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Study on Properties of Concrete with Partial Replacement of Cement with Wood Ash

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Abstract:- *With increasing industrialisation, the large extent of industrial by-products (wastes) are accumulated, leading to environmental pollution. So, this study focus the safe and economical reduction of these wastes. Wood Ash (WA) is the residue produced by the uncontrolled burning of wood for power generation and other purpose. The cement manufacturing industries will produce large amount of carbon dioxide to the environment these may cause greenhouse effect. The utilisation of Wood Ash as partial replacement of cement reduces the environmental and ecological problems. This paper intends to present the result of various experimental investigation leading with concrete incorporating Wood Ash replacing Ordinary Portland cement(43 grade) in concrete with various Infrastructure development across the world creates demand for construction materials. Concrete is the premier material civil engineering construction. Concrete manufacturing involve consumption of ingredients like cement, natural aggregates, water and admixtures. The production of Concrete requires huge quantities of cement. Cement production is not only energy consuming, is also responsible for a considerable part of manmade carbon dioxide emission which, along* With other greenhouse gases lead to global warming. From this point of view, cement is not an environmental- friendly material. The best way to reduce the CO_2 emission from cement manufacturing process by replacing cement with locally available by-products which are pozzolanic in nature. Ashes are one such by-product available around us from various sources from industries to agriculture. A part of these renewable resources is made by biomass resources including forestry and agricultural wastes. Forestry and agricultural biomasses are considered as efficient sources of fuel for energy production as their availability in abundance and are cheap. The residual solid wastes of these agricultural products are produced by thermal incineration which is environmentally safe and more economic. These Wood Ash can be obtained in abundance from industries which require wood as their fuel for operating the boiler units. The wood ash containing calcium oxides, aluminium, iron, silicon etc. These chemical composition of wood ash shows that it has pozzolanic property and using it as partial replacement of cement, which helps in avoiding bulk consumption of pure cement. The production of cement material all alone results in increased emission of certain greenhouse gases will cause environmental pollution. Hence replacing with wood ash will helps to reduce the production of cement for concrete, thus proving environmentally safe. Apart from this, this replacing technique reduces the cost also which will result an economic sustainable construction.

percentages (0%, 3%, 5%, 7% and 9%). The chemical characterisation of wood ash is done by XRD Test. The workability properties (slump test) and mechanical strength properties (compressive, split tensile and flexural strength) are determined and were compared with control M-20 mix.

Key words: Wood Ash, cement replacement, ordinary Portland cement, XRD Test, workability properties, slump test, compaction factor test, mechanical properties, compressive strength, split tensile strength and flexural strength.

1. INTRODUCTION

This replacing technique reduces the cost also which will result an economic sustainable construction. In this work the suitability of using Wood Ash as an alternative to Ordinary Portland Cement (43 Grade) is studied and an attempt has been made to study the mechanical properties like compression strength, split tensile strength and flexural strength of concrete as well as the quality using Ultra sonic Pulse Velocity (UPV) test.

1.1 Wood Ash

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. The chemical composition of the ash was determined the elements such as Total Potassium, Phosphorous, Nitrogen, Magnesium, Calcium were determined. 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.

2. LITERATURE REVIEW

Pranav S. Dhakulkar et.al studied the properties of concrete with cement replaced with Wood Ash. The Wood Ash has been chemically and physically characterised 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 0.5 water 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 ratios 3%, 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% and 5% 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 pozzolaic 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 0.45 water cement ratio. The samples were hydrated from one to four weeks. The hydrated samples were subjected to FTIR, SEM micrographs and 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 at 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 minimise 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, 7 and 28 days. 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]

2.1 Summary of literature review

Considering the strength criteria, the partial replacement of wood ash by cement is feasible. Therefore the utilisation of wood ash of wood ash in concrete as cement replacement is possible. The results of the compressive strength, split tensile strength and flexural strength are increased. The partial replacement of cement by wood ash is used up to M35 grade concrete. There was an increase in water absorption with increase in wood ash percentage. The soundness of cement paste was increased with increasing Wood Ash content. The bulk density of concrete was decreased with increasing Wood Ash content. So the wood ash blended concrete is a light weight and inexpensive building material and also reduces the overuse of landfills and environmental pollution.

3. OBJECTIVES AND PROJECT METHODOLOGY

3.1 Objectives of the project

The main objective of this work are

- To evaluate the utility of wood ash as a replacement of cement in concrete.
- To study and compare the performance of conventional concrete and wood ash blended concrete.
- Environmental friendly disposal of waste wood ash.

3.2 Project methodology

- Characterisation of materials
- Design mix proportioning of M20 mix as per IS 10262-1982(Reference specimen).
- Workability test
- Casting the specimens
- Testing of hardened concrete mix.

3.3 Scope of the study

The 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 incorporation of wood ash as partial replacement in concrete. It will provide an economic and environmental safe construction.

4. MATERIAL PROPERTIES AND TESTS

The materials used for casting the concrete mix are ordinary Portland cement, fine aggregate, coarse aggregate, water and wood ash. The properties of each of these materials contribute to the quality of concrete produced. For the present study, the material test for various materials were conducted as specified in the relevant IS codes for each material.

4.1 Cement

Ordinary Portland cement 43 grade conforming to IS 8112-1989 is used as binding material. The cement improves the mechanical strength properties of concrete. Because of the importance of cement, the ASTM provide some guide lines to follow. For this research work Ordinary Portland cement of 43 grade having specific gravity of 3.13, standard consistency 33 and 3% fineness is used. . Table 1 shows all the properties of cement.

Table 1 Material properties of cement

Sl.No	Propery of cement	Values	Requirement as per IS 8112-1989
1	Grade of cement	OPC 43	-
2	Finenes of cement	3%	Not > 10 %(max)
3	Specific gravity	3.13	3.1-3.15
4	Consisy	30%	26-33%
5	Initial setting time	78 minutes	Not >30 minutes (min)
6	Final setting time	253 minuts	Not < 600 minuts (max)

4.2 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 figure 1. 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: Wood ash

4.2.1 Chemical composition of wood ash

The chemical composition of the ash was determined by using XRD test.

4.2.1.1 X-Ray Powder Diffraction test

The XRD test is used to analyse the qualitative and quantitative chemical composition of wood ash. Figure 2 shows the XRD test of wood ash. Table 2 shows the chemical composition of wood ash. The properties of wood ash is given in table 4.

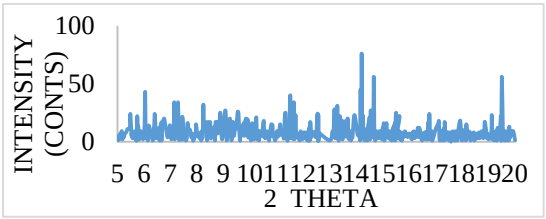

Chart-1: XRD test of wood ash.

Table 2 Chemical composition of wood ash

Sl.No	Particulates	Percentages
1	CaO	47
2	SiO_2	37
3	MgO	8.7
4	Al_2O_3	5.3
5	Fe_2O_3	1.53
6	K_2O	1.2

Table 3: Properties of different types of pozzolans as defined by ASTM C618 [9]

Properties	Class F type pozzolan	Class C type pozzolan	Wood ash
Min SiO_2 + Al_2O_3 + Fe_2O (%)	70	50	50.7
Max Na_2O + 0.658 K_2O	1.5	1.5	0.7896
Max loss of ignition	6	6	2.47

The wood ash is Class C type pozzolan. So it has pozzolanic and cementations property.

Table 4 Properties of wood ash

Sl.No	**properties**	**Observed values**
1	Specific gravity	2.13
4	Normal consistency	35%
2	Initial setting time	122 min
3	Final setting time	329 min
4	Fineness	3%

4.3 Fine Aggregate

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 4.75mm sieve. The fine aggregate is increased the consumption of binder content.

The fine aggregate used in this project is M sand.

The sieve analysis is performed on M sand and particle distribution curve for M sand is shown in table 5 and figure 3 respectively. Material properties of M sand is shown in table 6.

Table 5 Sieve analysis result of M sand

Sieve size in mm	Percent finer
4.75	98.1
2.36	95.2
1.18	80.6
0.6	53.7
0.3	10.6
0.15	0.5
pan	0

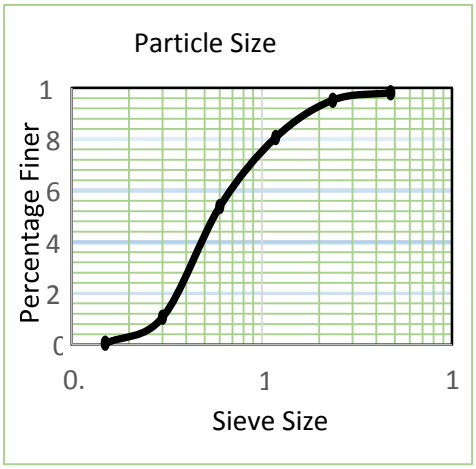

Chart-2: Particle size distribution of M sand

Table 6 Material properties of M sand

Sl.No	Properties	values	Specified as per IS 383-2016
1	Specific gravity	2.3	2 - 3
2	Fineness modulus	3.61	2 - 4
3	Grading zone	Zone II	zone II and zone III is recommended in reinforced concrete
4	Bulk density	1.207 g/cm^3	1.2g/cm^3 – 1.5 g/cm^3
5	Void ratio	0.537	0.4- 0.8
6	Water absorption	1%	Maximum 3%

4.4 Coarse Aggregate

Aggregate having size greater than 4.75 mm, is called as coarse aggregate. It give strength to the concrete.

Crushed stone is used as the coarse aggregate in concrete. It is angular in shape. Crushed natural stone of maximum size 20 mm were used as coarse aggregate for this project work.

The sieve analysis is performed on coarse aggregate and particle distribution curve for coarse aggregate is shown in table 7 and figure 4 respectively.

Table 7 Sieve analysis result of coarse aggregate

SIEVE SIZE	% FINER
31.5	100
25	99.9
20	77.8
16	25.5
12.5	6.3
10	0.8
4.75	0

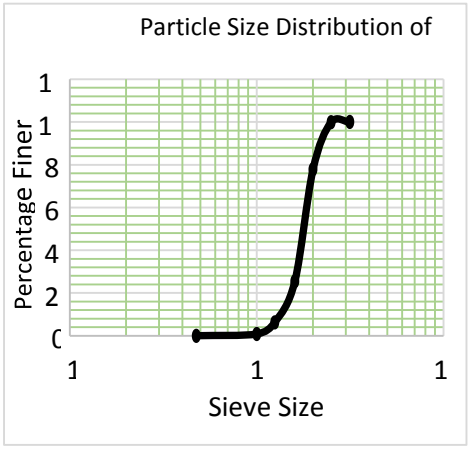

Chart-3: Particle size distribution of coarse aggregate

Table 8 Material properties of coarse aggregate

Sl.No	Properties	Observed values	Requirement as per IS 383 - 2016
1	Specific gravity	2.9	2.6 – 4
2	Maximum size of aggregate	20 mm	Maximum size 20 mm recommended in reinforced concrete
3	Fineness modulus	3.9	3.6 – 9 %
4	Water absorption	0.5%	Maximum 2%
5	Bulk density	1.62 g/cm^3	1.52 g/cm^3 – 1.68 g/cm^3
6	Void ratio	0.8	0.4- 0.8

4.5 Water

Water is an important ingredient 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 be free 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.

4.6 Mix design of M20 concrete by IS code method

Concrete mix design is the step by step procedure to work out various proportions of the materials required to make concrete. The proportioning of concrete mix consist of determination of the quantities of respective ingredients necessary to produce concrete having adequate, but not excessive, workability and strength for particular loading and durability for the exposure to which it is subjected. Another most convenient relationship applicable to normal concrete is that for a given type, size and gradation of aggregates, the amount of water determines its workability.

Based on the properties of aggregates and cement, the mix proportion for M20 concrete designed as per provisions in IS Codes for replacement of cement with wood ash. M sand was used as fine aggregate. M20 concrete mix was designed as per IS 10262-1982. The mix proportion is given in table 9.

Concrete of grade M20 was designed as per IS 10262 -2009 code procedure.

Table 9 Mix proportion of M20 concrete

Water (L)	Cement (Kg)	Fine aggregate (M sand) (Kg)	Coarse aggregate (Kg)
192	383.16	599.56	1233.43
0.5	1	1.56	3.22

5. RESULTS AND DISCUSSION

This deals with the results of test conducted on each mix to determine fresh and hardened properties of wood ash blended concrete. Slump cone test results, strength test results were discussed.

Table 10 Specimen descriptions

SI.NO	Specimen	Size (Mm)	Number
1	Cube (CB)	150X150X150 mm	30
2	Cylinder (CY)	300 mm length and 150 mm diameter	30
3	Beam (BM)	700X150X150mm	15

Fig-2: Casted specimen

- 0% replacement of cement with wood ash (WC 0)
- 3% replacement of cement with wood ash (WC 3)
- 5% replacement of cement with wood ash (WC 5)
- 7% replacement of cement with wood ash (WC 7)
- 9% replacement of cement with wood ash (WC 9)

5.1 TEST ON FRESH CONCRETE

The workability test conducted on concrete mixes to determine the fresh concrete properties. The control mix is prepared and fresh property of the mix was tested as per IS Code: IS: 1199-1959. 100mm slump was obtained for 1:1.56:3.19 with a water to cement ratio 0.5. The test results shows high degree of workability. The slump test is shown in figure 6.

Fig-3: Slump cone test

Concrete specimen were prepared with different percentage of wood ash in concrete by partially replacing the cement (0% - 9%). Table 12 and Figure 7 shows the slump value for concrete with various percentages.

Table 12 Slump value for various concrete mix

Concrete mix	Slump value (mm)	Nature of collapse
WC 0	100	True slump
WC 3	97	True slump
WC 5	94	True slump
WC 7	90	True slump
WC 9	88	True slump

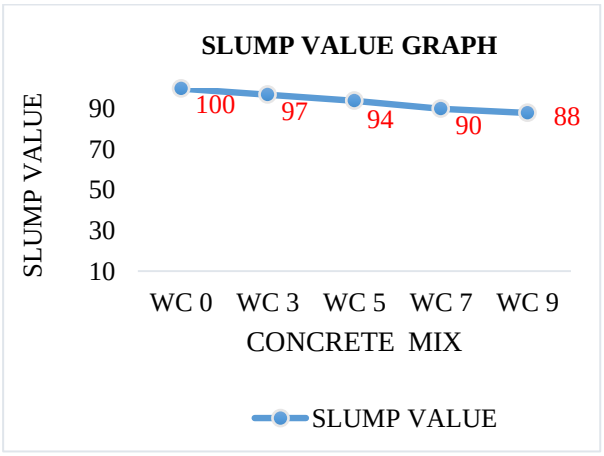

Chart-4: Slump cone test

The slump test shows that the slump value get decreased by increasing the wood ash content.

5.2 Test on hardened concrete

Water absorption test, compressive strength test, split tensile strength, flexural strength test, have been conducted on hardened concrete. The test was carried out after 28 days of water curing.

5.2.1 Compressive strength test

The compressive strength test was carried out by a compression testing machine. Cube of size 150mm x 150mmx 150mm is used for this test. The load applied on the specimen is 140Kg/Cm^2/minute till the specimen fails. The failure load obtained are tabulated and calculations are done as per IS: 506 -1959. The test set up is shown in figure 8.

Fig-4: Compressive strength testing of specimen

The compressive strength test result for 28 day of testing is given in table 13.The Figure 9 shows the average compression test results for each specimen.

Table 13 Average compressive strength test results

Specimen	Average compressive strength (N/mm^2)
WC 0	29.58
WC 3	30.42
WC 5	30.92
WC 7	33.70
WC 9	29.85

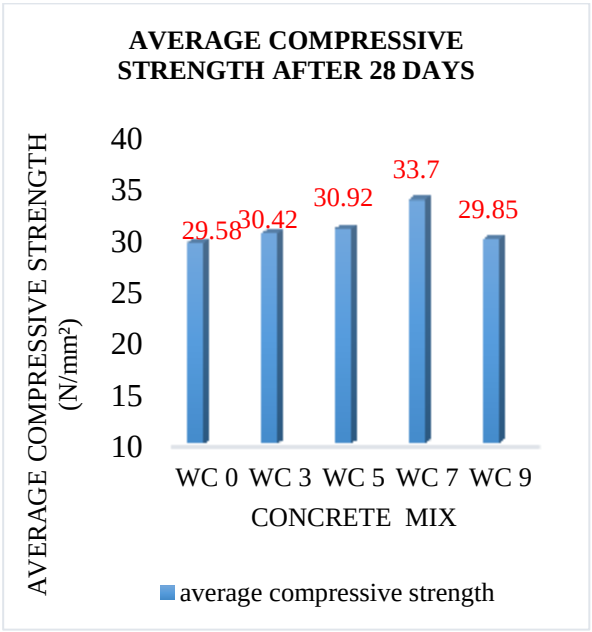

Chart-5: Average compressive strength test results

From compressive strength test result an increment of strength is observed for concrete with 7% wood ash content. Test result shows that the 7% replacement of cement with wood ash provide 13.93% higher compressive strength after 28 days. The strength gets reduced on further increment of wood ash in mix.

5.2.2 Split tensile strength test

The size of the cylinders having 300mm height and 150mm diameter are placed in the machine. A uniform tensile stress is applied along the length of the cylinder as shown in figure 10. The split tensile strength test was conducted on 28th day. The average split tensile strength result is given in table 14 and figure 11.

Fig-6: Split tensile strength testing of specimen

Table 14 Average split tensile strength results

Specimen	Average split tensile strength (N/mm^2)
WC 0	3.19
WC 3	3.24
WC 5	3.29
WC 7	3.51
WC 9	3.2

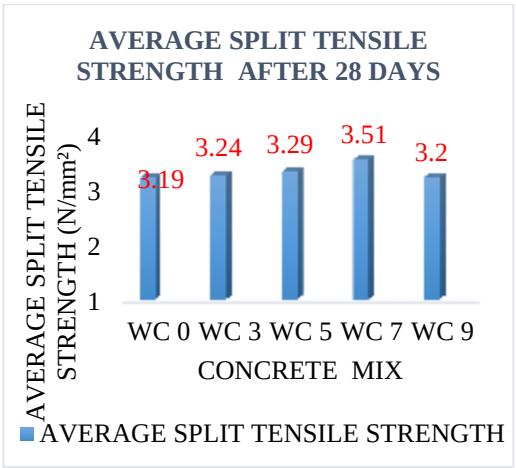

Chart-6: Average split tensile strength results

From split tensile strength test result an increment of strength is observed for concrete with 7% wood ash content. Test result shows that the 7% replacement of cement with wood ash provide 10.03% higher compressive strength after 28 days. The strength gets reduced on further increment of wood ash in mix

5.4.3 Flexural strength test

In this test a reinforced beam having size 150mm x 150mm x 700mm is tested to measure the resistance to bending. The test is performed under 2 point loading as per IS: 516-1959. The test set up is shown in figure 12.

Fig-7: Flexural strength testing of specimen

The flexural strength test was conducted on 28th day. The average split tensile strength result is given in table 15 and Figure 13.

Table 15 Average flexural strength test results

Specimen	Average Flexural strength (N/mm^2)
WC 0	4.47
WC 3	4.56
WC 5	4.67
WC 7	4.86
WC 9	4.48

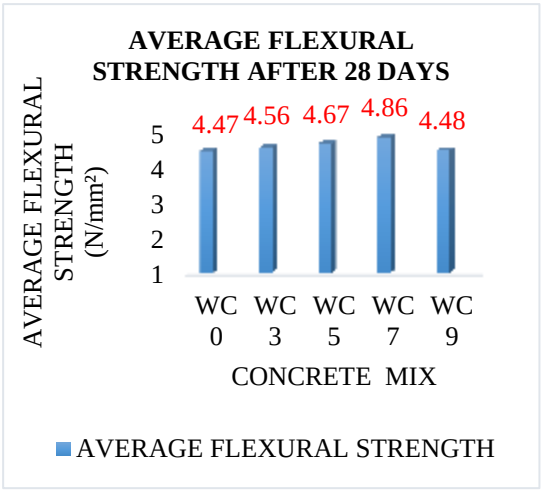

Chart-7: Average flexural strength test results

From flexural strength test result an increment of strength is observed for concrete with 7% wood ash content. Test result shows that the 7% replacement of cement with wood ash provide 8.73% higher compressive strength after 28 days. The strength gets reduced on further increment of wood ash in mix.

6. CONCLUSIONS

The experimental study leads to the following conclusions.

- Replacement of cement with wood ash helps to reduce the environmental pollution.
- Detailed literature review on wood ash blended concrete is done.
- Physical properties of materials are tested and verified with the IS code specifications.
- M20 grade wood ash blended concrete is designed.
- Tests on specimens were conducted.
- The specimens with cement replaced with 7% wood ash by weight of cement is optimum for the construction.
- For 7% replacement :

1. Compressive strength increased by 13.93%.
2. Flexural strength increased by 8.73%.
3. Split tensile strength increased by 10.03%.

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