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Effect of Hybrid Fibres on Flexural Behaviour of Reinforced Concrete Beams with Blended Cement

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Abstract - Hybrid fibre is the addition of two fibres which varies in properties. A single fibre added concrete specimen possess high flexural strength, better durability properties than normal concrete specimen. This paper attempts to study the behavior of hybrid fiber reinforced concrete beams in terms of flexural strength and ductility factor in comparison to a nominal concrete mix of grade M40. In addition to the usage of fibers other supplementary cementitious materials are replaced for cement such as micro silica, GGBS and fly ash to acquire high strength concrete. These materials are replaced for its optimum level to the weight of cement content. The fibres used are steel and polypropylene which are added in the concrete mix at a volume basis. The flexural strength of the reinforced concrete beams are determined by subjecting to four point static loading system. The results obtained have shown that GGBS replaced concrete specimens show increased strength capacity and also by using fibers in concrete its ductility has improved and the crack widths are reduced and controlled tightly.

Index terms - Hybrid fibres, flexural strength, Static load.

1. INTRODUCTION

Concrete is a composite material made from cement, fine aggregate, coarse aggregate and water. Apart from cement various other pozzolonic materials can be used in the production of concrete. These pozzolonic materials though not cementitious by themselves, contain reactive silica and alumina in a finely divided form which are capable of combining with lime at ordinary temperatures in the presence of water to form stable insoluble compounds possessing cementing properties and are called as supplementary cementitious materials. Some of which are micro silica, GGBS and flyash which are used in this paper. These materials help in improving the strength of concrete. Apart from the basic concrete producing materials fibers can also be used in concrete which helps in improving the integrity of the structure. These are short and discrete fibres which are uniformly or randomly oriented. These fibres does not help in improving the ductile capacity of concrete specimens by controlling and reducing the cracks and crack width. The fibres used in this paper are steel and polypropylene to check the ductile capacity of specimens under loads. The supplementary cementitious materials micro silica, GGBS and flyash are replaced for about 7.5%, 40%, and 30% respectively to weight of cement while the fibres steel and polypropylene are added in volume fraction of about 75% and 25% respectively. In this study, 3 different concrete mixtures are used to determine the high strength concrete by subjecting the reinforced concrete beams to flexure test under four point static loading condition which are compared to that of a nominal mix specimen.

2. MATERIALS

2.1. *Cement*

Ordinary Portland cement is used in this experimental work and its properties were tested as per Indian standards IS 4031. Table 1 shows the properties of OPC.

Table 1. Properties of ordinary Portland cement

Property	Value
Specific gravity	3.14
Normal consistency	30%
Initial setting time	50 mins
Final setting time	320 mins

2.2. *Aggregates*

Fine aggregate (FA) and coarse aggregates (CA) were used and two different sizes of coarse aggregates 12.5mm and 20mm were used. The test conducted to analyse the properties were according to IS 2386: 1963. Table 2 shows the properties of aggregates.

Table 2. Properties of fine aggregates and coarse aggregates

Property	CA (20mm)	CA (12.5mm)	FA
Specific gravity	2.72	2.7	2.52
Fineness modulus	6.2	4.6	2.85
Water absorption	0.4 %	0.6 %	1.5 %
Bulk density	1628 kg/m ^{3}	1533 kg/m ^{3}	1666 kg/m ^{3}

2.3. ***Silica fume***

Silica fume, also known as microsilica, is an amorphous (non-crystalline) polymorph of silicon dioxide and silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

2.4. ***Ground granulated blast furnace slag***

Ground granulated blast furnace slag is one of the greenest of construction materials. It is a non-metallic product consisting essential silicates and aluminates of calcium and other bases. Its only raw material is a very specific slag that is a by-product from the blast furnaces manufacturing iron. GGBS essentially consists of silico and alumino silicates and other bases that are developed in molten condition, simultaneously in iron furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportions vary. GGBS cement is routinely specified in concrete to provide protection both sulphate and chloride attack**.**

2.5. ***Fly Ash***

Fly ash, also known as "pulverized fuel ash" is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ,aluminium oxide and calcium oxide , the main mineral compounds in coal-bearing rock strata. It is often used as partial replacement for Portland cement in concrete production. Pozzolanas ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

2.6. ***Fibres***

Steel fibres are basically a cheaper and easier to use form of rebar reinforced concrete. This imparts the concrete with greater structural strength, reduces cracking and helps protect against extreme cold. Steel fibre is often used in conjunction with rebar or one of the other fiber types. Polypropylene fibres has low specific gravity hence yields the greatest volume of fiber for a given weight. This high yield means that polypropylene fibre provides good bulk and cover, while being lighter in weight. Polypropylene is the lightest of all fibres and is lighter than water. It is 34% lighter than polyester and 20% lighter than nylon. It provides more bulk and warmth for less weight.

Fig. 1. Steel and Polypropylene fibres

2.7. ***Super plasticizers***

Super plasticizers are highly distinctive in their nature and they make possible the production of concrete which in its fresh or hardened stage is substantially different from concrete made using water reducing admixtures. CONPLAST SP430 manufactured by FOSROC Chemicals is used in this project. The main objective of using this super plasticizer is to increase the workability of concrete so that there is a little or no vibration is required during placing. It has been specially formulated to give high water reduction up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

3. EXPERIMENTAL WORK

The concrete mixes for the present study comprised a portland cement concrete and three blended concrete mixes with constant steel and polypropylene fibers of 75% and 25% by volume fraction. Grade 40 concrete was aimed for the design. The other cementitious materials used in this project are GGBS, silica fume and fly ash. The design mix ratio is 1:2.03:3.58.For each of concrete mixes, cube of size (100x100x100)mm for compression test, cylinder of size (100x200)mm for tensile strength test, prism of size (500x100x100)mm and beam of size

(850x100x150)mm to investigate the flexural behavior of the mix.

Fig. 2. Addition of fibres in concrete mix.

The following tests are to be done on concrete specimens

- Compression strength,
- Split tensile strength,
- Flexural strength.

Table 3. Proposed mix types and designations.

Composition	Mix designation
Control mix	CM
Cement + Silica fume+ Fibres	CS
Cement + GGBS + Silica fume + Fibres	CG
Cement + Fly ash + Silica fume + Fibres	CF

3.1. *Compressive strength*

100mm cubes are used for determining the compressive strength of concrete and the results of the strength of each mix under 28th day are tabulated in table 4 and figure 4 shows the comparison chart of strength of cubes.

Fig. 3. Testing of cube specimen.

Table 4. Compressive strength results

Mix	CM	CS	CG	CF
Strength (N/mm^2)	41	48.3	51.3	50

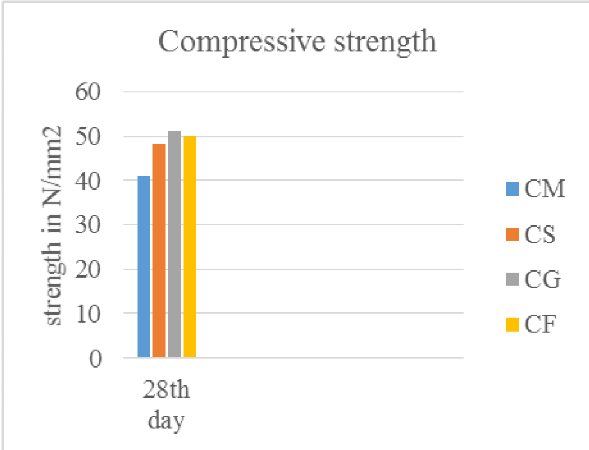

Fig. 4. Compressive strength of mix types.

3.2. *Tensile strength*

Split tensile test was done in cylindrical specimens of (100x200) mm size so as to determine the tensile capacity of the concrete and the results of 28th day testing are tabulated in table 5 and figure 6 shows the graphical representation of tensile capacity of cylinders of each mix.

Fig. 5. Testing of cylinder specimen.

Table 5. Split tensile capacity

Mix	CM	CS	CG	CF
Strength (N/mm^2)	3.58	4.33	4.69	4.13

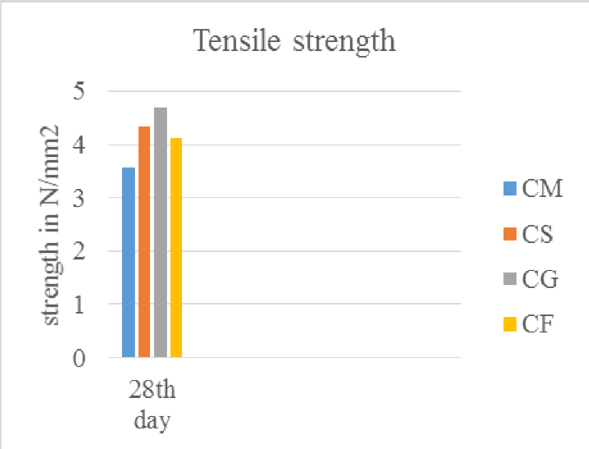

Fig. 6. Split tensile capacity of mix types.

3.3. *Flexural strength*

The most common purpose of a flexure test is to measure flexural strength. Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen.

3.3.1. *Flexural strength of plain Beams*

The following table 6 shows the results of plain beams of (500x100x100) mm in size subjected to flexural test. Figure 8 is a graphical representation of comparison of the flexural strength capacities of plain beam.

Fig. 7. Test setup of plain beam.

Table 6. Flexural strength of plain beams

Mix	CM	CS	CG	CF
Strength (N/mm^2)	9.5	9.55	10.15	9.75

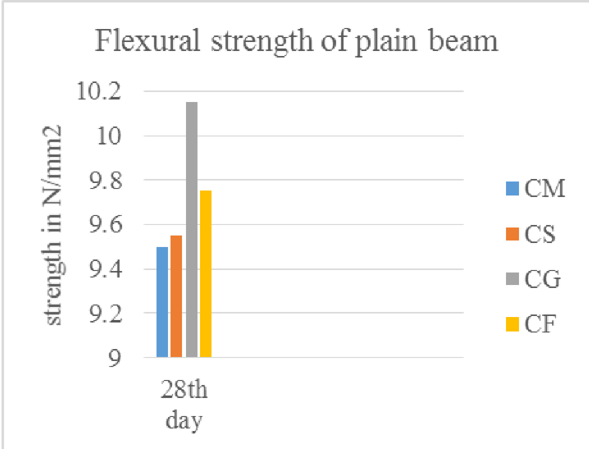

Fig. 8. Flexural strength capacity of plain beams.

3.3.2. *Flexural strength of Reinforced Beams*

The following table 7 shows the results of RC beams of (850x100x150) mm in size subjected to flexural test. Figure 11 is a graphical representation of comparison of the flexural strength capacities of RC beam.

Fig. 9. Test setup for RC beam.

Fig. 10. Flexural failure of fiber-reinforced beam

Table 7. Flexural strength of reinforced beams

MIX	CM	CS	CG	CF
STRENGTH (N/mm^2)	35.13	35.93	37.40	36.27

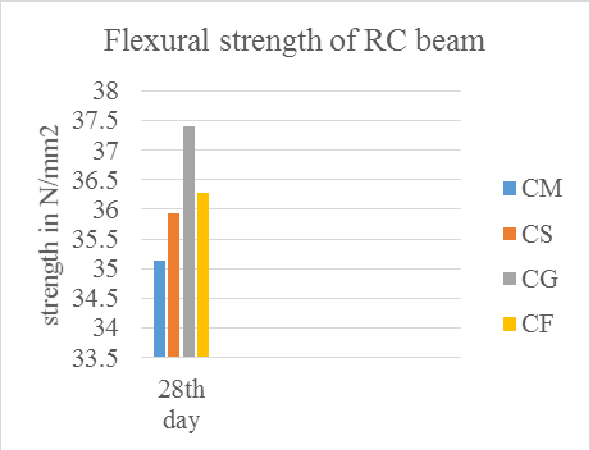

Fig. 11. Flexural strength capacity of RC beams.

4. CONCLUSION

The supplementary cementitious materials micro silica, GGBS and flyash used in this experiment has exhibited excellent pozzolonic characteristics and have improved the strength of the concrete and the fibres improved the ductile nature of concrete. The following conclusions can be drawn:

- Replacing cement with the supplementary cementitious materials has helped in increasing the strength of concrete under compression, tension and flexural characteristics.
- GGBS possessing high silica content has shown better strength properties compared to other concrete mixtures.
- Steel and polypropylene fibres helps in developing the ductile characteristic of concrete thereby increasing the load bearing capacity by reducing crack development and controlling crack width.

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