Studies on Behaviour of Crimped Steel Fibre Reinforced Concrete with Wood Waste Ash as an admixture

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Abstract

This paper deals with the study of the effect of addition of wood waste ash (WWA) and crimped steel fibre (CSF) in concrete. Wood ash is the residue produced from the incineration of wood, and its products like chips saw dust and bark for power generation or other uses. This is a bio waste and is used as a pozzolanic material admixed in concrete to increase durability and strength. CSF is produced as a by-product from industrial processes. Commercial production of CSF for use in concrete is also available now-a-days. In the present investigation an attempt is made to evaluate the workability, compressive strength, split tensile strength and flexure strength on addition of 0, 10, 20 and 30% WWA along with CSF of 0%, 0.5%, 1.0% and 1.5% in concrete. Standard cubes of 150 X 150 X 150 mm has been cast and tested for obtaining 28-day compressive strength. Standard cylinders of 150mm diameter and 300 mm height were cast and tested for Split tensile strength. Standard Beams of 500 X100 X100 were cast and tested for Flexural strength. The results obtained show that gradual increase of both WWA & CSF has decreased the workability. However, the compressive strength increased with the increase of WWA up to 20%and increase of CSF up to 0.75%. Similar trend was followed for split tensile strength of cylinders and flexural strength of beams.

Keywords — *Admixture, Concrete, Crimped steel fibre, Wood Waste Ash, Compressive Strength, Split Tensile Strength, Flexural Strength*

I. INTRODUCTION

The rapid development of construction industry has increased the consumption of cement. But the production of cement involves the depletion of natural resources and greenhouse-gas emissions. Also production cost of cement is increasing day by day. Thus, there is a need to search for alternative materials to cement for use in the construction. Continuous efforts were made in the recent past to produce different kinds of cement, suitable for different situations by changing oxide composition and fineness of grinding.[1] With the extensive use of cement, for widely varying conditions, the types of cement that could be made only by varying the relative proportions of the oxide compositions were not found to be sufficient. Recourses have been taken to add one or two newer materials, known as additives, to the clinker at the time of grinding, or to the use of entirely different basic raw materials in the manufacture of cement.[2,3] The use of additives, changing chemical composition, and use of different raw materials have resulted in the availability of many types of cements to cater to the need of the construction industries for specific purposes. The most important pozzolana materials are fly ash, silica fume and Metakaolin whose use in cement and concrete is thus likely to be a significant achievement in the development of concrete technology in the coming few decades.[4]

Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. The construction industry has been identified as the one that absorbs the majority of such materials as filler in concrete.[5] Some industrial wastes have been studied for use as supplementary cementing materials such as Fly ash, Silica fume, Pulverized fuel ash, volcanic ash, Rice's husk ash and Corn cob ash. Wood waste ash is generated as a by-product of combustion in wood-fired power plants, paper mills, and other wood burning facilities. Abdullahi determined the properties of wood ash to be used as partial replacement of cement.[6]

In order to overcome the problem of brittleness of concrete several research works has been carried out to enhance the properties of concrete such as durability, ductility, flexural strength, fracture toughness, thermal and shock strength, resistance under dynamic, fatigue and impact load by inclusion of fibres in the concrete mixture. The high-Performance fibre reinforced, polymer concrete composites and ready mixed concrete have been progressively introduced for specific applications.[7-10]

Over decades, attempts have been made to obtain concrete with certain desired characteristics such as high compressive strength, high workability, and high performance and durability parameters to meet the requirement of complexity of modern structures.[11-13] In addition to the above objective recycling of waste, economy and environmental concerns also play a very important role in production of different varieties of concrete with different admixtures.[14-15] Most of these experimentations are approved by construction industries, and are being in use. However, all of them were not included in the IS code. Here is an attempt to study the behaviour of concrete with addition of Wood Waste Ash (WWA) and Crimped Steel Fibres(CSF).

Need For Present Investigation

Though there is a lot of research focused in the last decade on use of various admixtures in producing concrete, very little information is available on behaviour of concrete with wood waste ash as an admixture for crimped steel fibre reinforced concrete. Wood ash is an admixture that acts like a pozzolana as it is generated as a by-product of combustion in wood-fired power plants, paper mills, and other wood burning factories. [16-17] Thus this new admixture has a lot of potential for use in concrete. Crimped steel fibres arrest the shrinkage cracks and help improve the strength of concrete. CSF will have an adverse effect on the workability of concrete, addition of more and more CSF will reduce the mobility of concrete, which reduces the compaction. [18-20]

However, there will be certain limiting point beyond which the additions of these materials do not yield the expected results. Hence, there is a need to study the strength and workability characteristics of WWA-FRC(Wood waste ash based fibre reinforced concrete). The outcome of the of the present research will be useful to estimate the optimum percentage of WWA and CSF as admixtures and additional ingredients.

II. MATERIALS AND METHOD

The present investigation was planned to study and evaluate the effect of addition of wood waste ash (0, 10, 20 & 30%) and Crimped Steel Fibres (0, 0.5, 0.75 & 1%) in concrete. First of all, workability of the mix was tested with compaction factor test. For evaluating the compressive strength, cubes of standard-size 150mmx150mmx150mm were cast and tested after 28 days. Standard cylinders of size 150mm x 300mm were cast and tested for estimating 28days split tensile strength. Also standard beams of size 500mm x100mm x 100mm were cast and were tested for 28 days flexural strength. The change in these parameters corresponding to the percentage addition of WWA and CSF were discussed.

A. Materials Used

Cement: - OPC Cement of 53-grade was used.

Coarse Aggregate: - Crushed granite metal with 50% passing 20mm and retained on 12.5mm sieve and 50% passing 12. 5mm and retained on the 10mm sieve was used. Specific gravity of coarse aggregate was 2.75.

Fine aggregate: - River sand from local sources was used as the fine aggregate. The specific gravity of sand is 2.68.

Water: - Potable fresh water, which is free from concentration of acid and organic substances was used for mixing the concrete.

Crimped Steel Fibres: Steel Fibres are obtained from a local industry. The most important parameter describing a fibre is its Aspect ratio. "Aspect ratio" is the length of fibre divided by an equivalent diameter of the fibre, where the equivalent diameter is the diameter of the circle with an area equal to the cross-sectional area of fibre. The properties of fibre reinforced concrete are very much affected by the type of fibre. Different types of fibres which have been tried to reinforce concrete are steel, carbon, asbestos, vegetable matter, polypropylene and glass. In the present investigation crimped round steel fibres of around 25mm length with the aspect ratio of 50 are used. The properties of the CSF used in the present experimentation are given by the supplier and are presented here.

Wood waste ash: - Wood waste ash is generated as a by-product of combustion in wood-fired power plants, paper mills, and other wood burning factories. In the present research the wood waste ash used, is detained from 300 microns. Wood waste ash required for the present experimental investigation was obtained from local hotels where the saw dust is used as fuel for cooking. Some of the Physico-chemical properties of this WWA are adopted from literature and presented here.

B. Material Properties

Physical properties of the cement used in the present experimental work are given in the Table.1 below.

Table.1 Physical Properties of Cement

S.NO	PROPERTY	VALUES
1	Fineness of Cement	225 m^2/kg
2	Specific Gravity	3.1
3	Normal Consistency	33 %
4	Setting Time i) Initial Setting time ii) Final setting time	 45 mins 6 hours
5	Compressive Strength i) 3 days ii) 7 days iii) 28 days	 32 N/mm^2 46 N/mm^2 58 N/mm^2

Physical properties of the coarse aggregate used in the present experimental work are given in the Table.2 below.

Table. 2 Physical Properties of Coarse Aggregate

S.NO	PROPERTY	VALUES
1	Specific Gravity	2.68
2	Fineness Modulus	2.8
3	Bulk Density i) Loose State ii) Compacted State	15.75 kN/m^3 17.05 kN/m^3
4	Grading of Sand	Zone - II

Physical properties of the fine aggregate used in the present experimental work are given in the Table.3 below.

Table. 3 Physical properties of Fine Aggregate

S.NO	PROPERTY	VALUES
1	Specific Gravity	2.75
2	Bulk Density i) Loose State ii) Compacted State	14.13 kN/m^3 16.88 kN/m^3
3	Water Absorption	0.7%
4	Flakiness Index	14.22%
5	Elongation Index	21.33%
6	Crushing Value	21.43%
7	Impact Value	15.5%
8	Fineness Modulus	3.4

Physical properties of the Wood Waste Ash used in the present experimental work are given in the Table.4 below. These are adopted from Abdullahi, M. (2006).Ref.[6]

Table. 4 Physical Properties of WWA
(Abdullahi, M. (2006))

S.NO	PROPERTY	VALUES
1	Silicon dioxide (SiO2)	31.00%
2	Aluminium Oxide (Al_2O_3)	14.40%
3	Iron oxide (Fe_2O_3)	6.90%
4	Calcium oxide (CaO)	12.60%
5	Magnesium oxide (MgO)	0.69%
6	Potassium Oxide(K2O)	1.57%
7	Alkalis	0.89%
8	Loss of Ignition (1000oC)	34.30
9	Moisture content	1.6%
10	Specific gravity	2.56

Some of the properties of the crimped steel fibres used in the present experimental work that are supplied by the manufacturer are presented in the Table.5 below.

Table .5 Properties of Crimped Steel Fibre

S.NO	PROPERTY	VALUES
1	Equivalent Diameter, mm	0.15 to 1.00
2	Specific Gravity, kg/m3	7840
3	Tensile Strength, MPa	345 to 3000
4	Young's Modulus. GPa	200
5	Ultimate Elongation, %	4 to 10
6	Thermal Conductivity, 1%	2.74
7	Aspect Ratio	50 to 100

C. Experimental Programme

To evaluate the strength characteristics in terms of compressive, split tensile and flexural strengths, a total of 16 mixes were tried with different percentages of wood waste ash (0,10,20 & 30%) and different percentages of crimped steel fibres (0,0.5,0.75 & 1%). M30 is considered as the reference mix. In all mixes the same type of aggregate, i.e. crushed granite aggregate; river sand and the same proportion of fine aggregate to total aggregate are used. The relative proportions of cement, coarse aggregate, sand and water are obtained by IS - Code method.

The concrete with the stipulated mix proportions along with wood waste ash and crimped steel fibres is shown in the following Fig.1.

Fig. 1 CSF and WWA Added Mix before Casting

The concrete filled cubes, cylinders and beam moulds are shown in the following Fig.2. Total 16 mixes were prepared with the above mentioned mix proportions and percentages of WWA and CSF. Two more samples of each category were also made additionally without adding WWA&CSF for plain concrete results used for comparison.

Fig. 2 Moulds filled with Concrete before Curing

III. RESULTS AND DISCUSSION

The test specimen samples brought after 28 day-curing were tested in the material testing laboratory. Cubes were tested for compressive strength, cylinders were tested for split tensile strength, and beams were tested for bending. All the tests were performed under hydraulically loaded machine operated compression testing machine. Cubes and cylinders were directly placed for testing but for testing beams a three point set up was made to flex the beam till failure. Plain concrete cubes, cylinders and beams without addition of the WWA & CSF are also tested for reference values. The results obtained from the experimental procedures were tabulated and presented below. The variations of parameters with respect to the percentage of admixtures are also shown in graphs below for better visual interpretation. The critical discussion on the obtained results was given in the following sections:

A. Effect of Addition of Wood Waste Ash on Workability

The workability of WWA-FRC (Wood Waste ash fibre reinforced concrete) mixes has been measured by conducting the Compaction factor tests. The test results were presented in the Table.6. From Fig.3 it can be observed that the compaction factor of WWA-FRC mixes decrease with the increase with the addition of wood waste ash content indicating a decrease in the workability. This is due to the absorption of water from the mix by the wood waste ash. Along with WWA the CSF is also contributed to less workability.

Table.6 Workability in terms of Compaction Factor

S. No	% of CSF	Compaction Factor			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0.00% CSF	0.920	0.867	0.832	0.790
2	0.50% CSF	0.802	0.834	0.812	0.781
3	0.75% CSF	0.871	0.845	0.812	0.761
4	1.00% CSF	0.843	0.776	0.770	0.741

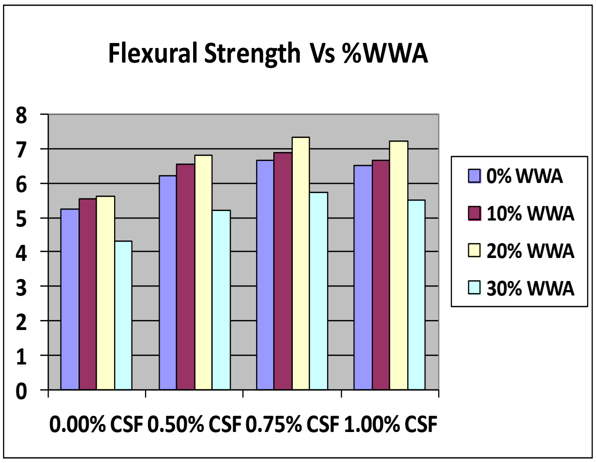

Fig. 3 Compaction Factor Vs % of WWA

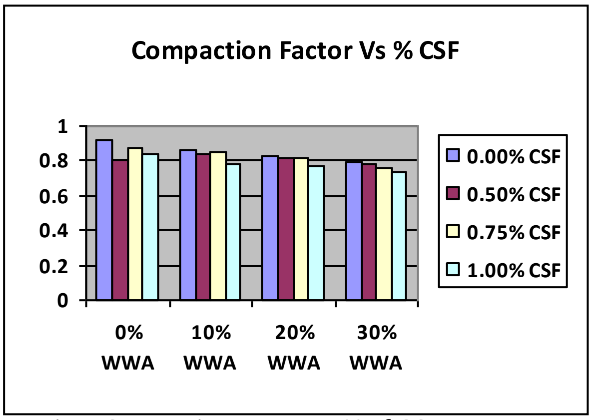

Fig. 4 Compaction Factor Vs % of CSF

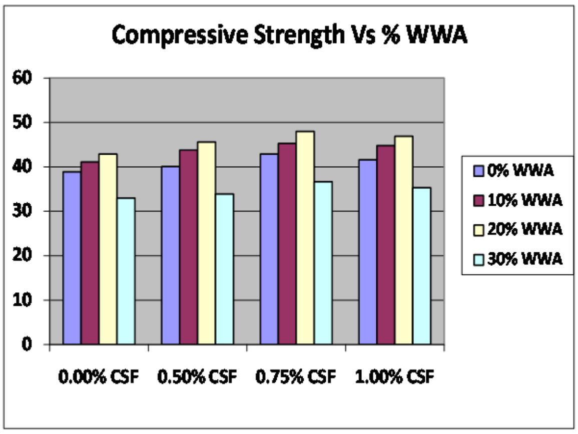

Fig. 6 Compressive Strength Vs % of CSF

Table.7 Compressive Strength in N/mm^2

S. No	% of CSF	Compressive Strength (Mpa)			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0.00% CSF	38.9	41.1	42.9	33.0
2	0.50% CSF	40.1	43.8	45.6	33.9
3	0.75% CSF	42.9	45.3	48.0	36.7
4	1.00% CSF	41.6	44.8	46.9	35.3

Table.8 Split Tensile Strength in N/mm^2

S. No	% of CSF	Split Tensile Strength (MPa)			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0.00% CSF	4.26	4.67	4.76	3.65
2	0.50% CSF	5.45	5.61	5.91	4.43
3	0.75% CSF	5.57	5.90	6.33	4.65
4	1.00% CSF	5.32	5.72	6.10	4.45

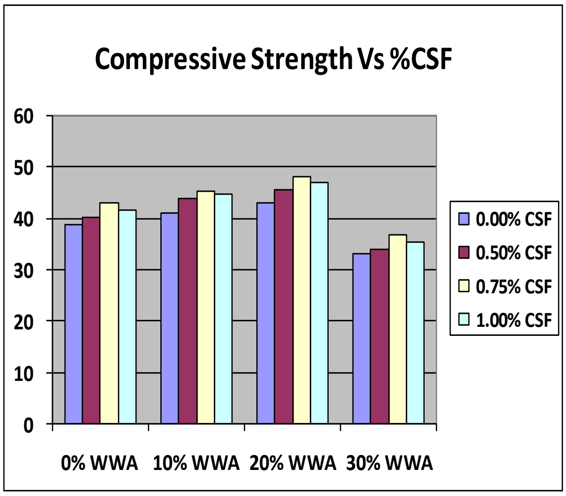

Fig. 5 Compressive Strength Vs % of WWA

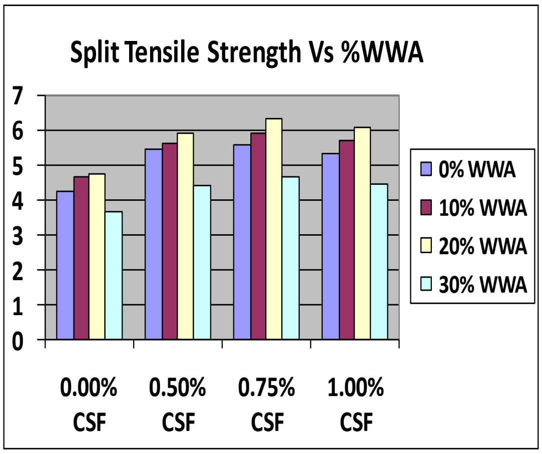

Fig. 7 Split Tensile Strength Vs % of WWA

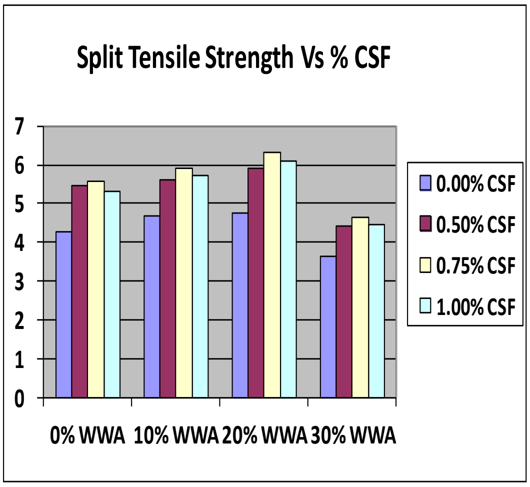

Fig. 8 Split Tensile Strength Vs % of CSF

Table .9 Flexural Strength values in N/mm^2

S. No	% of CSF	Flexural Strength (MPa)			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0.00% CSF	5.25	5.56	5.62	4.33
2	0.50% CSF	6.23	6.56	6.81	5.21
3	0.75% CSF	6.67	6.89	7.33	5.72
4	1.00% CSF	6.52	6.67	7.21	5.51

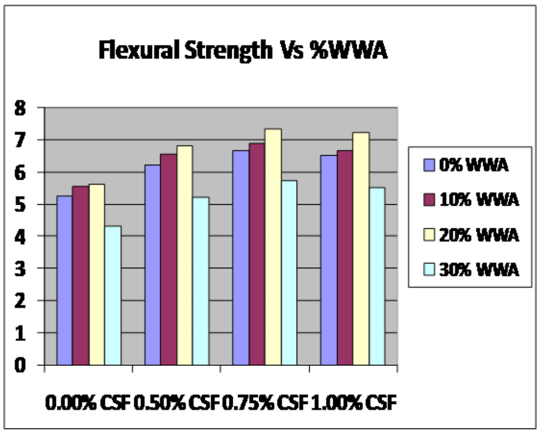

Fig.9 Flexural Strength Vs % of WWA

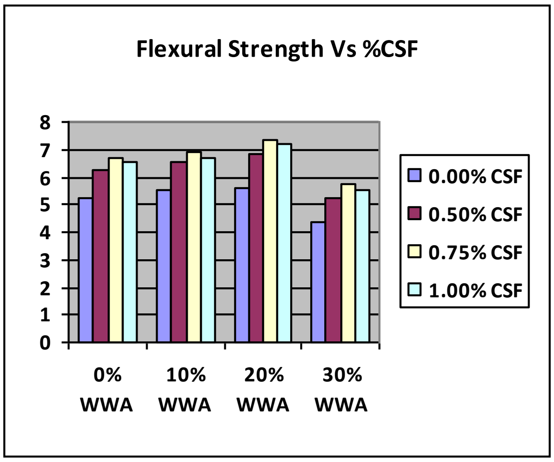

Fig.10 Flexural Strength Vs% CSF

B. Effect of Percentage of Steel Fibres on Workability

It can be observed from the Fig.4, that the compaction factor decreases with the increase in the percentage of crimped steel fibre. Thus indicating a decrease in the workability with the increase in the crimped steel fibre content. This is mainly due to the obstruction and frictional resistance caused by the CSF in the concrete mixture.

C. Effect of Addition of Wood Waste Ash on Compressive Strength:

Compressive strengths of the cubes were tested under compression testing machine, and the results were presented in the Table.7. From Fig.5 it can be observed that the 28-day compressive strength increases with the increase in the percentage of wood waste ash up to 20% addition level. On 20% addition of wood waste, compressive strength reaches the maximum value.

D. Effect of Percentage of Steel Fibres on Compressive Strength:

From Table .7 and Fig.6, it can be observed that with the increase in the percentage of fibre up to 0.75%, the compressive strength has increased but beyond 0.75% fibre strength value decreased. Hence 0.75% of fiber volume can be taken as optimum content. This increase in compressive strength is due to the action of fibres, as they improve the bond compressive strength increases. But beyond 0.75% CSF, it might severely affect the workability, and the compaction, hence compressive strength got reduced.

E. Effect of Addition of Wood Waste Ash on Split Tensile Strength:

From Fig.7, it can be observed that the 28 days split tensile strength increases with the increase in the percentage of wood waste ash up to 20% addition level. Beyond 20% WWA addition split tensile strength decreases. This is due to absorption of moisture content by WWA.

F. Effect of Percentage of Steel Fibres on Split Tensile Strength:

From Fig.8, it can be observed that with the increase in the percentage of fibre up to 0.75%, the split tensile strength has increased but beyond 0.75% fibre split tensile strength value decreased. Hence 0.75% of fiber volume can be taken as optimum content.

G. Effect of Addition of Wood Waste Ash on Flexural Strength:

From Fig.9, it can be observed that the 28-day flexural strength increases with the increase in the percentage of wood waste ash up to 20% addition level. Beyond 20% WWA addition flexural strength decreases, this is due to absorption of moisture content by WWA.

H. Effect of Percentage of Steel Fibres on Flexural Strength

From Fig.10, it can be observed that with the increase in the percentage of fibre up to 0.75%, the flexural strength has increased but beyond 0.75% fibre flexural strength value decreased. Hence 0.75% of fiber volume can be taken as optimum content.

IV. CONCLUSIONS

In this work, experimental investigation was made to understand the behaviour of concrete with addition of varying quantities of wood waste ash and crimped steel fibres. Workability, compressive strength, split tensile strength and flexural strengths were tested. Results were analysed to derive useful conclusions regarding the strength characteristics of wood waste ash fibre reinforced concrete (WWA-FRC). M30 concrete has been used as a reference mix. The following conclusions may be drawn from the study on strength characteristics of wood waste ash fibre reinforced concrete properties.

The workability of concrete measured from the compaction factor degree, as the percentage of wood waste ash and steel fibre increases in mix compaction factor decreases. Hence it can be concluded that with the increase in the wood waste ash content and fibre, content workability decreases. This is mainly due to absorption of water content by WWA and mechanical obstruction by the CSF for free movement of particles in the concrete mass.

The compressive strength of WWA-FRC mixes at 28 days found to increase with the addition of wood waste ash up to 20% level. This increased strength is mainly because of conversion of calcium hydroxide (C-H) compounds into calcium silicate hydrates(C-S-H) gel due to the presence of siliceous material present in WWA. Hence for normal concreting works we can go up to 20% addition level of wood waste ash.

The steel fibres also contribute to the increase of compressive strength up to 0.75% only. This is due to the arrest of micro-cracks that develop due to shrinkage and external loads.

The split tensile strength of WWA-FRC mixes at 28 days increased with the addition of wood waste ash up to 20% level. Beyond 20% addition of WWA, the split tensile strength was found to decrease. The split tensile strength also found to increase with addition of CSF up to 0.75%.

The flexural strength of WWA-FRC mixes at 28 days also increased with the addition of wood waste ash up to 20% level. The flexural strength was found to increase up to 0.75% and beyond which it starts decreasing.

RECOMMENDATIONS FOR FUTURE INVESTIGATIONS:

1. Studies on different lengths, proportions and aspect ratios of steel fibres may be carried out.
2. Studies on the different proportions of wood waste ash may be carried out. Mathematical / Empirical models can be developed for the Stress/Strain behaviour of strength characteristics on wood waste ash fibre reinforced concrete.
3. Durability studies such as resistance to Sulphate attack, Acid resistance etc., can be carried out on wood waste ash fibre reinforced concrete.

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