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Combine Effect of Metakaolin, Fly Ash and Steel Fiber on Mechanical Properties of High Strength Concrete

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Abstract: *In this experimental study the changes on some mechanical properties of concrete specimens produced by Metakaolin, fly Ash and steel fibers were investigated. The main objective of this work is to obtain a more ductile high strength concrete produced by using Metakaolin, Fly Ash and Steel Fiber. Three types of steel fibers were used in the experiments and volume fractions of steel fiber were 0.5% to 4.0 %. Addition of metakaolin and fly ash into the concrete were 5 % and 10 % by weight of cement content respectively. Water/cement ratio was 0.27. Compressive strength and split tensile strength tests were made on hardened concrete specimens. The use of metakaolin increased mechanical strength of concrete. On the other hand, the addition of steel fiber into concrete improves ductility of high strength concrete significantly.*

Keywords–*Compressive Strength, Fly Ash, High Strength Concrete (HSC), High Strength Fiber Reinforced Concrete (HSFRC), Metakaolin, Split Tensile Strength, Steel Fiber.*

I. INTRODUCTION

The study of high strength concrete has become interesting when the concrete structures are growing taller and larger. High strength concrete is a type of high performance concrete with a specified compressive strength of 40 N/mm^2 or greater. Metakaolin, or heat-treated clay, may be used as a Supplementary Cementitious Material (SCM) in concrete to reduce cement consumption, to increase strength and the rate of strength gain, to decrease permeability, and to improve durability. Metakaolin reduces the porosity of concrete. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to the concrete would act as crack arrester and would substantially improve its compressive and flexural strength properties. This type of concrete is known as fiber reinforced concrete. Fiber reinforced concrete can be defined as composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers.

II. MATERIAL USED

2.1 Cement

Ordinary Portland Cement of 53 Grade conforming to IS: 12269-1987 was used in the investigation. The specific gravity of cement was 3.10.

2.2 Coarse Aggregate

Crushed stone metal with a maximum size of 12.5 mm from a local source having the specific gravity of 2.7 conforming to IS: 383-1970 was used.

2.3 Fine Aggregate

Locally available river sand passing through 4.75 mm IS sieve conforming to grading zone-II of IS: 383-1970 was used. The specific gravity of fine aggregate was 2.54.

2.4 Metakaolin

Metakaolin is not a byproduct. It is obtained by the calcinations of pure or refined Kaolinite clay at a temperature between 650^0 C and 850^0C, followed by grinding to achieve a fineness of 700-900 m^2/kg. Metakaolin is a high quality pozzolonic material, which is blended with cement in order to improve the durability of concrete. When used in concrete it will fill the void space between cement particles resulting in a more impermeable concrete. The physical properties and chemical composition of metakaolin are shown in table 2.1and table 2.2 respectively.

Table 2.1: Physical Properties of Metakaolin (www.metakaolin.com)

Property	Specific Gravity	Bulk Density (g/cm^3)	Physical Form	Colour
Value	2.60	0.3 to 0.4	Powder	Off White

Table 2.2: Chemical Composition of Metakaolin (www.metakaolin.com)

Oxide	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_3	TiO_2	Na_2O	L.O.I.
% by mass	51.52	40.18	1.23	2.0	0.12	0.53	0.0	2.27	0.08	2.01

2.5 Fly Ash

Fly ash is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nasik. The light grey fly ash under the product name “Pozzocrete 83” is available in 30 kg bags. The fly ash produced by the company satisfies all the requirements of the IS: 3812-1981.

2.6 Super plasticizer

Sulphonated Naphthalene formaldehyde condensate CONPLAST SP-430 super plasticizer obtained from Fosroc Chemicals (India) Pvt. Ltd. was used. It conforms to IS: 9103-1999 and has a specific gravity of 1.20.

2.7 Steel Fiber

The main variables used in the study are three different types of steel fibers, i.e. Round Crimped Steel Fiber (RCSF), Hook Ended Steel Fiber (HESF) and Flat Crimped Steel Fiber (FCSF) with different dosages of fibers are used by weight of cementitious material. The properties of steel fibers are shown in table 2.3.

Table 2.3: Properties of Steel Fiber used

Type	**Length L (mm)**	**Diameter d (mm)**	**Aspect Ratio (L/d)**
RCSF	25	0.55	45
FCSF	30	2 mm thick	15
HESF	25	0.55	45

2.8 Water

Fresh portable water which is free from concentration of acid and organic substances is used for mixing the concrete and curing.

III. MIXTURE PROPORTION AND SPECIMEN PREPARATION

The experimental investigation was carried out to study the properties of high strength concrete of M70 grade which was design by British DoE method. Metakaolin was added as 5 % weight of cementitious material and fly is by 10 % weight of cementitious material. There are three types of steel fibers are used in this investigation, i.e. Round Crimped Steel Fiber (RCSF), Hook Ended Steel Fiber (HESF) and Flat Crimped Steel Fiber (FCSF) with different dosages of fibers are used by 0.5 %, 1%, 1.5%,2 %,2.5%,3%,3.5% and 4% weight of cementitious material. Table 3.1 shows the mixtures used and their compositional contents.

Table 3.1: Mix Proportion

Sr. No	**Material**	**Mass**
1	Cementitious Material	556 Kg/M^3
2	Ordinary Portland Cement (85 % Of CM)	472.6 Kg/M^3
3	Metakaolin (5 % Of CM)	27.8 Kg/M^3
4	Fly Ash (10 % Of CM)	55.6Kg/M^3
5	Fine Aggregate	702Kg/M^3
6	Coarse Aggregate	1042 Kg/M^3
7	Water	150 Kg/M^3
8	Superplasticizer (CONPLAST SP-430)	18 Ml Per Kg Of Cement
9	Water Binder Ratio	0.27

IV. METHODOLOGY

For compressive strength test, cube specimens of dimensions (100 mm x 100 mm x 100 mm) were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank for 28 days. The compressive strength of concrete was determined in accordance with Indian Standards IS: 516-1959. The result obtained are shown in Table 4.1

Table 4.1: Compressive Strength at 28 Days

Sr. No	Fiber Volume Fraction V*f*(%)	Compressive Strength At 28 Days (N/mm^2)		
		RCSF	FCSF	HESF
1	0	75.30	75.30	75.30
2	0.5	79.85	78.40	76.50
3	1.0	83.25	79.80	77.85
4	1.5	85.40	81.25	79.38
5	2.0	86.50	82.75	79.85
6	2.5	87.30	83.40	80.85
7	3.0	88.50	85.50	81.60
8	3.5	89.40	86.85	83.55
9	4.0	87.65	84.80	82.15

4.1 Split Tensile Strength

For split tensile strength test, cylinder specimens of dimensions (150 mm x 300 mm) were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank for 28 days. These specimens were tested under Universal Testing Machine. In each category three cylinders were tested and their average value is reported. The split tensile strength of concrete was determined in accordance with Indian Standards IS: 5816-1999. Split tensile strength was calculated as: Split Tensile strength (N/mm^2) = $2P / \pi DL$, where P= failure load, D= diameter of cylinder, L=Length of cylinder. The result obtained are shown in Table 4.2

Table 4.2: Split Tensile Strength at 28 Days

Sr. No	Fiber Volume Fraction V*f*(%)	Split Tensile Strength At 28 Days (N/mm^2)		
		RCSF	FCSF	HESF
1	0	3.26	3.26	3.26
2	0.5	3.30	3.38	3.27
3	1.0	3.40	3.45	3.32
4	1.5	3.45	3.53	3.40
5	2.0	3.52	3.60	3.45
6	2.5	3.59	3.65	3.50
7	3.0	3.68	3.72	3.60
8	3.5	3.72	3.79	3.65
9	4.0	3.67	3.73	3.63

V. RESULT AND DISCUSSION

5.1 Effect of fiber volume fraction V*f* (%) on Compressive Strength of High Strength Concrete

The compressive strength increases significantly due to the addition of steel fiber compared with normal concrete. In general, the compressive strength of the concrete having Round Crimped Steel Fiber (RCSF) was higher than that of concrete with Flat Crimped Steel Fiber (FCSF) and Hook Ended Steel Fiber (HESF) at the same volume fractions of steel up to the limit. The compressive strength of concrete with steel fiber is increased up to the 3.5 % of fiber volume fraction and then decreases. The maximum values of compressive strength at 3.5 % fiber volume fraction are 89.40 N/mm^2, 86.85 N/mm^2 and 83.55 N/mm^2 for RCSF, FCSF and HESF respectively. The effect of metakaolin, fly ash and steel fiber on compressive strength of concrete shown in figure 5.1.

5.2 Effect of fiber volume fraction V*f* (%) on Split Tensile Strength of High Strength Concrete

The result from Table 4.2 shows that the cylinder split tensile strength of concrete increases considerably with an increase in fiber content. A continuous increase in strength is observed up to a limit. The 3.5 % of fiber content has given maximum increase in split tensile strength as compared to that of normal concrete. The Flat Crimped Steel Fiber (FCSF) gives maximum split tensile strength than that of Round Crimped Steel Fiber (RCSF) and Hook Ended Steel Fiber (HESF).The effect of metakaolin, fly ash and steel fiber on split tensile strength of concrete shown in figure 5.2.

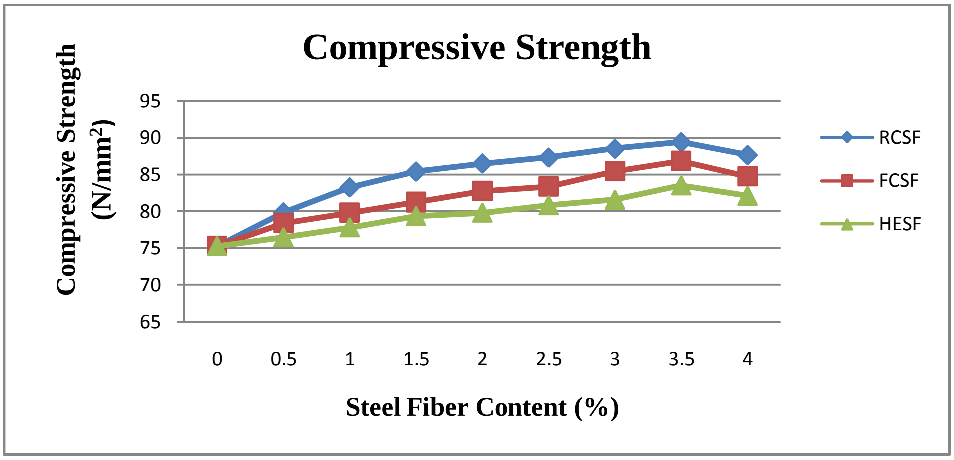

Fig. 5.1 Compressive Strength of concrete with percentage variation of Steel Fibers

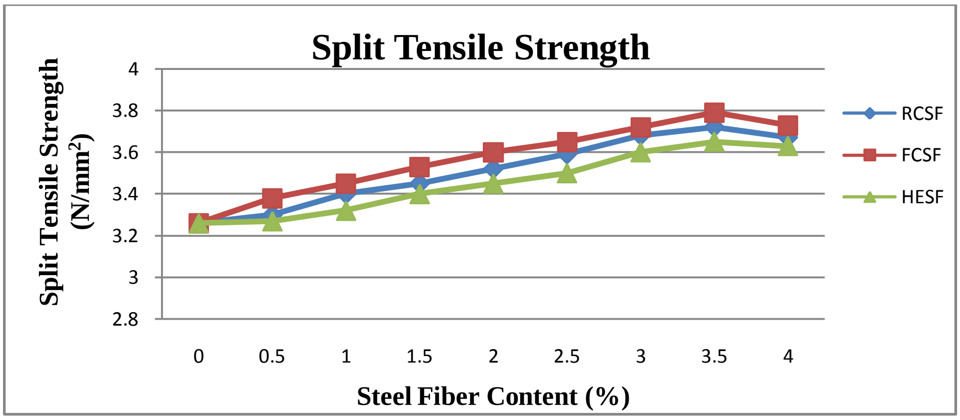

Fig. 5.2 Split Tensile Strength of concrete with percentage variation of Steel Fibers

VI. Conclusion

Plain concrete is a brittle material and fails suddenly. Addition of steel fibers to concrete changes its brittle mode of failure into a more ductile one and improves the concrete ductility. The compressive strength and split tensile strength of concrete increasing with fiber content. The maximum value of compressive strength gives the RCSF and split tensile strength gives FCSF at 3.5 % fiber content.

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