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STRENGTH CHARACTERISTICS OF GLASS FIBRE ON BOTTOM ASH BASED CONCRETE

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Abstract: Bottom ash is a hazardous by-product from coal based thermal power plants. In this study fine aggregate in concrete mix has been replaced with bottom ash and glass fibre is additionally used to enhance the strength characteristics of concrete. The concrete mix design is done for M30 grade concrete. The mix is prepared for different combinations of 0%, 30%, 40%, 50% and 100% of replacement of sand by bottom ash with 0.3% of glass fibre by weight of cement. The mechanical properties were compared with control mix and it was found that the optimal combination as 50% bottom ash and 0.3% glass fibre (BGC). Flexural strength was compared by testing beams of size 1 x 0.1 x 0.2m under two point loading. Results showed that there was no degradation of strength for beams with bottom ash as replacement for fine aggregates.
Keywords: Bottom ash, flexure, Glass fibre, Stiffness, Ultimate load.

1. INTRODUCTION

Plain cement concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Recent trends in concrete technology are to improve the workability, strength and resistance to smaller cracks in the concrete. The fibres of short length and small diameters can be used in concrete to convert its brittle nature to a ductile one.

The coarser material which collects in furnace bottom in thermal power plants is known as bottom ash. This paper presents the experimental investigations carried out to study the effect of use of bottom ash as a replacement of fine aggregate.

Earlier research work in the usage of bottom ash as replacement for fine aggregates shows degradation in characteristic compressive strength of concrete apart from increasing the workability of concrete. The usage of fibres to improve the strength of reinforced concrete is also justified in the past studies. Experimental study by Rama Mohan Rao.P et. al., [2] on different volume fractions of glass fibres with 25% and 40% replacement of cement by flyash showed that the volume fraction of glass fibre of 0.3% gives better strength values compared to control mix. Ilker Bekir Topcu et. al., [4] attempted to study the effects of

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replacement of cement (by weight) with three percentages of fly ash and effects of addition of steel and polypropylene fiber and concluded that the addition of fibers provide better performance for the concrete, while fly ash in the mixture may adjust the loss in workability caused by fibers and improve strength gain.

Sivakumar. A, et. al., [5] showed that fibre addition was seen to enhance the pre-peak as well as post-peak region of the load–deflection curve, causing an increase in flexural strength and toughness by conducting investigation on high strength concrete reinforced with hybrid fibres, combination of hooked steel and a non-metallic fibre up to a volume fraction of 0.5%.

Aggarwal P. et. al., [3] showed that workability of concrete decreased with the increase in bottom ash content and concluded that compressive strength, splitting tensile strength and flexural strength of fine aggregates replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. It was concluded that bottom ash concrete containing 50% bottom ash is acceptable for most structural applications.

Study by Maslehuddin et. al., [9] for replacing sand by 30% equal weight of flyash, showed higher compressive strength gain and corrosion resistance.

The effects of class F fly ash on workability, compressive strength, and permeability, depth of carbonation and chloride penetration of concrete were investigated by Siddique et. al., [7]. The natural sand was replaced with class F fly ash by 30, 50, 70 and 100 % by mass at fixed free w/c ratio of 0.45 and 0.55 and cement content of 382 kg/m3. The results showed increase in the workability of concrete, and decreased compressive strength, at fixed cement content and w/c ratio.

The use of bottom ash in normal strength concrete is a new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry, by economizing the construction cost and decreasing the ash content. Results from earlier works indicate that loss in strength of concrete due to replacement of fine aggregate with bottom ash could be overcome with the addition of 0.3% of glass fibers.

2. EXPERIMENTAL

2.1 *Materials and Method*

2.1.1 *Glassfibres*

On a specific strength (i.e. strength to weight) basis, glass fibre is one of the strongest and most commonly used structural materials. There are several types of glass fibre with different chemical compositions providing the specific physical/chemical properties. The E glass fibre used in this study has following properties as provided by the supplier.

Table 1: Properties of E-Glass fibres

Length of fibre (mm)	Diameter (μm)	Specific Gravity	Failure strain %	Elasticity (GPa)	Tensile strength (GPa)
6	12	2.6	3.0	80	2.5

Fig 1. E-Glass Fibres

2.1.2 *Bottom ash*

Bottom ash used in this study is from Metur thermal power plant. The plant produce about 100 ton of ash. Most of the ash has to be disposed off either dry, or wet to an open area available near the plant or by grounding both the fly ash and bottom ash and mixing it with water and pumping into artificial lagoon or dumping yards. This causes the pollution in water bodies and loss of productive land. The bottom ash is replaced for fine aggregate starting from 30%, 40%, 50% upto 100% in concrete. Specific gravity of bottom ash is 1.76.

Fig 2. Bottom ash

2.1.3 *Concrete*

The concrete mix was designed according to IS 10262-1982 method to have characteristic compressive strength of 30MPa with w/c ratio 0.43 and slump of 60mm. Specific gravity of cement, fine aggregate and coarse aggregate are 3.1, 2.63 and 2.65 respectively. The sieve analysis for fine and coarse aggregate as per IS: 383-1970 gave the fineness modulus as 2.85 and 7.56. The concrete mix is given in table 2.

Table 2: Concrete mix proportion

Percentage replacement of FA with bottom ash	0 (BGC0)	30% (BGC1)	40% (BGC2)	50% (BGC3)	100% (BGC4)
Cement (kg/m^3)	432.55	432.55	432.55	432.55	432.55
Fineaggregate (kg/m^3)	536.55	375.585	321.93	268.25	0
Coarse aggregate(kg/m^3)	1195.49	1195.49	1195.49	1195.49	1195.49
Bottomash (kg/m^3)	0	160.965	214.62	268.3	536.55
Glass fibre (kg/m^3)	1.298	1.298	1.298	1.298	1.298
Water (lts)	186	186	186	186	186

2.2 *Experimental investigation*

For this experimental work cubes, cylinders and beams were casted in the laboratory. Cubes and cylinders were casted using concrete mixes with fine aggregates replaced by bottom ash of 30%,40%,50% ,100% along with 0.3% glass fibre by weight of cement.

2.2.1 *Compression test on cubes as per IS: 516-1959*

The cube specimen of the size 150 x 150 x 150 mm were tested after curing for period of 7 and 28 days for different combinations and results were compared with control specimens. No strength degradation occurred up to BGC3. Test set up for cube is as shown in Figure 3.

Fig 3: Concrete cube in compression test

2.2.2 ***Split tensile strength on cylinders as per IS: 516-1959***

The test is carried out for 7 and 28 days on cylindrical specimens 150mm diameter (D) and 300mm (L) placed horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. Comparison of results showed that tensile strength was maintained same up to BGC3. The loading of cylinder is as shown in Fig.4.

Fig 4: Concrete cylinder in tensile test

The optimum replacement percentage was chosen as 50% replacement of fine aggregate with bottom ash along with 0.3% of glass fibres by weight of cement (BGC3).

2.2.3 ***Beam Reinforcement Details***

Two groups of beam specimens of size - 0.1 x 0.2 x 1.0m were casted. One group was used as control beam and another group was casted with BGC3 mix.

Two numbers of 10 mm diameter bars at bottom and two numbers of 10mm diameter bars at top were used as main reinforcement. Shear reinforcement consists of 6mm diameter 2-legged stirrups @ 100mm c/c throughout the length of the beam. The reinforcement detail is as shown in Fig.5.

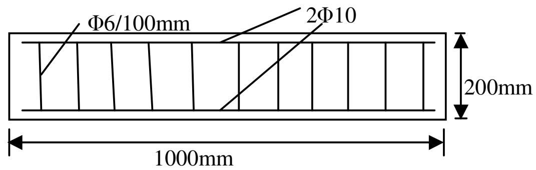

Fig 5: Reinforcement detail for beam

2.2.4. *Testing of beams*

Flexural test on beams were carried out in universal testing machine of capacity 1000KN. Deflectometers were fixed to measure the deflection at salient points. The load set up is as shown in Fig.6.

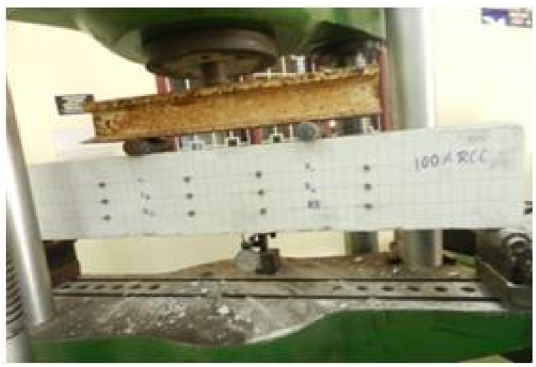

Fig 6: Load setup for beams

The load was applied without shock and increased until failure occurs. The load-deformation pattern was plotted and maximum load applied to the specimens were recorded.

3. RESULTS

3.1. *Cube compressive strength*

Test result showed that up to BGC3, no significant reduction in the characteristic compressive strength occurred after curing for 28 days. The initial strength gain is at slower rate, since pozzolanic action of bottom ash at early age is slow which do not contribute for the strength of concrete. The cube compressive strength for different mixes at period of 7 and 28 days are given in Fig.7 and Fig. 8 respectively.

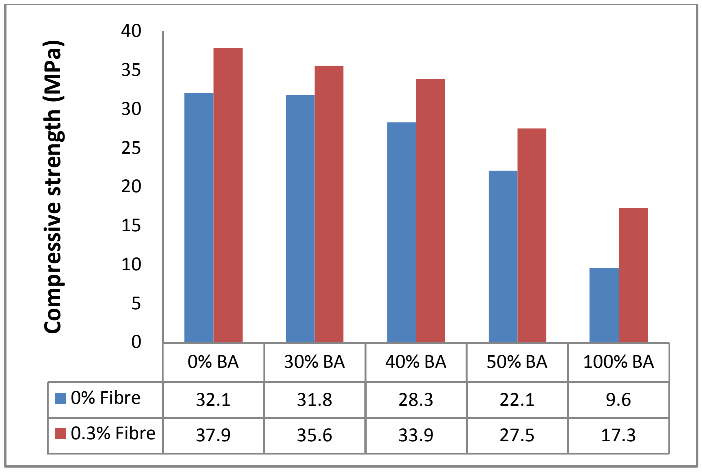

Fig 7: Cube compressive strength 7days (MPa)

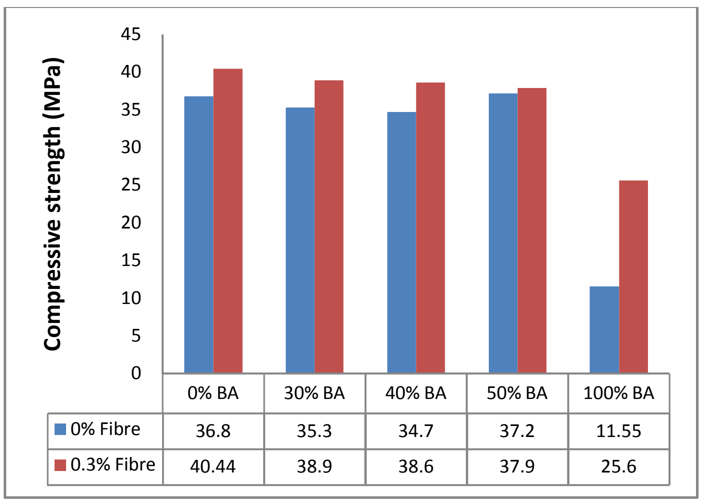

Fig 8: Cube compressive strength 28days (MPa)

3.2. *Cylinder split tensile strength*

The split tensile strength of specimens also showed that the optimum mix is BGC3 with no change in values compared to control specimen. The split tensile strength for different mixes at period of 7 and 28 days are given in Fig. 9 and Fig. 10 respectively.

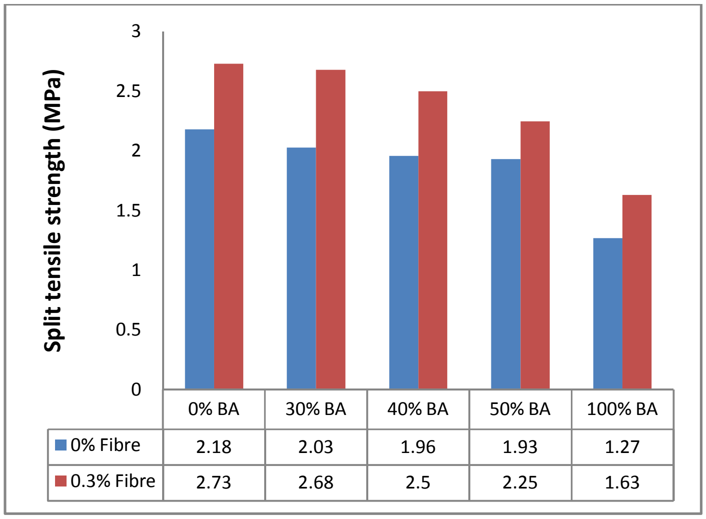

Fig 9: Cylinder Split tensile strength 7 days (MPa)

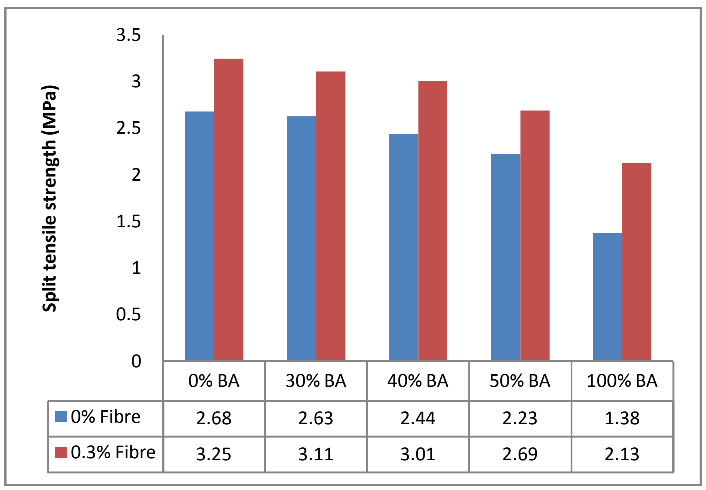

Fig 10: Cylinder Split tensile strength 28 days (MPa)

3.3. *Flexure strength*

Loading of control beam and BGC3 were carried out as shown in Fig.9 and Fig.10. respectively. Comparisons of various test results are given in Table.3. The loads versus midspan deflection for both the beams were recorded, and their mean values were compared as shown in Fig.11. Similar response was observed for beam in both groups.

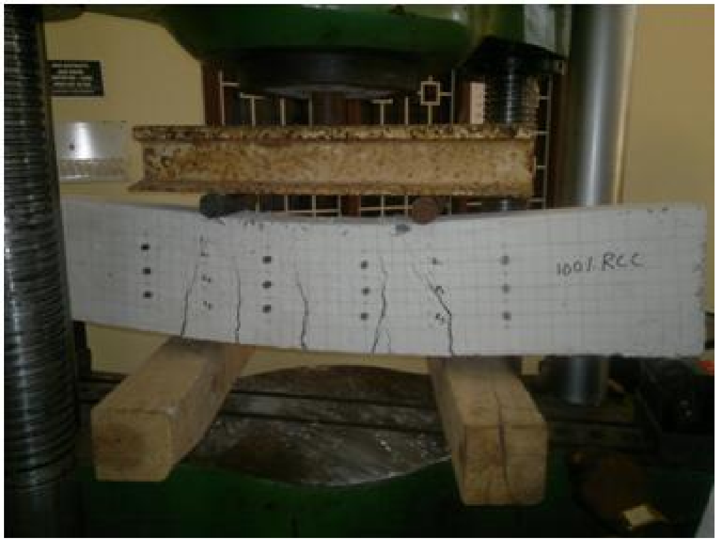

Fig 11. Flexural test on control beam

Fig 12: Flexural test on beam with BGC3 mix

Table 3: Comparison of beam test results

Data	Peak Load (kN)	Flexural strength (N/mm²)	Young's modulus (N/mm²)	Max Bending Moment (kNm)	Maximum displacement (mm)
Control beam	68.60	18.00	20180	11.43	12.4
BGC3	72.25	18.96	20480	12.04	13.6

Both the curves were linear upto 30KN load showing that stiffness was not altered. Cracks started to set up at 42KN and 46KN respectively for control beam and BGC3 respectively. The ultimate load carrying capacity is increased from 62.8KN for control beam to 72.25KN for beam with BGC3 mix.

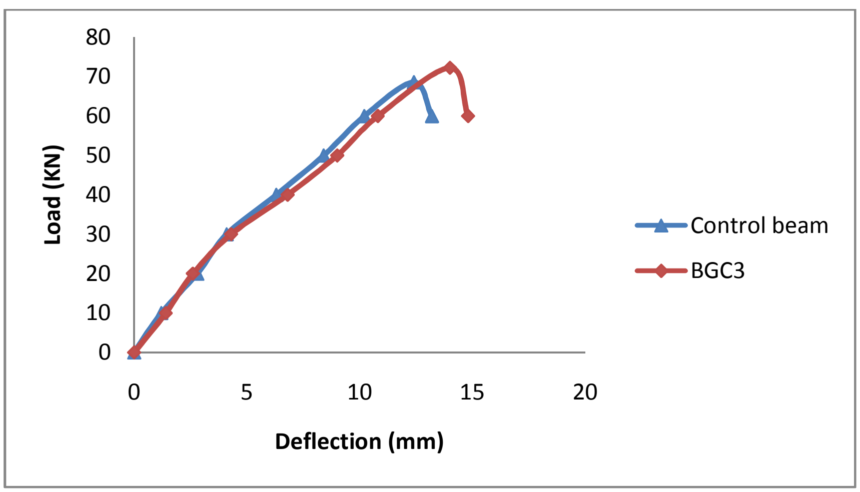

Fig 13: Comparison of mean Load - Displacement curve for control beam and beam with BGC3 mix

Cracks formed in control beam were fewer in number but width was more, whereas in BGC3 numerous cracks with reduced crack width were formed which shows that the fibres arrested the widening of cracks. The beams after the test were as shown in Fig.12.

Fig 14: Flexural cracks in control beam and beam with BGC3 mix

The moment curvature plot indicates that the response of beams were similar in both groups with BGC3 having increased moment carrying capacity.

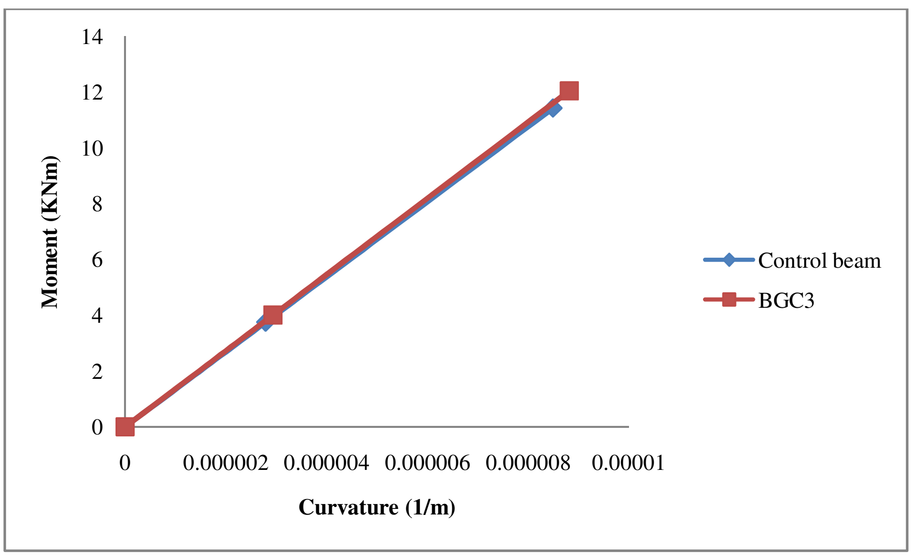

Fig 15: Comparison of moment-curvature relation

4. CONCLUDING REMAKS

The study was conducted to evaluate the strength characteristics of concrete with bottom ash and glass fibre. The concrete mix design was done for M30 grade concrete. The following points are concluded from this study.

- The 7 days cube compressive strength results showed reduced strength of concrete due to slow pozzolonic action.
- The strength of concrete cubes at 28 days with 50% replacement of bottom ash along with 0.3% of glass fibre shows an increase of 113% in compressive strength.
- Addition of glass fibre increases the tensile strength of the specimens.
- 50% bottom ash with 0.3% glass fibre showed the maximum 7 day and 28 day split tensile strength indigating that BGC3 mix is the most optimum. The addition of fibres reduces the workability of concrete which was overcome by the addition of bottom ash as replacement of fine aggregate.
- BGC3 showed high flexural strength and high modulus of elasticity compared to control specimen.
- Experimental result showed that BGC3 retained the stiffness similar to that of control beam.
- Fibres in BGC3 checked the development of cracks and thereby had many flexural cracks of reduced width.
- Result showed that BGC3 had similar moment curvature relationship as control beam with enhanced moment carrying capacity.

In this study bottom ash which is a hazardous material is used as a replacement for fine aggregate to bring down the pollution. The reduction in strength and stiffness of concrete due to bottom ash is overcome by adding glass fibres to the mix.

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