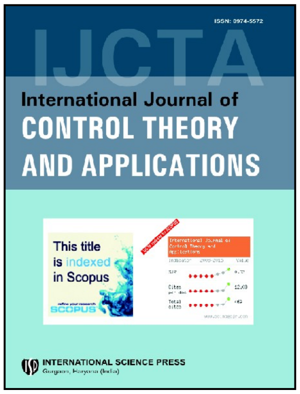

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 29 • 2017

An Experimental Study on the Mechanical Properties of Steel Fibre Reinforced Concrete with Bottom Ash As a Replacement for Sand

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Abstract: Concrete is the most widely used construction material today. Various research activities have been conducted so far and more research is being conducted than ever, owing to the scarcity of raw materials available for making concrete.

In this investigative study, bottom ash, the waste material obtained from thermal power plants is used in concrete as a replacement for sand, which is a scarce material.

The objective of this experimental work is to study various mechanical properties of concrete using steel fibres and bottom ash. Various percentages of sand are replaced with bottom ash and are used for making M25 concrete. The water cement ratio and other parameters are kept constant throughout and the mix is designed for medium exposure condition. Steel fibres at the rate of 2% by weight of cement are added to increase the crack resistive property.

The results obtained in this study have been compared with those of a control mix, to understand the behaviour of this concrete on adding bottom ash.

The compressive strength of concrete was found to increase with 25% addition of bottom ash. The split tensile strength and flexural strength tests showed that a replacement of 25% gave satisfactory results.

Hence from this experimental study, it can be suggested that sand can be replaced by bottom ash upto a percentage of 25. It has been observed that increased percentages of bottom ash result in poor quality concrete, which may be used for less important, non-load bearing concrete.

1. INTRODUCTION

The scarcity of river sand is a critical problem faced in the country. This has led to many a research work, seeking an alternate material. Here, in this study, bottom ash has been selected for replacing sand. This is so, because tonnes of bottom ash are deposited in landfill, thereby causing a threat to the environment. This has also posed a danger to ground water due to contamination.

Bottom ash in the percentages of 0%, 25%, 50%,75% and 100% are added in place of sand. Steel fibres at the rate of 2% by weight of cement are also added. The addition of steel fibres is for increasing the crack resistance of concrete. Moreover, not much research has been carried out on steel fibre reinforced concrete with bottom ash as fine aggregate. Use of plasticisers has also been avoided in the mixes, so as to understand the behavior of the said concrete without admixtures.

Here, bottom ash was collected from the thermal power plant in Ennore, Chennai. Locally available river sand was used as fine aggregate. This experimental study presents some of the properties of concrete in fresh and hardened state, on addition of bottom ash as fine aggregate. This replacement will help in solving the problem of bottom ash waste disposal to a large extent and also reduce the demand for natural river sand as a construction material.

1.1. Materials Used

The materials used in this study are cement, sand, bottom ash, coarse aggregate, steel fibres and potable water. The mix was designed for M25 concrete under medium exposure condition. The water cement ratio was taken as 0.45. As the percentage of bottom ash added was increased, the water content was also increased to account for the high water absorptive property of bottom ash. Steel fibres used were of corrugated type with a length of 30 mm and diameter 0.5 mm with aspect ratio of 60. Cement used was of OPC grade 43.

1.2. Literature Review

Research work on bottom ash has been going on in the past decades. Different experimental programs with other materials have been studied.

Kadam and Patil [1] have studied the properties of sand replaced concrete with bottom ash for various percentages and w/c ratios. According to their observation, upto 30% replacement of sand with bottom ash, the strength values increased for 7, 14, 28, 56 and 90 days curing period.

Kim and Lee [2] have experimented with bottom ash percentages of 25%, 50%,75% and 100% in high strength concrete. They have used both fine and coarse bottom ash. The flow characteristics of fresh concrete and density were studied along with compressive strength and modulus of elasticity. A reduction in flow characteristics was observed for coarse bottom ash, whereas it was unchanged for fine bottom ash. The density, modulus of elasticity and other strength characteristics showed a linear decrease.

Aggarwal *et al.* [3] have done research on bottom ash in the initial period of study of utilizing bottom ash as a construction material. A 0% to 50% of sand was replaced by bottom ash and the results showed a linear decrease in workability with increase in bottom ash percentage. The same pattern was observed for other strength characteristics like compressive strength, split tensile strength and flexural strength.

Shende *et al.* [4] have investigated the strength characteristics of M40 concrete with different percentages of steel fibres, namely 0%, 1%, 2% and 3% with aspect ratios 50, 60 and 67. An increase was found in the strength characteristics for 3% steel fibre addition with aspect ratio 50.

Lee *et al.* [5] have used bottom ash in fibre reinforced cellular concrete, with steel and polypropylene fibres. Better crack resistance was observed on using steel fibres. Likewise there was an observed increase in compressive strength for 2.4% of steel fibre addition.

Remya Raju *et al.* [6] have studied the strength performance of concrete using bottom ash as fine aggregate. Microsilica in various percentages was added to replace cement. M Sand was the fine aggregate used and replacement percentages adopted were 5 to 30% of bottom ash, with an increment of 5% each. In this study, a decrease in slump value with increase in bottom ash percentage was observed. The compressive strength, flexural strength and modulus of elasticity showed a decrease as compared with conventional concrete, whereas the split tensile strength increased.

Nataraj *et al*. [7] have done experiments by replacing sand with bottom ash and cement with fly ash. It was found that bottom ash could be taken as a replacement for sand. It was also observed that 30% replacement of cement with fly ash was also acceptable.

MATERIALS USED

The materials adopted in this study are cement, sand, bottom ash, coarse aggregate, steel fibres and potable water. The mix was designed for M25 concrete under medium exposure condition [8]. The water cement ratio was taken as 0.45. River sand used conforms to Zone III [9]. As the percentage of bottom ash added was increased, the water content was also increased to account for the high water absorptive property of bottom ash. Steel fibres used were of corrugated type with a length 30 mm and diameter 0.5 mm, with the aspect ratio of 60. Cement used was of OPC grade 43.

The physical properties of the fine aggregate used are tabulated below in Table 1.

Table 1
Properties of fine aggregate

Sl. No:	*Properties*	*River sand*	*Bottom ash*
1	Specific gravity	2.66	2.18
2	Water absorption	12%	17%
3	Fineness Modulus	3.12	2.86

EXPERIMENTAL PROGRAM

The slump values of different concretes were measured initially. It is intended to find out the different mechanical properties such as cube compressive strength, split tensile strength and flexural strength of steel fibre reinforced concrete. The mix was designed for M25 concrete, under medium exposure condition. Steel fibres were added at the rate of 2% by weight of cement. Fine aggregate, sand was replaced with bottom ash, in increments of 20% from 0-100%. The mix with 0% bottom ash is taken as the control mix. Water cement ratio of 0.45 was adopted and excess water accounting for the water absorption property of bottom ash was added for the mixes with bottom ash replacement. Hand mixing was done, without the addition of superplasticisers.

Details of the mixes adopted are given below in Table 2.

Table 2
Mix designation of concrete

Mix designation	*% of Bottom Ash*	*% of sand*	*Remarks*
Mix 1 (M1)	0	100	Control mix
Mix 2 (M2)	25	75	-
Mix 3 (M3)	50	50	-
Mix 4 (M4)	75	25	-
Mix 5 (M5)	100	0	-

Cubes of size 150 mm x 150 mm x 150 mm were cast for each mix (Fig. 1) at the rate of 3 cubes per mix for each curing period. The compressive strength was tested after a curing period of 7 days, 14 days and 28 days. Hence a total of 45 cubes were cast, cured and tested for compressive strength [10].

Figure 1: Casting of cubes

Similarly, cylinders of size 150 mm diameter and 300 mm height were also cast with the different mixes. A total of 45 cylinders were cast for testing the split tensile strength after a curing period of 7, 14 and 28 days.

Prisms of size150 mm x 150 mm x 500 mm were cast, cured and tested for finding the flexural strength under single point loading, after a curing period of 7 days and 28 days.

RESULTS AND DISCUSSION

The properties of fresh and hardened concrete were determined for each mix.

Slump Test

It was observed that the slump being a measure of workability decreased with increase in bottom ash content. This owes to the fact that water absorption rate of bottom ash is higher than that of sand. The texture of bottom ash is comparatively rough and angular as compared with sand. The slump values obtained are depicted below in Table 3.

Table 3
Slump test results

Mix	*Slump value (mm)*
M1	103
M2	95
M3	80
M4	60
M5	42

Compressive Strength of Hardened Concrete

The compressive strength of cubes was tested after a curing period of 7, 14 and 28 days, for all different mixes. It was observed that the cubes with more bottom ash content weighed less, thereby indicating that the density of concrete decreased with increase in bottom ash content. The results obtained are presented in Table 4 by taking the average strength values of three cubes per test.

Table 4
Cube strength results

Mix	*Cube compressive strength after curing period of (N/mm²)*		
	7 days	*14 days*	*28 days*
M1	24.49	27.6	30.73
M2	20.75	22.50	28.22
M3	16.8	19.82	20.85
M4	14.67	17.10	18.33
M5	13.78	15.80	16.68

Split Tensile Strength Test

The split tensile strength test was carried out on cylindrical specimens, for each concrete mix. The test was conducted after a curing period of 7, 14 and 28 days. The results obtained are given in Table 5 taking the mean strength values of three cylinders per test.

Table 5
Split tensile strength results

Mix	*Split tensile strength after curing period of(N/mm²)*		
	7 days	*14 days*	*28 days*
M1	2.75	3.10	4.13
M2	2.46	2.77	3.70
M3	2.10	2.40	2.75
M4	1.7	2.05	2.20
M5	1.15	1.70	1.80

FLEXURAL STRENGTH TEST

The flexural strength of concrete was found out by casting prisms and testing them after curing them for 7 days and 28 days (Fig. 2). Single point load was applied on the specimens. The results obtained are given in Table 6.

Table 6
Flexural test results

Mix	*Flexural strength after curing period of(N/mm²)*	
	7 days	*28 days*
M1	3.17	5.05
M2	2.91	4.00
M3	2.01	3.23
M4	1.75	2.52
M5	1.04	1.95

CONCLUSIONS

The above experimental study has given satisfactory results so as to use of bottom ash for replacing sand. It was observed that the compressive strength of bottom ash replaced concrete showed a decrease of 8.16% for a

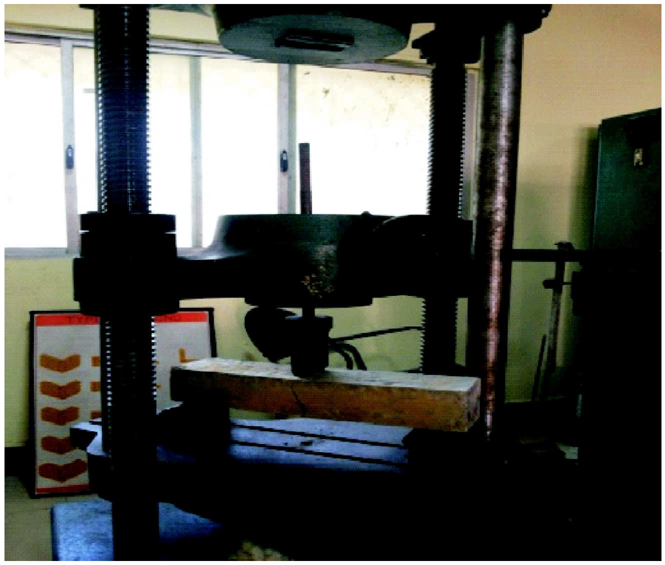

Figure 2: Flexural test setup

replacement of 20%. It further decreased by 32.15%, 40.35% and 45.72% for replacement of sand by 50%, 75% and 100% of bottom ash respectively, as compared with the control specimen. This indicates a linear pattern of decrease.

The same pattern was observed for split tensile strength as well as flexural strength. The split tensile strength decreased by 10.41%, 33.41%, 46.73% and 56.42% for replacement of sand by 25%, 50%, 75% and 100% of bottom ash.

The flexural strength decrease was by 20.79%, 36.04%, 50.10% and 61.39% for sand replacement by bottom ash in percentages of 25, 50, 75 and 100, respectively.

The results clearly indicate that bottom ash can replace sand upto a percentage of 25%. Further increase yields concrete of less strength values which may be used for less important, non-load bearing concrete work.

More research is to be conducted so as to arrive at an optimum percentage replacement of sand by bottom ash, in order to achieve the stipulated strength values.

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