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AN EXPERIMENTAL STUDY ON FIBER REINFORCED CONCRETE WITH INCORPORATION OF WOOD WASTE ASH

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ABSTRACT

Cementations materials have been used by mankind for construction from time immemorial. The every rising functional requirement of the structures and the capacity to resist aggressive elements has necessitated developing new cementations materials and concrete composites to meet the higher performance and durability criteria. The environmental factors and pressure of utilizing waste materials from industry have also been the major contributory factors in new developments in the field of concrete technology.

Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. The concrete has become so popular and indispensable because of its inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Its great versatility and relative economy in filling wide range of needs has made it very competitive building material.

With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable for a by situations. Added to this is the necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixtures is found to be an important alternative solution.

Keywords- Portland cement ,Micro silica, Rice husk ash & GGBS.

1. INTRODUCTION

India is the second largest producer of cement on the globe after China. In total, India manufactures 251.2 Million Tons of cement per year. The cement industry in India has received a great impetus from a number of infrastructure projects taken up by the Government of India like road networks and housing facilities. While the Indian cement industry enjoys a phenomenal phase of growth, experts reveal that it is poised towards a highly prosperous future over the very recent years. The annual demand for cement in India is consistently growing at 8-10%. NCAER has estimated after an extensive study that the demand for cement in the country is expected to increase to 244.82 million tons by 2012. At the same time, the demand will be at 311.37 million tones if the projections of the road and housing segments are met in reality

Concrete is the world's most consumed man-made material. To produce 1 ton of Portland cement, 1.5 tons of raw materials are needed. These materials include good quality limestone and clay. Therefore, to manufacture 1.5 billion tons of cement annually, at least 2.3 billion tons of raw materials are needed. Over 5-million BTU of energy is needed to produce one tone of cement. In the year 1914, India Cement Company Ltd started cement production in Porbandar with an output of 10,000 tons and a production of 1000 installed capacity. At the time of independence 1947, the installed capacity of cement plants in India was approximately 4.5 million tons and actual production around 3.2 million tons per year. The partial deep control in 1982 prompted various industrial houses to set a setup new cement plants in the country, capacity was nearly 30 million tons, which has now, increase to nearly 120 million tons during a period of 20 years. The full decontrol on cement industry in 1988 further provided momentum for the growth.

The production of superior quality of Ordinary Portland Cement (OPC) in the country was primarily responsible for introducing the grading system in OPC by Bureau of Indian Standard (BIS) during 1986-87. The other varieties of structural cements, such as sulphate resisting Portland cement, Pozzolana cement and blast furnace slag cement found their way in the improve quality of prompted the structural engineers and major consumers to adopt higher grades of concretes in the construction work. This has been marked difference in the quality of concrete during this period primarily due to the availability of superior quality of cements in the market. The trend is continuing more and more varieties of cements are coming to the markets which help to the consumers to make appropriated grade quality of concrete to meet the specific construction requirement. The high performance fiber reinforced, polymer concrete composites and ready mixed concrete have been progressively introduced for specific applications.

2. LITERATURE REVIEW

Extensive research work both at National and International level has been done on the use of various admixtures and fibres in concrete with common goals are:

- To bring down the increasing cost economics of cement & building blocks.
- To modify the properties of traditional concrete to the desired level suitable to the specific circumstances.
- To conserve the natural resources used in the production of construction materials.
- Of late, rehability the existing structures which are deteriorated over period of time etc.

In India, only government educational and research institutions and consultants are responsible for research. While in advanced countries the most remarkable break troughs have been achieved by the building material industries and their R&D laboratories.

An accepted fact is that these encouraging results on the use of admixtures are not penetrating into the user community and the entire research work is getting flocked in their organizations. With the result, the very purpose of research work is becoming questionable. Along with and R&D units, the policy makers and consultants should take more interest in handling these issues directly keeping not only the techno-economics in view but also national obligations.

Typically, wood ash contains carbon in the range of 5-30% (Campbell, 2009). The major elements of wood ash include calcium (7-30%), potassium (3-4%), magnesium (1-2%), manganese (0.3-1.3%), phosphorus (0.3-1.4%) and sodium, (0.2-0.5%). Density of wood ash decreases with increasing carbon content. The chemical and physical properties depend upon the type of wood, combustion temperature, etc.

Etiegni and Campbell (2010) studied the effect of combustion temperature on yield and chemical properties of wood ash. For this investigation, lodge-pole pine saw dust collected from a saw-mill was combusted in an electric furnace at different temperatures for 6–9 hours or until the ash weight became constant. The results showed that wood ash yield decreased by 45% when combustion temperature were increased from about 550–1100°C. The average article size of the wood ash was found to be 230µm. The concentration of potassium, sodium, zinc, and carbonate decreased while concentrations of other metal ions remained constant or increased with increasing temperature. The pH of wood ash was found to vary between 9 and 13.5.

Kraus RN (2012) evaluated the wood ashes from five different sources for possible use in making controlled low-strength materials (CLSM). They used wood ashes from five different sources in Wisconsin (USA) and were designated as W1, W2, W3, W4, and W5. ASTM standards do not exist for wood ash.

Udoeyo FF, Inyang H, Young DT, Oparadu, EE (2013) reported the physical properties of waste wood ash (WWA), used as additive in concrete. They used wood waste collected from a dump site at the timber market in Uyo, Akwa Ibom State of Nigeria. The waste was subjected to a temperature of 1000°C in an oven to incinerate it into ash before it was used as an additive in concrete. The WWA had a specific gravity of 2.43, a moisture content of 1.81%, and a pH value of 10.48. The average loss on ignition of the ash was found to be 10.46.

Etiegni (2008) and Etiegni and Campbell (2009) obtained X-ray diffraction data to determine the presence of various compounds in dry and wet ash, which was then dried for 24 hours. The major oxides detected in the wood ash were lime (CaO), calcite ($CaCO_3$), portlandite ($Ca(OH)_2$) and calcium silicate (Ca_2SiO_4). The authors reported that swelling of wood ash occurred due to the possible hydration of silicates and lime present in the ash.

Alton G. Campbell (2012), wood ash can be used to lime acidic agricultural and forest soils and replace micro- and macro elements removed during plant growth and harvesting. Ash has a low fertilizer equivalent (NPK ratio of 0:1:2), but it can be used as an excellent substitute for lime and limestone to neutralize acidic soils and to add calcium, potassium, and magnesium. Liming with wood ash may also reduce the toxic effect of aluminum and manganese in acidic soils.

From the above review of literature it is observed that no work has been carried out using Steel Fibers and Wood Ash as admixture. Hence, an attempt has been made in this investigation to study the behavior of these two materials when used in concrete. The review presented above reveals that very little information is available on the Wood waste ash based fiber reinforced concrete (WWAFRC). Hence, there is need to conduct experimental investigation in this direction.

3. EXPERIMENTAL INVESTIGATION

The scope of present investigation is to study and evaluate the effect of addition of wood waste ash (0, 10, 20 & 30%) and Crimped Steel Fibers (0, 1 & 2%) in concrete. Cubes of standard size 150mmx150mmx150mm were cast and tested for 28 and 90 days compressive strength. Standard cylinders of size 150mm x 300mm were cast and tested for 28days and 90days split tensile strength. Also standard beams of size 500mm x100mm x 100mm were cast and were tested for 28 days and 90 days flexural strength

3.1. Objective

The specific objectives of the present investigations are as listed below.

- To conduct feasibility study of producing wood waste ash concrete using Crimped Steel Fibers
- To evaluate the workability characteristics in terms of compaction factor and vee bee time on addition of wood waste ash (0-30%) along with crimped steel fibers (0-2%)
- To evaluate the compressive strengths at 28 and 90 days of WWAFRC
- To evaluate the split tensile strengths at 28 and 90 days of WWAFRC
- To evaluate the Flexural strengths at 28 and 90 days of WWAFRC

3.2. Test 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 fibers (0,1 & 2%). 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. M30 is considered as the reference mix.(Appendix-I)

The parameters studies are:

- Percentage of Wood Ash – 0, 10, 20 & 30%.
- Percentage of Crimped Steel Fiber – 0, 1 & 2%.

For each mix, 6 cubes of size 150 x 150 x 150 mm and 6 cylinders of 150 mm diameter & 300 mm height and 6 flexural beams of size 500 x 100 x 100 mm were cast and tested. A sample calculation for determination of weight and volumes is presented in Appendix-II. The test programmed consisted of conducting Compressive tests on Cubes, Split Tensile tests on Cylinders and Flexural strength on beams at 28 and 90 days.

4. EXPERIMENTAL INVESTIGATION AND OF TEST RESULTS

Experimental investigation was planned to provide sufficient information about the strength characteristics of wood waste ash concrete fiber reinforced concrete (WWAFRC)

4.1. Materials

Cement: - OPC Cement of 53 grade was used. The Physical Properties of cement are shown in Table 4.1.

Coarse Aggregate: - Crushed granite metal with 50% passing 20mm and retained on 12.5mm sieve and 50% passing 12.5mm and retained on 10mm sieve was used. Specific gravity of coarse aggregate was 2.75. The details are shown in Table 4.2 and 4.3.

Fine aggregate: - River sand from local sources was used as fine aggregate. The specific gravity of sand is 2.68. Other details are presented in Table 4.4 and 4.5.

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

Fiber: Steel Fibers is supplied by "STEWOLS INDIA (P) LTD, An ISO 9001: 2008 Company" at Nagpur. The most important parameter describing a fiber is its Aspect ratio.

4.1. Casting

The cubes were cast in steel moulds of inner dimensions of 150 x 150 x 150mm, the cylinders were cast in steel moulds of inner dimensions as 150mm diameter and 300mm height and finally, the flexural beams were cast in steel moulds and timber moulds with inner dimensions of 100 x 100 x 500mm.

All the materials used in this investigation i.e. cement, fine aggregate, coarse aggregate, crimped round steel fibres and wood waste ash are shown in Plate No: 4.2. The cement, sand, coarse aggregate, wood waste ash and crimped steel fibers were mixed thoroughly manually. Approximately 25% of water required is added and mixed thoroughly with a view to obtain uniform mix. After that, the balance of 75% of water was added and mixed thoroughly with a view to obtain uniform mix. Care has to be taken in mixing to avoid balling effect.

4.2. Compaction factor test

The apparatus for conducting compaction factor test is depicted in Plate No: 4.5. The compaction factor test apparatus consists of two hoppers, each in the shape of frustum of a cone and one cylinder. The upper hopper is filled with concrete this being placed gently so that no work is done on the concrete at this stage to produce compaction. The second hopper is smaller than the upper one and is therefore filled to overflowing.

4.3. Vee-Bee time test

The Vee-Bee consistometer test is suitable for mixes with low workability whose slump cannot be measured with slump test. Since low water-binder ratios are adopted in the production of HPC, this V-B test is quite suitable to find out the workability. The apparatus for conducting Vee-Bee test is depicted in Plate No: 4.6. Placing the slump cone inside the metal cylindrical pot of consistometer the slump test is performed. The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the pot.

4.4. Cube Compressive Strength test

The test set up for conducting cube compressive strength test is depicted in Plate No: 4.7. Compression test on the cubes is conducted on the 2000 kN AIMIL - make digital compression testing machine. The pressure gauge of the machine indicating the load has a least count of 1 kN. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate up to the failure of the specimen and the ultimate load is noted. The cube compressive strength of the concrete mix is then computed. A sample calculation for determination of cube compressive strength is presented in Appendix-III (A). This test has been carried out on cube specimens at 28 days and 90days age.

4.5. Split Tensile Strength test

This test is conducted on 2000 kN AIMIL make digital compression testing machine as shown in Plate No: 4.8. The cylinders prepared for testing are 150 mm in diameter and 300 mm long. After noting the weight of the cylinder, diametrical lines are drawn on the two ends, such that they are in the same axial plane. Then the cylinder is placed on the bottom compression plate of the testing machine and is aligned such that the lines marked on the ends of the specimen are vertical.

4.6. Flexural Strength test

The loading arrangement to test the HPC beam specimens for flexure is shown in Plate No: 4.9. The test is conducted on a loading frame. The beam element is simply supported on two rollers of 4.5 cm diameter over a span of 450 mm. The element is checked for its alignment longitudinally and adjusted if necessary. Required packing is provided using rubber material. Care was taken to ensure that the two loading points were at the same level. The loading was applied on the specimen through hydraulic jacks and was measured using a 500 kN pre-calibrated proving ring.

Table 1: Physical properties of Coarse Aggregate

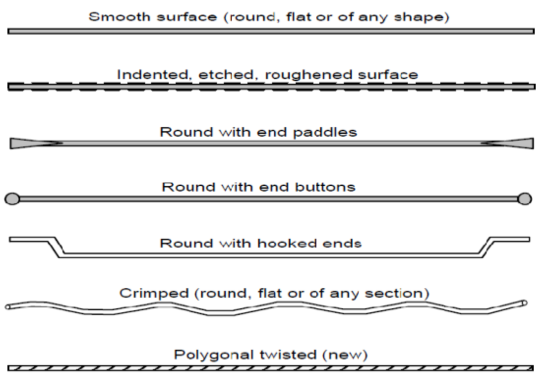
S.NO	PROPERTY	VALUES
1	Specific Gravity	2.75
2	Bulk Density i) Loose State ii) Compacted State	 14.13 kN/m^3 16.88 kN/m^3
3	Water Absorption	0.7%
4	Flakiness Index	14.22%
5	Elongation Index	21.33%
6	Crushing Value	21.43%
7	Impact Value	15.5%
8	Fineness Modulus	3.4

Table 2: Sieve Analysis of Coarse Aggregate

S.No	IS Seieve	Weight retained	% Weight retained	Cumulative % weight retained	% Passing
1	80 mm	0	0	0	100
2	63 mm	0	0	0	100
3	40 mm	0	0	0	100
4	20 mm	365	7.3	7.3	92.7
5	12.5 mm	2525	50.5	57.8	42.2
6	10 mm	1100	22	79.8	20.2
7	4.75 µ	985	19.7	99.5	0.5
8	2.36	25	0.5	100	0
Fineness Modules = 3.44 Total =344.4					

Table 3: Properties of Rounded Crimped Steel Fiber

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



(a)

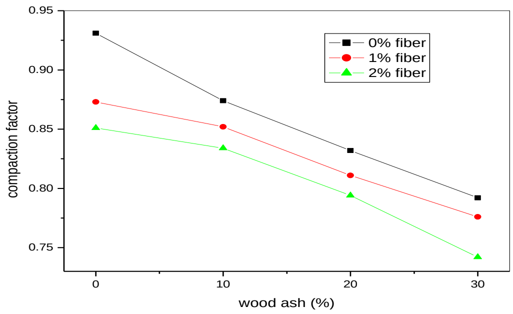
Fig.1. Percentage increase in compressive strength of ternary blended concrete

5. DISCUSSION OF TEST RESULTS

The workability of WWAFRC (Wood Waste ash fibre reinforced concrete) mixes has been measured by conducting Compaction factor test and Vee Bee time test. The values of compaction factors and vee bee times obtained from present investigation are presented in Table.

Table 4: Properties of Rounded Crimped Steel Fiber

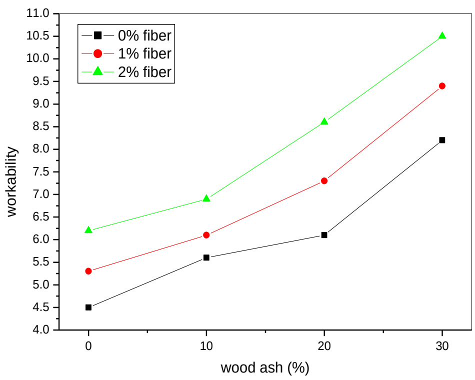
S.No	% of fiber	Compaction Factor			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	0.931	0.874	0.832	0.792
2	1%	0.873	0.852	0.811	0.776
3	2%	0.851	0.834	0.794	0.742



Graph 1: Compaction Factor Vs % of Wood waste Ash

Table 5: Workability in terms of Vee-Bee Time (Sec)

S.No	% of fiber	Vee-Bee Time (Sec)			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	4.5	5.6	6.1	8.2
2	1%	5.3	6.1	7.3	9.4
3	2%	6.2	6.9	8.6	10.5



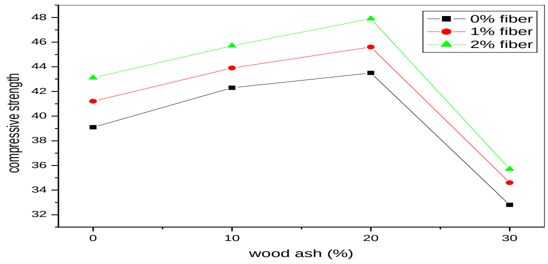
Graph 2: Vee-Bee Time Vs % of Wood waste Ash

From above figure it can be observed that the compaction factor of WWAFRC 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. Similar observation can also be made with respect to the Vee Bee results presented in Graph 2. It is observed that there is increase in Vee Bee time with the increase in the wood waste ash content, which in turn indicates the decrease in workability.

5.1. Effect of addition of Wood ash

Table 6: 28 Days Compressive Strength values in N/mm^2

S.No	% of fiber	Compressive Strength-Mpa			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	39.1	42.3	43.5	32.8
2	1%	41.2	43.9	45.6	34.6
3	2%	43.1	45.7	47.9	35.7



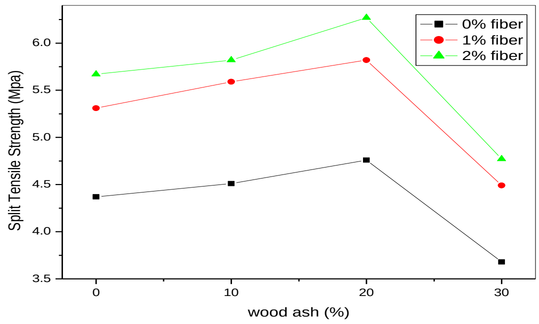
Graph 3: Vee-Bee Time Vs % of Wood waste Ash

From Graph 3 it can be observed that the 28 days compressive strength increases with the increase in the percentage of wood waste ash up to 20% addition level. On 20% addition of wood waste ash there is increase of cube compressive strength by 11.3% over plain concrete. At 10% level, the compressive strength has increased by 8.18%. But at 30% level, the compressive strength has decreased by 16.1%. Similar trends were observed even in case of FRC (Fiber reinforced concrete) mixes on addition of wood waste ash. For example: at 0.75% of fiber volume and on addition of 20% wood waste ash the compressive strength has increased by 11.1% over plain FRC. On 10% addition of wood waste ash there is increase in the compressive strength by 6.03%. But at 30% level, the compressive strength has decreased by 17.2%. Hence 20% addition of wood waste ash is taken as the optimum content. Thus, the effect of addition of wood waste ash is very similar for both plain concrete as well as fiber reinforced concrete. Similar trends were observed even at 90 days age.

5.2. Split Tensile Strength Results

Table 7: 28 Days Split Tensile Strength values in N/mm^2

S.No	% of fiber	Split Tensile Strength-Mpa			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	4.37	4.51	4.76	3.68
2	1%	5.31	5.59	5.82	4.49
3	2%	5.67	5.82	6.27	4.77

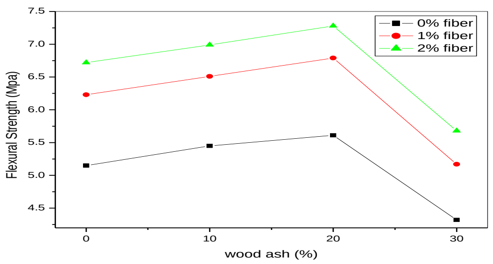


Graph 4: 28 days Split Tensile Strength Vs % of Wood waste Ash

5.3. Flexural Strength Results

Table 8: 28 Days Flexural Strength values in N/mm^2

S.No	% of fiber	Flexural Strength-Mpa			
		0% WWA	10% WWA	20% WWA	30% WWA
1	0%	5.15	5.45	5.61	4.32
2	1%	6.23	6.51	6.79	5.17
3	2%	6.72	6.99	7.28	5.68



Graph 5: 28 days Flexural Strength Vs % of Wood waste Ash

Graph.5 it can be observed that the 28 days flexural strength increases with the increase in the percentage of wood waste ash up to 20% addition level. On 20% addition of wood waste ash there is increase of flexural strength by 8.93% over plain concrete. At 10% level, the flexural strength has increased by 5.83%. But at 30% level, the split tensile strength has decreased by 16.11%. Similar trends were observed even in case of FRC (Fiber reinforced concrete) mixes on addition of wood waste ash. For example: at 0.75% of fiber volume and on addition of 20% wood waste ash the flexural strength has increased by 8.33% over plain FRC. On 10% addition of wood waste ash there is increase in the flexural strength by 4.01%. But at 30% level, the flexural strength has decreased by 15.47%. Hence 20% addition of wood waste ash is taken as the optimum content. Thus, the effect of addition of wood waste ash is very similar for both plain concrete as well as fiber reinforced concrete.

6. CONCLUSION

Results were analyzed to derive useful conclusions regarding the strength characteristics of wood waste ash fiber reinforced concrete (WWAFRC). M_{20} concrete has been used as 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 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 fiber content workability decreases.
- The workability of concrete measured from vee-bee degree, as the percentage of wood waste ash and steel fibre increases in mix the vee bee time increases. Hence it can be concluded that with the increase in the wood waste ash content and fiber content workability decreases.
- From the experimental results, the optimum percentage recommended is 1% steel fiber volume with 20% addition of in wood waste ash achieving maximum benefits in compressive strengths, split tensile strengths and flexural strengths at

any age for the characteristics of wood waste ash fibre reinforced concrete.

- The compressive strength of WWAFRC mixes at 28 days increased with the addition of wood waste ash up to 20% level when compared to that of plain concrete. Hence for normal concreting works we can go up to 20% addition level of wood waste ash. The maximum percentage increase over plain concrete is 22.50% and the percentage increase ranges from 11.25 to 22.50% over plain mix. Similar trends were observed even at 90 days age. The maximum percentage increase over plain concrete is 26.33% and the percentage increase ranges from 11.83 to 26.33% over plain mix.
- The split tensile strength of WWAFRC mixes at 28 days increased with the addition of wood waste ash up to 20% level when compared to that of plain concrete. The maximum percentage increase over plain concrete is 43.47% and the percentage increase ranges from 8.92 to 43.47% over nominal mix. Similar trends were observed even at 90 days age. The maximum percentage increase over plain concrete is 49% and the percentage increase ranges from 7.54 to 49% over nominal mix.
- The flexural strength of WWAFRC mixes at 28 days increased with the addition of wood waste ash up to 20% level when compared to that of plain concrete. The maximum percentage increase over plain concrete is 41.36% and the percentage increase ranges from 8.93 to 41.36% over normal mix. Similar trends were observed even at 90 days age. The maximum percentage increase over plain concrete is 46.45% and the percentage increase ranges from 7.83 to 46.45% over normal mix.

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