Moreover, a check for slump test to observe workability and type of concrete was done. For this trial study 3 cubes of 150mm X 150mm X 150mm for compression test were prepared. Besides this 3 cylinders for Split Tensile Strength and 3 Beams for Flexural strength were casted.

5.4.1 Calculation of quantity of cement, sand, aggregate and water to cast 3 cubes, 3 cylinders and 3 beams:

$$\text{Dry volume for 1 cum of concrete } = 1 \times 1.54 = \mathbf{1.54m^3}$$

$$\text{Now, volume of 1 cube} = .150\text{mm} \times .150\text{mm} \times .150\text{mm} = \mathbf{3.375 \times 10^{-3}m^3} = \mathbf{0.003375m^3}$$

$$\text{Thus,} \quad \text{Dry volume for } .375 \times 10^{-3}\text{m}^3 \text{ of concrete} = .375 \times 10^{-3}\text{m}^3 \times 1.54$$
$$= \mathbf{5.1975 \times 10^{-3}m^3} = \mathbf{0.0051975m^3}$$

$$\text{Cement required for 1 cube} = \frac{5.1975 \times 10^{-3}}{5.17} \times 1470 = 1.478\text{kg}$$

$$\text{cement required for 3 cubes} = 1.478 \times 3 = \mathbf{4.434kg}$$

$$\text{sand required for 1 cube} = \frac{5.1975 \times 10^{-3}}{5.17} \times 1.33 \times 1450 = 1.96\text{kg} \approx 2\text{kg}$$

$$\text{sand required for 3 cubes} = 2 \times 3 = \mathbf{6kg}$$

$$\text{Also aggregates required for 1 cube} = \frac{5.1975 \times 10^{-3}}{5.17} \times 2.84 \times 1500 = 4.28\text{kg}$$

$$\text{Thus aggregates required for 3 cubes} = 4.28 \times 3 = \mathbf{12.84kg}$$

$$\text{quantity of water to be added for 3 cubes} = 4.434 \times 0.47 = \mathbf{2.084liters}$$

Similarly, for 3 circular cylinders of dimension 0.030mm X 0.010mm calculations are carried as under:

$$\text{volume of cylinder}, \mathbf{V = \pi r^2 h}$$

$$\mathrm{v} = 3.14 \times 0.05^2 \times 0.30 = 2.355 \times 10^{-3}\mathrm{m}^3$$

$$\text{Thus, dry volume} = 2.355 \times 10^{-3} \times 1.54 = 3.63 \times 10^{-3}\mathrm{m}^3$$

$$\text{cement required for 1 cylinder} = \frac{3.63 \times 10^{-3}}{5.17} \times 1470 = 1.03\mathrm{kg}$$

$$\text{Cement required for 3 cylinders} = 1.03 \times 3 = \mathbf{3.09kg}$$

$$\text{Sand required for 1 cylinder} = \frac{3.63 \times 10^{-3}}{5.17} \times 1.33 \times 1450 = 1.35\mathrm{kg}$$

$$\text{sand required for 3 cylinders} = 1.35 \times 3 = \mathbf{4.05kg}$$

$$\text{Aggregates required for 1 cylinder} = \frac{3.63 \times 10^{-3}}{5.17} \times 2.84 \times 1500 = 2.99\mathrm{kg} \approx 3\mathrm{kg}$$

$$\text{Thus Aggregates required for 3 cylinders} = 3 \times 3 = \mathbf{9kg}$$

$$\text{quantity of water to be added for 3 cylinders} = 3.09 \times 0.47 = \mathbf{1.45liters}$$

Similarly, for 3 beams of dimensions 0.10m X0.10m X 0.50m calculations are carried as under:

$$\text{volume of beam} = 0.10\mathrm{m\ X\ } 0.10\mathrm{m\ X\ } 0.50\mathrm{m} = 5 \times 10^{-3}\mathrm{m}^3$$

$$\text{Thus dry volume} = 5 \times 10^{-3} \times 1.54 = 7.7 \times 10^{-3}\mathrm{m}^3$$

$$\text{Cement required for 1 beam} = \frac{7.7 \times 10^{-3}}{5.17} \times 1470 = 2.19\mathrm{kg}$$

$$\text{Cement required for 3 beams} = 2.19 \times 3 = \mathbf{6.57kg}$$

$$\text{Sand required for 1 beam} = \frac{7.7 \times 10^{-3}}{5.17} \times 1.33 \times 1450 = 2.88\mathrm{kg}$$

$$\text{Sand required for 3 beams} = 2.88 \times 3 = \mathbf{8.64kg}$$

$$\text{Aggregates required for 1 beam} = \frac{7.7 \times 10^{-3}}{5.17} \times 2.84 \times 1500 = 6.34\mathrm{kg}$$

$$\text{Thus Aggregates required for 3 beams} = 6.34 \times 3 = \mathbf{19.02kg}$$

$$\text{quantity of water to be added for 3 beams} = 6.57 \times 0.47 = \mathbf{3.09liters}$$

Now, Calculation for all castings:

$$\text{Total amount of cement required} = 4.434\mathrm{kg} + 3.09\mathrm{kg} + 6.57 = \mathbf{14.09kg}$$

$$\text{Total amount of sand required} = 6\mathrm{kg} + 4.05\mathrm{kg} + 8.64\mathrm{kg} = \mathbf{18.69kg}$$

$$\text{Total amount of aggregates required} = 12.84\text{kg} + 9\text{kg} + 19.02\text{kg} = \mathbf{40.86kg}$$

$$\text{Total volume of water required} = 2.084\text{liters} + 1.45\text{ liters} + 3.09\text{liters} = \mathbf{6.624liters}$$

Add 2% wastage for each.

5.4.2 Preparation of fresh concrete mix according to obtained data of 5.4.1 and check for workability and slump test to ensure correct water cement ratio:

In the next process all the obtained results are put into the practical view to analyze the results. It was seen that slump obtained was a true slump which indicated that concrete mix prepared was pumpable. This means that the adopted water cement ratio of 0.47 is correct and can further be used to carry our research work. No need of super plasticizer was observed.

Experiment Carried: Slump Test for Concrete (referring to IS: 7320- 1974)

Observations recorded:

Settlement of concrete mix = **10.5cm**

Figure 2 Slump Test for trial mix

Results:

- 10cm of settlement was observed which means that the slump obtained was the true slump in that case according to **(referring to IS: 7320- 1974).**
- Workability of concrete mix was observed to be consistent as mix obtained was easily pumpable to be used for normal construction purposes.
- Water cement ratio of **0.47** was observed to be appropriate to carry further work.

5.4.3 Test for compressive strength, split tensile strength and flexural strength at 7 days for trial mixes:

1. **Experiment Carried:** compressive strength test of 150mm X 150mm X 150mm cubes **(IS: 516)**
   Apparatus required: Digital Compression Testing Machine (CTM).
   Procedure Adopted: CTM was operated and load results were obtained simply

Figure 3 Testing of trial specimen **Figure 4 Failure of trial specimen**

Observations:

Table 8 Load Vales of CS for trial mix on 7 days

Samples	**Observed Loads (KN)**
Cube 1	415
Cube 2	430
Cube 3	424

Calculations:

$$\textbf{Rate of loading} = \mathbf{5.4KN/min}$$

$$\text{Average load } = \frac{415 + 430 + 424}{3} = 423\text{kN}$$

$$\text{Thus Compressive Strength} = \frac{423}{150 \times 150} \times 10^3 = \mathbf{18.8N/mm^2}$$

We have calculated our target strength for 28 days earlier which is;

$$\text{Target compressive strength for 28 days} = 27.67\text{N/mm}^2$$

From the researches we know that 75% of strength is gained by concrete at 7days.

Thus 75% of $27.67\text{N/mm}^2 = 75 \times \frac{1}{100} \times 27.67 = \mathbf{20.75N/mm^2}$ **(Referring to IS: 516)**

Thus our obtained CS for trial mixes is nearly equal to target strength.

Target Strength	Obtained Strength of trial mixes
20.75N/mm^2	18.8N/mm^2

2. **Experiment Carried:** Split Tensile Strength of cylinders of dimensions 100mm X 300mm **(IS: 5816- 1999)**
   Apparatus required: Digital Compression Testing Machine (CTM).
   Procedure Adopted: CTM was operated and load results were obtained simply.

Observations:

Table 9 Load values of STS for trial mix on 7days

Samples	Observed Loads (KN)
Cylinder 1	49
Cylinder 2	47
Cylinder 3	53

Calculations:

$$\text{Average Load} = \frac{49 + 47 + 53}{3} = \mathbf{49.67KN = 49670N}$$

Thus Split Tensile Strength, $\text{fct} = \frac{2P}{\pi ld} = \frac{2 \times 49670}{3.14 \times 300 \times 100} = \mathbf{1.05N/mm^2}$ **(Referring to IS:5816-1999)**

This value for 7 days is valid according to **IS:5816-1999.**

3. **Experiment Carried:** Flexural Strength of Beams of dimensions 10mm X 10mm X 50mm **(IS: 516-1959)**
   Apparatus Required: Digital Compression Testing Machine (CTM).
   Procedure Adopted: CTM was operated and load results were obtained simply with the help of 2point load system.

   Flexural Strength= 6.36N/mm^2

5.4.4 Calculation of quantities of cement, sand, aggregate and water for control samples (without wood ash):

This part included the calculation of quantities for the resources to be used for research work only for control specimen. An analysis of no. of specimens to be casted are given as:

Table 10 No. of castings for control specimen

No. of Days	Cubes (150mm× 150mm×150mm) For CS	Cylinders for STS	Beams for FS	Cubes(70mm ×70mm ×70mm) for carbonation	Cubes(70mm ×70mm ×70mm) for shrinkage
7	3	3	3	3	3
28	3	3	3	3	3
56	3	3	3	-	-
90	3	3	3	-	-
Total	**12**	**12**	**12**	**6**	**6**

Quantity of Cement, sand, aggregates and water required for 150mm × 150mm × 150mm Cubes:

$$\text{Dry volume for 1 cum of concrete } = 1 \times 1.54 = \mathbf{1.54m^3}$$

$$\text{Now, volume of 1 cube} = .150\text{m} \times .150\text{m} \times .150\text{m} = \mathbf{3.375 \times 10^{-3}m^3} = \mathbf{0.003375m^3}$$

$$\text{Thus, Dry volume for } 3.375 \times 10^{-3}\text{m}^3 \text{ of concrete} = .375 \times 10^{-3}\text{m}^3 \times 1.54 = \mathbf{5.1975 \times 10^{-3}m^3} = \mathbf{0.0051975m^3}$$

$$\text{Cement required for 1 cube} = \frac{5.1975 \times 10^{-3}}{5.17} \times 1470 = 1.478\text{kg}$$

$$\text{cement required for 12 cubes} = 1.478 \times 12 = \mathbf{17.736kg}$$

$$\text{Sand required for 12 cubes} = 17.736 \times 1.33 = \mathbf{23.59kg}$$

$$\text{Aggregates required for 12 cubes} = 17.736 \times 2.84 = \mathbf{50.37kg}$$

$$\text{Volume of water required for 12 cubes} = 17.736 \times 0.47 = \mathbf{8.34liters}$$

Quantity of Cement, sand, aggregates and water required for 30Cm × 10Cm cylinders:

$$\text{volume of cylinder, } \mathbf{V = \pi r^2 h}$$

$$v = 3.14 \times 0.05^2 \times 0.30 = 2.355 \times 10^{-3}\text{m}^3$$

$$\text{Thus, dry volume} = 2.355 \times 10^{-3} \times 1.54 = 3.63 \times 10^{-3}\text{m}^3$$

$$\text{cement required for 1 cylinder} = \frac{3.63 \times 10^{-3}}{5.17} \times 1470 = 1.03\text{kg}$$

$$\text{Cement required for 12 cylinders} = 1.03 \times 12 = \mathbf{12.36kg}$$

$$\text{Sand required for 12 cylinders} = 12.36 \times 1.33 = \mathbf{16.44kg}$$

$$\text{Aggreate required for 12 cylinders} = 12.36 \times 2.84 = \mathbf{35.10kg}$$

$$\text{Volume of water required for 12 cylinders} = 12.36 \times 0.47 = \mathbf{5.81liters}$$

Quantity of Cement, sand, aggregates and water required for 10Cm × 1Cm × 50Cm of beams

$$\text{volume of beam} = 0.10\text{m X } 0.10\text{m X } 0.50\text{m} = 5 \times 10^{-3}\text{m}^3$$

$$\text{Thus dry volume} = 5 \times 10^{-3} \times 1.54 = 7.7 \times 10^{-3}\text{m}^3$$

$$\text{Cement required for 1 beam} = \frac{7.7 \times 10^{-3}}{5.17} \times 1470 = 2.19\text{kg}$$

$$\text{Cement required for 12 beams} = 2.19 \times 12 = \mathbf{26.28kg}$$

$$\text{Sand required for 12 beams} = 26.28 \times 1.33 = \mathbf{34.95kg}$$

$$\text{Aggreate required for 12 beams} = 26.28 \times 2.84 = \mathbf{74.63kg}$$

$$\text{Volume of water required for 12 beams} = 26.28 \times 0.47 = \mathbf{12liters}$$

Quantity of Cement, sand, aggregates and water required for 70Cm × 70m × 70Cm of cubes.

$$\text{Dry volume for 1 cum of concrete } = 1 \times 1.54 = \mathbf{1.54m^3}$$

$$\text{Now, volume of 1 cube} = .070\text{m} \times .070\text{m} \times .070\text{m} = \mathbf{3.343 \times 10^{-4}m^3}$$

Thus, $\text{Dry volume for } 3\,.375 \times 10^{-4}\text{m}^3 \text{ of concrete} = 3.375 \times 10^{-4}\text{m}^3 \times 1.54$
$= \mathbf{5.197 \times 10^{-4}m^3}$

$$\text{Cement required for 1 cube} = \frac{5.197 \times 10^{-4}}{5.17} \times 1470 = 0.15\text{kg}$$

$$\text{cement required for 12 smaller cubes} = 0.15 \times 12 = \mathbf{1.8kg}$$

$$\text{Sand required for 12 smaller cubes} = 1.8 \times 1.33 = \mathbf{2.39kg}$$

$$\text{Aggreate required for 12 smaller cubes} = 1.8 \times 2.84 = \mathbf{5.11kg}$$

$$\text{Volume of water required for 12 smaller cubes} = 1.8 \times 0.47 = \mathbf{0.846liters}$$

Now,

$$\text{Total no. of castings} = 12 + 12 + 12 + 6 + 6 = \mathbf{48}$$

Total quantity of Cement required for 48 castings $= 17.736 + 12.36 + 26.28 + 1.8 = \mathbf{58.176kg}$

Total quantity of Sand required for 48 castings $= 2.59 + 16.44 + 34.95 + 2.39 = \mathbf{77.37kg}$

Total quantity of aggregates required for 48 castings $= 50.37 + 35.10 + 74.63 + 5.11 = \mathbf{165.21kg}$

Total volume of Water required for 48 castings $= 8.34 + 5.81 + 12 + 0.846 = \mathbf{26.99liters} \approx \mathbf{27liters}$

Check for Fresh Properties of Control Specimen:

Workability: Slump test was carried to ensure the exact water cement ratio of 0.47 as valid. Mix was consistent enough to be used for normal construction purposes. A true slump was observed. Same as trial mix.

Casting: All the cubes, cylinders and beams were casted for 7,28,56 and 90 days.

Curing: It was carried in a curing tank immediately after dissembling the moulds.

5.4.5 Calculation of quantities of cement, sand, aggregate and water for samples with 5% wood ash by weight of OPC:

Below table will provide an exact detail about the number of castings with 5% replacement of OPC.

Table 11 No. of castings with 5% WA

No. of Days	Cubes (150mm× 150mm×150mm) For CS	Cylinders for STS	Beams for FS	Cubes(70mm ×70mm ×70mm) for carbonation	Cubes(70mm ×70mm ×70mm) for shrinkage
7	3	3	3	3	3
28	3	3	3	3	3
56	3	3	3	-	-
90	3	3	3	-	-
Total	**12**	**12**	**12**	**6**	**6**

The quantities of all the materials to be used will remain same except OPC which is to be replaced by 5% of wood ash.

Thus,

$$\text{Total no. of castings} = 12 + 12 + 12 + 6 + 6 = \mathbf{48}$$

$$\text{Total quantity of Cement required for 48 castings } = 58.176\text{kg}$$

&

$$\text{Quantity of cement to be replaced by wood ash} = 5\% \text{ of } 58.176 = \frac{5}{100} \times 58.176 = 2.91\text{kg}$$

Thus, $$\text{Required quantity of Cement} = 58.176 - 2.91 = \mathbf{55.266kg}$$

$$\text{Required quantity of wood ash to be added} = \mathbf{2.91kg}$$

Also

$\text{Total quantity of Sand required for 48 castings} = 2.59 + 16.44 + 34.95 + 2.39 = \mathbf{77.37kg}$

$\text{Total quantity of aggregates required for 48 castings} = 50.37 + 35.10 + 74.63 + 5.11 = \mathbf{165.21kg}$

$\text{Total volume of Water required for 48 castings} = 8.34 + 5.81 + 12 + 0.846 = \mathbf{26.99liters} \approx \mathbf{27liters}$

Table: Required quantities with 5% replacement of OPC with Wood Ash

Wood ash (kg)	Cement (kg)	Sand (kg)	Aggregate (kg)	Water (liters)
2.91	55.266	77.37	165.21	27

5.4.6 Calculation of quantities of cement, sand, aggregate and water for samples with 10% wood ash by weight of OPC:

Below table will provide an exact detail about the number of castings with 10% replacement of OPC.

Table 12 No. of castings with 10% WA

No. of Days	Cubes (150mm× 150mm×150mm) For CS	Cylinders for STS	Beams for FS	Cubes(70mm ×70mm ×70mm) for carbonation	Cubes(70mm ×70mm ×70mm) for shrinkage
7	3	3	3	3	3
28	3	3	3	3	3

56	3	3	3	-	-
90	3	3	3	-	-
Total	**12**	**12**	**12**	**6**	**6**

The quantities of all the materials to be used will remain same except OPC which is to be replaced by 10% of wood ash.

Thus,

$$\text{Total no. of castings} = 12 + 12 + 12 + 6 + 6 = \mathbf{48}$$

$$\text{Total quantity of Cement required for 48 castings } = 58.176\text{kg}$$

& $\quad \text{Quantity of cement to be replaced by wood ash} = 10\% \text{ of } 58.176 = \frac{10}{100} \times 58.176 = 5.82\text{kg}$

Thus, $\quad \text{Required quantity of Cement} = 58.176 - 5.82 = \mathbf{52.36kg}$

$$\text{Required quantity of wood ash to be added} = \mathbf{5.82kg}$$

Also

$\text{Total quantity of Sand required for 48 castings} = 2.59 + 16.44 + 34.95 + 2.39 = \mathbf{77.37kg}$

$\text{Total quantity of aggregates required for 48 castings} = 50.37 + 35.10 + 74.63 + 5.11 = \mathbf{165.21kg}$

$\text{Total volume of Water required for 48 castings} = 8.34 + 5.81 + 12 + 0.846 = \mathbf{26.99liters} \approx \mathbf{27liters}$

Table: Required quantities with 10% replacement of OPC with Wood Ash

Wood ash (kg)	Cement (kg)	Sand (kg)	Aggregate (kg)	Water (liters)
5.82	52.36	77.37	165.21	27

5.4.7 Calculation of quantities of cement, sand, aggregate and water for samples with 15% wood ash by weight of OPC:

Below table will provide an exact detail about the number of castings with 15% replacement of OPC.

Table 13 No. of castings with 15% WA

No. of Days	Cubes (150mm× 150mm×150mm) For CS	Cylinders for STS	Beams for FS	Cubes(70mm ×70mm ×70mm) for carbonation	Cubes(70mm ×70mm ×70mm) for shrinkage
7	3	3	3	3	3

28	3	3	3	3	3
56	3	3	3	-	-
90	3	3	3	-	-
Total	**12**	**12**	**12**	**6**	**6**

The quantities of all the materials to be used will remain same except OPC which is to be replaced by 15% of wood ash.

Thus,

$$\text{Total no. of castings} = 12 + 12 + 12 + 6 + 6 = \mathbf{48}$$

$$\text{Total quantity of Cement required for 48 castings} \; = 58.176\text{kg}$$

& $\quad \text{Quantity of cement to be replaced by wood ash} = 15\% \text{ of } 58.176 = \frac{15}{100} \times 58.176 = 8.73\text{kg}$

Thus, $\quad \text{Required quantity of Cement} = 58.176 - 8.73 = \mathbf{49.45kg}$

$$\text{Required quantity of wood ash to be added} = \mathbf{8.73kg}$$

Also

$\text{Total quantity of Sand required for 48 castings} = 2.59 + 16.44 + 34.95 + 2.39 = \mathbf{77.37kg}$

$\text{Total quantity of aggregates required for 48 castings} = 50.37 + 35.10 + 74.63 + 5.11 = \mathbf{165.21kg}$

$\text{Total volume of Water required for 48 castings} = 8.34 + 5.81 + 12 + 0.846 = \mathbf{26.99liters} \approx \mathbf{27liters}$

Table: Required quantities with 15% replacement of OPC with Wood Ash

Wood ash (kg)	**Cement (kg)**	**Sand (kg)**	**Aggregate (kg)**	**Water (liters)**
8.73	49.45	77.37	165.21	27

5.4.8 Calculation of quantities of cement, sand, aggregate and water for samples with 20% wood ash by weight of OPC:

Below table will provide an exact detail about the number of castings with 20% replacement of OPC.

Table 14 No. of castings with 20% WA

No. of Days	**Cubes (150mm× 150mm×150mm)**	**Cylinders for STS**	**Beams for FS**	**Cubes(70mm ×70mm ×70mm) for**	**Cubes(70mm ×70mm ×70mm) for**

	For CS			carbonation	shrinkage
7	3	3	3	3	3
28	3	3	3	3	3
56	3	3	3	-	-
90	3	3	3	-	-
Total	**12**	**12**	**12**	**6**	**6**

The quantities of all the materials to be used will remain same except OPC which is to be replaced by 10% of wood ash.

Thus,

$$\text{Total no. of castings} = 12 + 12 + 12 + 6 + 6 = \mathbf{48}$$

$$\text{Total quantity of Cement required for 48 castings } = 58.176\text{kg}$$

& $\text{Quantity of cement to be replaced by wood ash} = 20\% \text{ of } 58.176 = \frac{20}{100} \times 58.176 = 11.64\text{kg}$

Thus, $\text{Required quantity of Cement} = 58.176 - 11.64 = \mathbf{46.54kg}$

$$\text{Required quantity of wood ash to be added} = \mathbf{11.64kg}$$

Also

$\text{Total quantity of Sand required for 48 castings} = 2.59 + 16.44 + 34.95 + 2.39 = \mathbf{77.37kg}$

$\text{Total quantity of aggregates required for 48 castings} = 50.37 + 35.10 + 74.63 + 5.11 = \mathbf{165.21kg}$

$\text{Total volume of Water required for 48 castings} = 8.34 + 5.81 + 12 + 0.846 = \mathbf{26.99liters} \approx \mathbf{27liters}$

Table: Required quantities with 20% replacement of OPC with Wood Ash

Wood ash (kg)	Cement (kg)	Sand (kg)	Aggregate (kg)	Water (liters)
11.64	46.54	77.37	165.21	27

5.4.9 Calculation of quantities of cement, sand, aggregate and water for samples with 25% wood ash by weight of OPC:

Below table will provide an exact detail about the number of castings with 25% replacement of OPC.

Table 15 No. of castings with 25% WA

No. of Days	Cubes (150mm× 150mm×150mm)	Cylinders for STS	Beams for FS	Cubes(70mm ×70mm ×70mm) for	Cubes(70mm ×70mm ×70mm) for

	For CS			carbonation	shrinkage
7	3	3	3	3	3
28	3	3	3	3	3
56	3	3	3	-	-
90	3	3	3	-	-
Total	**12**	**12**	**12**	**6**	**6**

The quantities of all the materials to be used will remain same except OPC which is to be replaced by 25% of wood ash.

Thus,

$$\text{Total no. of castings} = 12 + 12 + 12 + 6 + 6 = \mathbf{48}$$

$$\text{Total quantity of Cement required for 48 castings } = 58.176\text{kg}$$

& $\quad \text{Quantity of cement to be replaced by wood ash} = 15\% \text{ of } 58.176 = \frac{25}{100} \times 58.176 = 14.54\text{kg}$

Thus, $\quad \text{Required quantity of Cement} = 58.176 - 14.54 = \mathbf{43.63kg}$

$$\text{Required quantity of wood ash to be added} = \mathbf{14.54kg}$$

Also

$\text{Total quantity of Sand required for 48 castings} = 2.59 + 16.44 + 34.95 + 2.39 = \mathbf{77.37kg}$

$\text{Total quantity of aggregates required for 48 castings} = 50.37 + 35.10 + 74.63 + 5.11 = \mathbf{165.21kg}$

$\text{Total volume of Water required for 48 castings} = 8.34 + 5.81 + 12 + 0.846 = \mathbf{26.99liters} \approx \mathbf{27liters}$

Table: Required quantities with 25% replacement of OPC with Wood Ash

Wood ash (kg)	Cement (kg)	Sand (kg)	Aggregate (kg)	Water (liters)
14.54	43.63	77.37	165.21	27

5.5 Testing of Specimen at 7days

5.5.1 Testing of Control Specimen:

Compressive Strength test at 7days (control Specimen): A digital CTM was used to carry the test. Rate of loading was fixed as 5.4KN/minute.

Observations:

Table 16 Load values of CS for Control Specimen on 7 days

Samples	Observed Loads (KN)
Cube 1	425
Cube 2	441
Cube 3	413

Calculations:

$$Rate\ of\ loading = 5.4KN/min$$

$$Average\ load\ = \frac{425 + 441 + 413}{3} = 426.33kN$$

$$Thus\ Compressive\ Strength = \frac{426.33}{150 \times 150} \times 10^3 = \mathbf{18.95N/mm^2}$$

We have calculated our target strength for 28 days earlier which is;

$$Target\ compressive\ strength\ for\ 28\ days\ =\ 27.67N/mm^2$$

From the researches we know that 75% of strength is gained by concrete at 7days.

$Thus\ 75\%\ of\ 27.67N/mm^2 = 75 \times \frac{1}{100} \times 27.67 = \mathbf{20.75N/mm^2}$ **(Referring to IS: 516)**

Thus our obtained CS for trial mixes is nearly equal to target strength.

Target Strength	Obtained Strength of trial mixes
$20.75N/mm^2$	$18.95N/mm^2$

Split Tensile Strength at 7days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute

Observations:

Table 17 Load values of STS for Control Specimen on 7days

Samples	Observed Loads (KN)
Cylinder 1	79
Cylinder 2	84
Cylinder 3	72

Calculations:

$$\text{Rate of loading} = 2.6\text{KN/min}$$

$$\text{Average Load} = \frac{79 + 84 + 72}{3} = \mathbf{78.33KN = 78330N}$$

Thus Split Tensile Strength, $fct = \frac{2P}{\pi ld} = \frac{2 \times 78330}{3.14 \times 300 \times 100} = \mathbf{1.66 N/mm^2}$ **(Referring to IS:5816-1999)**

This value for 7 days is valid according to **IS:5816-1999.**

Flexural Strength at 7days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute. A 2point loading system was used.

Flexural Strength= **4.91N/mm^2** which is valid according to **IS:516-1959**

5.5.2 Testing of Specimen with varying wood ash content as partial replacer for OPC for 7days

Similar Procedure was adopted as for control specimen for 7days. The obtained results from the calculations are given as under:

Figure 5 C.S test at 7days with WA

Figure 6 STS test at 7days

Table 18 Values of CS, STS, FS and Carbonation on 7days testing

Wood Ash %	Compressive Strength N/mm^2	Split Tensile Strength N/mm^2	Flexural Strength N/mm^2	Cubes(70mm ×70mm ×70mm) for carbonation
0	18.95	1.66	4.91	
5	16.43	1.07	4.26	
10	17.08	1.31	4.57	
15	17.85	1.44	4.11	
20	16.96	1.25	3.74	
25	16.31	1.11	3.62	

5.6 Testing of Specimen at 28days

5.6.1 Testing of control specimen:

Compressive Strength test at 28days: A digital CTM was used to carry the test. Rate of loading was fixed as 5.4KN/minute

Observations:

Table 19 Load values of CS for Control Specimen on 28days

Samples	**Observed Loads (KN)**
Cube 1	728
Cube 2	746
Cube 3	721

Calculations:

$$\text{Rate of loading} = 5.4\text{KN/min}$$

$$\text{Average load } = \frac{728 + 746 + 721}{3} = 731.67\text{kN}$$

$$\text{Thus Compressive Strength} = \frac{731.67}{150 \times 150} \times 10^3 = \mathbf{32.51 N/mm^2}$$

We have calculated our target strength for 28 days earlier which is;

Target compressive strength for 28 days $= 27.67\text{N/mm}^2$ **(Referring to IS: 516)**

Thus our obtained CS for trial mixes is greater than the target strength.

Target Strength	**Obtained Strength of trial mixes**
$27.67 N/mm^2$	$32.51 N/mm^2$

Split Tensile Strength at 28days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute

Observations:

Table 20 Load values of STS for Control Specimen on 28days

Samples	**Observed Loads (KN)**
Cylinder 1	116
Cylinder 2	126
Cylinder 3	121

Calculations:

$$\text{Rate of loading} = 2.6\text{KN/min}$$

$$\text{Average Load} = \frac{116 + 126 + 121}{3} = \mathbf{121.00KN = 121000N}$$

Thus Split Tensile Strength, $\text{fct} = \frac{2P}{\pi ld} = \frac{2\times121000}{3.14\times300\times100} = \mathbf{2.57N/mm^2}$ **(Referring to IS:5816-1999)**

This value for 28days is valid according to **IS:5816-1999.**

Flexural Strength at 28days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute. A 2point loading system was used.

Flexural Strength= **6.89/mm^2** which is valid according to **IS:516-1959**

5.6.2 Testing of Specimen with varying wood ash content as partial replacer for OPC for 28days

Similar Procedure was adopted as for control specimen for 28days. The obtained results from the calculations are given as under:

Figure 7 STS test at 28days

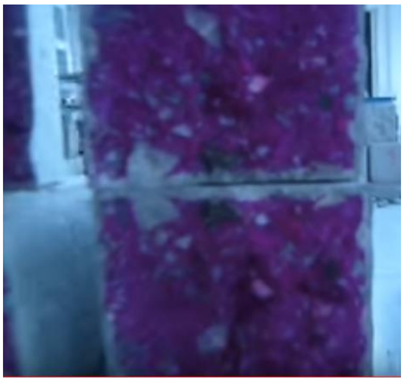

Figure 8 Carbonation Test on 28 days

Table 21 Values of CS, STS, FS and Carbonation on 28days testing

Wood Ash %	**Compressive Strength** $\mathbf{N/mm^2}$	**Split Tensile Strength** $\mathbf{N/mm^2}$	**Flexural Strength** $\mathbf{N/mm^2}$	
0	32.51	2.57	6.89	
5	30.22	1.96	6.19	
10	31.11	2.15	6.53	
15	31.86	2.37	6.01	

20	30.61	2.21	5.92	
25	30.14	2.05	5.85	

5.7 Testing of Specimen at 56days

5.7.1 Testing of control Specimen:

Compressive Strength test at 56days: A digital CTM was used to carry the test. Rate of loading was fixed as 5.4KN/minute

Observations:

Table 22 Load values of CS for Control Specimen on 56days

Samples	Observed Loads (KN)
Cube 1	794
Cube 2	811
Cube 3	827

Calculations:

$$\text{Rate of loading} = 5.4\text{KN/min}$$

$$\text{Average load} = \frac{794 + 811 + 827}{3} = 810.67\text{kN}$$

$$\text{Thus Compressive Strength} = \frac{810.67}{150 \times 150} \times 10^3 = \mathbf{36.03 N/mm^2}$$

We have calculated our target strength for 28 days earlier which is;

Target compressive strength for 28 days $= 27.67\text{N/mm}^2$**(Referring to IS: 516)**

Thus our obtained CS for trial mixes is greater than the target strength.

Target Strength	Obtained Strength of trial mixes
$27.67N/mm^2$	$36.03N/mm^2$

Split Tensile Strength at 56days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute

Observations:

Table 23 Load values of STS for Control Specimen on 56days

Samples	Observed Loads (KN)

Cylinder 1	164
Cylinder 2	178
Cylinder 3	171

Calculations:

$$\text{Rate of loading} = 2.6\text{KN/min}$$

$$\text{Average Load} = \frac{164 + 178 + 171}{3} = \mathbf{171.00KN = 171000N}$$

Thus Split Tensile Strength, $fct = \frac{2P}{\pi ld} = \frac{2\times171000}{3.14\times300\times100} = \mathbf{3.63N/mm^2}$ **(Referring to IS:5816-1999)**

This value for 90days is valid according to **IS:5816-1999.**

Flexural Strength at 56days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute. A 2point loading system was used.

Flexural Strength= **7.84N/mm^2** which is valid according to **IS:516-1959**

5.7.2 Testing of Specimen with varying wood ash content as partial replacer for OPC for 56days

Similar Procedure was adopted as for control specimen for 56days. The obtained results from the calculations are given as under:

Figure 9 CS test on 56days

Figure 10 FS test on 56days

Table 24 Values of CS, STS and FS on 56days testing

Wood Ash %	Compressive	Split Tensile	Flexural

	Strength $\mathbf{N/mm^2}$	**Strength** $\mathbf{N/mm^2}$	**Strength** $\mathbf{N/mm^2}$
0	36.03	3.63	7.84
5	33.68	2.93	7.23
10	34.95	3.16	7.58
15	35.76	3.42	6.95
20	34.18	3.09	6.77
25	33.91	2.94	6.64

5.8 Testing of Specimen at 90days

5.8.1 Testing of control Specimen:

Compressive Strength test at 90days: A digital CTM was used to carry the test. Rate of loading was fixed as 5.4KN/minute

Observations:

Table 25 Load values of CS for Control Specimen on 90days

Samples	**Observed Loads (KN)**
Cube 1	882
Cube 2	875
Cube 3	866

Calculations:

$$\text{Rate of loading} = 5.4\text{KN/min}$$

$$\text{Average load} \;=\; \frac{882 + 875 + 866}{3} = 874.33\text{kN}$$

$$\text{Thus Compressive Strength} = \frac{874.33}{150 \times 150} \times 10^3 = \mathbf{38.86N/mm^2}$$

We have calculated our target strength for 28days earlier which is;

Target compressive strength for 28days $= 27.67\text{N/mm}^2$ **(Referring to IS: 516)**

Thus our obtained CS for trial mixes is greater than the target strength.

Target Strength	**Obtained Strength of trial mixes**

$27.67N/mm^2$	$38.86N/mm^2$

Split Tensile Strength at 90days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute

Observations:

Table 26 Load values of STS for Control Specimen on 90days

Samples	Observed Loads (KN)
Cylinder 1	198
Cylinder 2	192
Cylinder 3	196

Calculations:

$$\text{Rate of loading} = 2.6\text{KN/min}$$

$$\text{Average Load} = \frac{198 + 192 + 196}{3} = \mathbf{195.33KN = 1195330N}$$

Thus Split Tensile Strength, $\text{fct} = \frac{2P}{\pi ld} = \frac{2\times195330}{3.14\times300\times100} = \mathbf{4.15N/mm^2}$ **(Referring to IS:5816-1999)**

This value for 56days is valid according to **IS:5816-1999.**

Flexural Strength at 90days: A digital CTM was used to carry the test. Rate of loading was fixed as 2.6KN/minute. A 2point loading system was used.

Flexural Strength= $\mathbf{8.44N/mm^2}$ which is valid according to **IS:516-1959**

5.8.2 Testing of Specimen with varying wood ash content as partial replacer for OPC for 90days

Similar Procedure was adopted as for control specimen for 90days. The obtained results from the calculations are given as under:

Figure 11 CS test on 90days

Figure 12 FS test on 90days

Table 27: Values of CS, STS and FS on 90days testing

Wood Ash %	Compressive Strength N/mm^2	Split Tensile Strength N/mm^2	Flexural Strength N/mm^2
0	38.86	4.15	8.44
5	36.17	3.06	7.66
10	36.93	3.45	8.17
15	37.62	3.86	7.72
20	37.04	3.51	7.59
25	36.57	3.33	7.51

CHAPTER 6

RESULTS AND DISCUSSION

6.1 Fresh Properties of Concrete with Wood Ash as Replacer

6.1.1 Workability: Adopting the w/c ratio of 0.47 the workability of the concrete 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. Beyond 10% replacement workability decreased proportionally. A true slump was observed in all cases.

Table 1 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

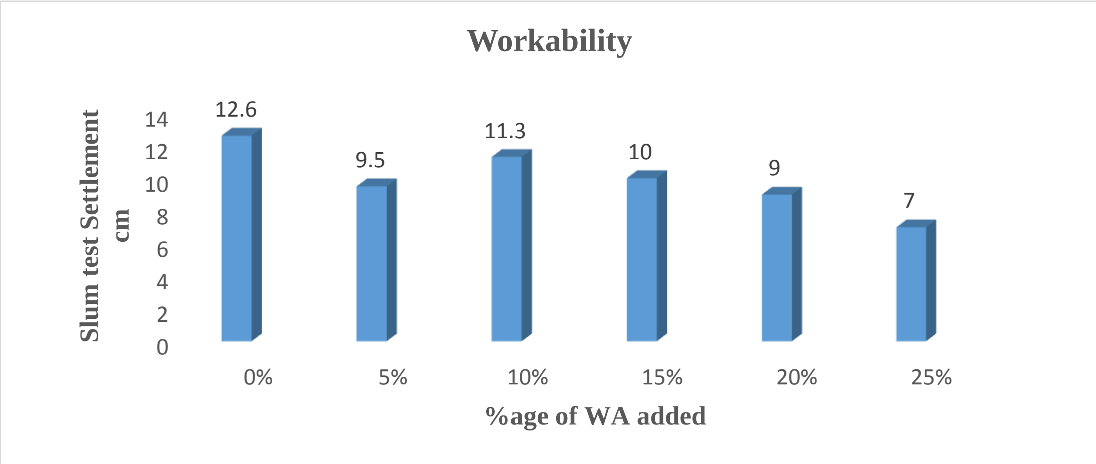

Figure 1 Change in workability with WA

6.2 Hardened Properties of Concrete

6.2.1 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 2:**

The conclusions drawn based on the results are:

(1) The compressive strength for the control mixes for 7days, 28days, 56days and 90days obtained were 18.95N/mm^2, 32.51 N/mm^2, 36.03N/mm^2 and 38.86 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 2:**

(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 control specimen, as the development of cracks started increasing slowly under same rate of loading.

(a) **(b)**

Figure 2 Compressive Strength Testing

Table 2: Values of CS for all days with and without WA

%age of wood ash added	7 days	28 days	56 days	90 days
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

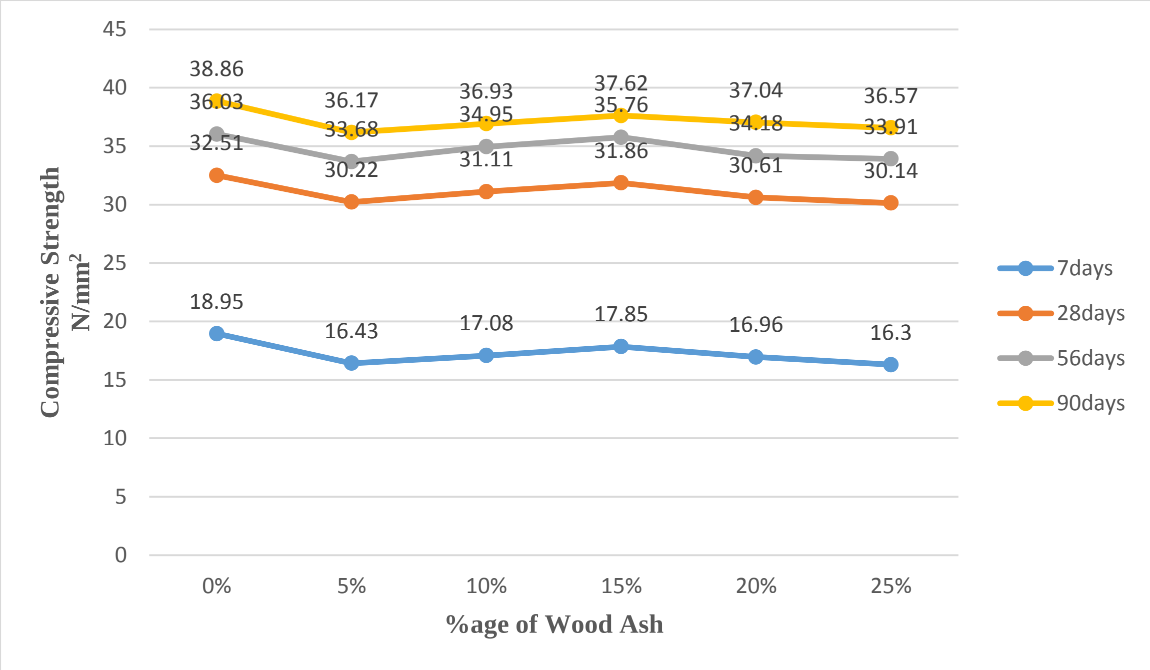

Figure 3 Variation of compressive strength with addition of wood ash

The variation gap of strength between 28days and 56days is much higher which is because of the maximum pozzolonic reaction in that period. Concrete gains 75% of strength in 7days and almost 95% to 98% of strength in 28days. Rest of the period the increase of strength can be seen to be very slow. From the graph it can be concluded that the control specimen has the maximum strength but there is an efficient increase with wood ash at 15% which can be considered as an optimum content and thus can be used in casting.

6.2.2 Split tensile strength:

The procedure was carried according to **IS:5816-1999 [19].** The split tensile strength of the concrete with wood ash increased. The enhancement in split tensile strength was because of proper binding and insignificant surface area of binding particles **(Table 3)**. But the increase was not higher than the control mix. We can say almost same results were obtained for 15% as the control specimen.

(1) The average split tensile strength achieved by the control specimens for 7 days, 28 days and 56 days were 2.32 N/mm^2, 3.64 $N/mm^2$and 4.16 N/mm^2, respectively.

(2) The strength of concrete along with the wood ash varied accordingly given in **Table 3:** The Optimum results were obtained on **15%** replacement.

(3) Increase in the split tensile strength is because of the enhanced quality of cement paste due to addition of wood ash.

(4) The failure for control specimen was brittle which resulted its splitting in two equal halves whereas when wood ash was incorporated the failure observed was not sudden but quite uniform upon load condition as given in figure:

Figure 4 Failure of control specimen

Figure 5 Failure of Specimen along WA

Table 3 Values of STS for all days with and without WA

%age of wood ash added	Split tensile strength at 7days (N/mm^2)	Split tensile strength at 28days (N/mm^2)	Split tensile strength at 56days (N/mm^2)	Split tensile strength at 90days (N/mm^2)
0%	1.66	2.57	3.63	8.44
5%	1.07	1.96	2.93	7.66
10%	1.31	2.15	3.16	7.82
15%	1.44	2.37	3.42	8.17
20%	1.25	2.21	3.09	7.91
25%	1.11	2.05	2.94	7.53

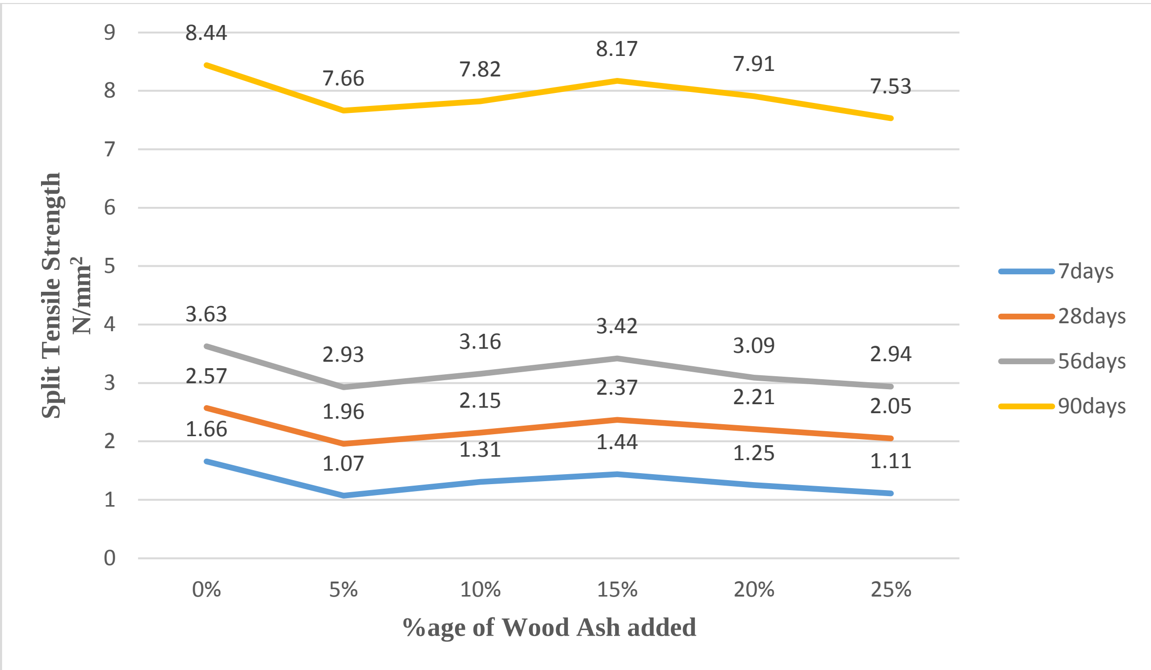

Figure 6 Variation of Split tensile strength with the addition of wood ash

6.2.3 Flexural Strength:

Beams were casted having dimensions of 300mm X 10mm X 10mm to check flexural strength as per **IS: 516 – 1959 [20]**. Vibration of mix was done on vibrating machine according to IS recommendations. A system of 2point loading was used with CTM to test the specimens. It was observed that there was an increase in the flexural strength specimens with wood ash but not greater than control specimens. Optimum results were obtained at 10% replacement. The results are given in **Table 4.**

An increase in the ductile behavior was observed when wood ash was added.

Figure 7 FS test without WA

Figure 8 FS test with WA

Table 4 Values of FS for all days with and without WA

%age of wood ash	Flexural strength at 7days (N/mm^2)	Flexural strength at 28days (N/mm^2)	Flexural strength at 56days (N/mm^2)	Flexural strength at 90days (N/mm^2)
0%	4.91	6.89	7.84	8.44
5%	4.26	6.19	7.23	7.66
10%	4.57	6.53	7.58	8.17
15%	4.11	6.01	6.95	7.72
20%	3.74	5.92	6.77	7.59
25%	3.62	5.85	6.64	7.51

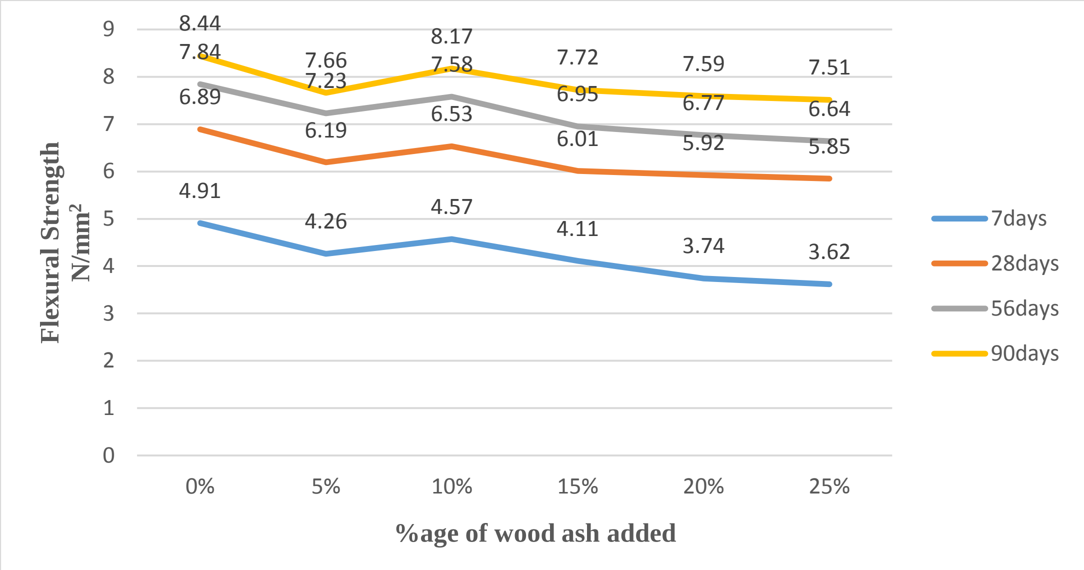

Figure 9 Variation of Flexural Strength with wood ash

6.2.4 Water absorption:

An increases in water absorption was observed maximum for 15% at 28 days which indicates that rate of pozzolonic reaction is much higher at 15% replacement. Beyond 15% replacement the water absorption significantly decreased.

6.3 Durability Properties

6.3.1 Carbonation:

The carbonation results along with the wood ash as partial replacement when water cement ratio of 0.47 was observed to decrease providing optimum results at 5% of replacement. From other researches similar results were observed. The tests for carbonation showed that with 5% incorporation of wood ash in cement resulted in reduction in depth of carbonation. With the 10%, 15% & 25% the reduction in depth was insignificant**.** This test was conducted with the help phenolphthalein solution (white pale yellow solution) which when brought in contact with our alkaline concrete specimen changed the color to pink. Control specimen when sprayed with the indicator developed purple color showing PH value less than 8.6. But with the addition of wood ash depth of carbonation decreased at 5%. The indicator did not change the color on all sides predicting that these near surface regions were carbonated.

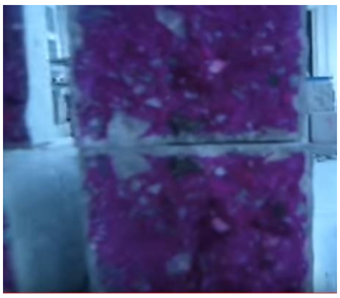

Figure 10 Carbonation Test

Table 5 Carbonation depth with and without WA

%age of wood ash added	Depth of carbonation on 7days (mm)	Depth of carbonation on 28days (mm)
0%	1.82	1.86
5%	1.35	1.29
10%	2.41	2.45
15%	2.58	2.63
20%	3.19	3.24
25%	3.74	3.82

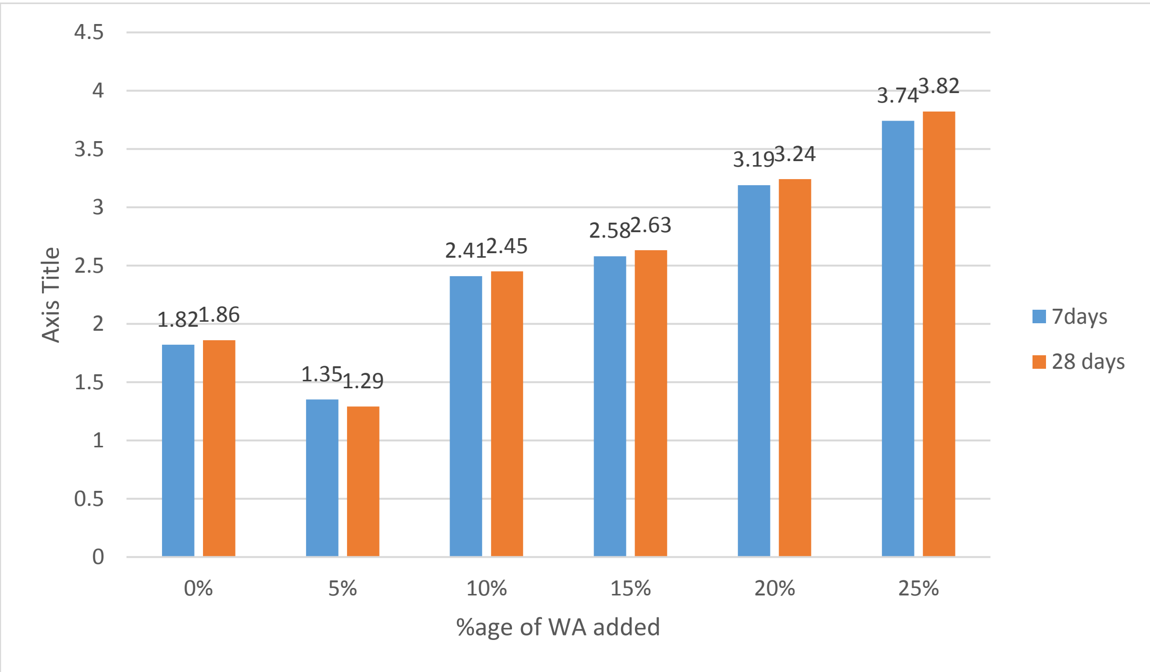

Figure 11 Variation of Carbonation depth with WA

CHAPTER 7

CONCLUSION

7.1 Conclusion for conducted research

Following are some of the investigated conclusions from the above study:

(1) 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.
(2) Workability was consistent at 0.47 of water cement ratio. No need of any superplasticizer was observed.
(3) 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.
(4) 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.
(5) Setting Time was observed to decrease as the mix when prepared got stiffer in lesser time.
(6) 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.
(7) Incorporation of wood ash enhanced the quality of paste, thereby increasing both split tensile strength and flexural strength of concrete.
(8) An increase in flexural strength was observed at 10% replacement. The increase was not up to the level of control specimen.
(9) Depth of carbonation decreased with the addition of wood ash. Optimum results were obtained at 5% replacement both for 7days and 28days.

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