

Experimental Investigation on Strength Characteristics of Metakaolin Based High Performance Concrete with Steel and Polypropylene Fibres

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ABSTRACT: The present investigation deals with the study of the behavior of composite fibers in metakaolin based High Performance Concrete. To attain the setout objectives of the present investigation, an aggregate binder ratio of 2.5 has been chosen and cement has been replaced partially with metakaolin in three different percentages viz. 0, 10 and 20 %. Steel fibres by 0, 0.5, 0.75, and 1.0 % and polypropylene fiber of 0.25% constant and with different water binder ratios of 0.30, 0.35, 0.40 to produce High Performance Concrete. The mix is tested for strength properties such as cube compressive strength, split tensile strength and flexural strength at different ages. The results are quite encouraging.

KEYWORDS: Metakaolin, HPC, Composite Fibres.

I. INTRODUCTION

With the spurt in technology and vast usage of concrete and mortars, the strength workability, durability and other characteristics of the normal concrete require modifications to make it more suitable for all situations. Because of these the use of admixtures became alternative solution. The addition of admixture increases pozzolanic activity due to the presence of finer particles. The ordinary concrete has low tensile strength and brittle in nature. The tensile strength can be increased by the use of fibres in concrete.

In the recent years the strength and durability properties of concrete are enhanced by adding cementitious materials such as flyash, GGBS, silica fume and metakaolin. Super plasticizers are used in HPC to lower water binder ratio in turn to attain high strength. To overcome various problems encountered in the construction field and to achieve better performance in aggressive environment, use of HPC is becoming more popular. The addition of fibres along with mineral admixture in concrete makes matrix strengthened and results in, increase of strength characteristics. The commonly used fibres are steel, glass, polypropylene, jute and coir.

II. REVIEW OF LITERATURE

P. Dinakar et.al., By using Metakaolin and cement with low water/binder ratio of 0.3 , high performance concretes can be developed . From results it can be realized that Cube Compressive strength ,Splitting tensile strengths and elastic modulus results shown higher values at 10% replacement of cement by metakaolin.

Nova John ,The results shows by the partial replacement of cement with metakaolin helps in achieving high strengths in concrete. At 15% replacement of cement with metakaolin content improves the strength characteristics such as of Cube Compressive Strength, Split Tensile Strength and Flexural Strength.

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M. Tamil Selvi, Dr. T.S. Thandavamoorthy , The test results showed by introducing steel fibers in concrete which increased the cube compressive strength and split tensile strength values. Cube compressive strength was increased in range of 3 to 60 percent between 7 and 28 days for Steel Fiber Reinforced concrete.

For PPFRC it was observed that the cube compressive strength was increased between 10 per cent and 18 per cent for 7 and 28 days. For composite fiber (steel and polypropylene fibers) reinforced concrete the strength was increased by 3 per cent to 22 per cent for 7 to 28 days when compared to normal concrete. The ductility properties of concrete specimens were also observed to be increased by the use of fibers.

Avinash Gornale et.al., The increase in Compression strength for M-20,M-30 and M-40 at 3,7 and 28 days was increased by 20% to 30%. The increase in flexural strength for M-20, M-30 and M-40 at 3,7 and 28 days was increased by 25% to 30%.The increase in Flexural strength for M-20,M-30 and M-40 at 3,7 and 28 days was increased by 25% to 30% when compared with the normal concrete at 28 days.

Dr.K.Srinivasu et.al., Better Results are achieved by adding mineral admixtures like metakaolin with silica fume, fly ash and steel fibres in HPC. Water absorption is improved by use of metakaolin in concrete which increases density.

M. Nazeer, R. Arun Kumar, The impact resistance of both binary blended and ternary blended mixes shows remarkable improvement compared to concrete mix with cement as the only binder.

III. MATERIALS

a)Cement (OPC): Ultra tech cement 43 grade was used. Specific Gravity of Cement was 3.08.

b)Coarse aggregate: - Crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.70.

c)Fine aggregate: - River sand from local sources was used as fine aggregate. Specific Gravity was 2.50.

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

e) Metakaolin:- The Metakaolin is obtained from the 20 MICRON LIMITED company at Vadodara in Gujarat. The specific gravity of Metakaolin was 2.6. The Metakaolin is in conformity with the general requirements of Pozzolana.

f) Steel Fibres: -Steel Fibres were supplied by name STELWORKS. Crimped steel fibres of 30mm length with a diameter of 0.6mm and an aspect ratio of 50, density is 7840 Kg/m³ and specific gravity was 7.9 were used throughout the experimental program

g) Polypropylene fibres: RECRON 3S TYPE-CT 2012 polypropylene fibres of density 946 Kg/m³ were used in experimental program.

h) Super Plasticizer: - The super plasticizer used in this experiment was SP 430. It is manufactured by FOSROC, Bangalore. It complies to IS: 9103 – 1999 and also to BS, ASTM Standards. On adding to concrete, it disperses the cement particles i.e. enhances the workability without much affecting the set rate of concrete.

IV. MIX DESIGN

Sample calculation of the quantities required for the mix with aggregate-binder ratio 2.5 and for water binder ratios of 0.30, 0.35 and 0.40 and for 0%,10%and 20% metakaolin are tabulated below.

Materials	0% Metakaolin			10% Metakaolin			20% Metakaolin		
	0.30% W/B Ratio	0.35% W/B Ratio	0.4% W/B Ratio	0.30% W/B Ratio	0.35% W/B Ratio	0.4% W/B Ratio	0.30% W/B Ratio	0.35% W/B Ratio	0.4% W/B Ratio
Cement (kg)	35.60	34.51	33.48	31.92	30.95	30.03	28.27	27.41	26.60
Metakaolin(kg)	0.00	-	-	3.55	3.44	3.34	7.07	6.85	6.65
Water (ml)	10.68	12.08	13.39	10.64	12.03	13.35	10.60	11.99	13.30
Coarse aggregates (kg)	53.40	51.77	50.23	53.20	51.58	50.05	53.00	51.39	49.87
Fine aggregates (kg)	35.60	34.51	33.48	35.47	34.38	33.36	35.33	34.26	33.25

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Super plasticizer (ml)	35.60	207.06	200.88	212.81	206.3	200.19	212.00	205.55	199.481
Mix proportion	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5

V. CASTING AND TESTING PROCEDURE

The cubes were cast in steel moulds of inner dimensions of 150 x 150 x 150mm and the cylinders were cast in steel moulds of inner dimensions as 150mm diameter and 300mm height. All the materials used in this investigation i.e. cement, metakaolin, fine aggregate, coarse aggregate, steel fibres and polypropylene fibres and super plasticizer. The cement, sand and metakaolin were mixed thoroughly then added steel and polypropylene fibres. Then water added to the above mixture. Care has to be taken in mixing to avoid balling effect. The test were conducted on compression strength, split tensile strength and flexural strength and results are tabulated in table 1 to 6 for 7 days and 28 days.

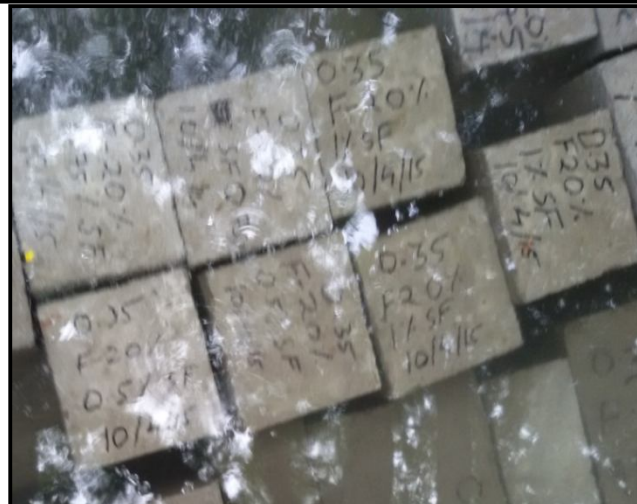


TABLE 1 **CUBE COMPRESSIVE STRENGTH AT 7 DAYS IN N/mm²**

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	Cube Compressive strength (MPa)								
				0% Metakaolin w/c Ratio			10% Metakaolin w/c Ratio			20% Metakaolin w/c Ratio		
				0.3	0.35	0.40	0.3	0.35	0.40	0.30	0.35	0.40
1	0.0	0	0	44.22	43.88	41.33	47.55	45.77	43.55	43.77	42.44	41.77
2	0.50	0.25	0.75	47.77	46.22	44.22	51.77	48.66	47.11	46.88	45.55	43.55
3	0.75	0.25	1.0	52.66	48.44	47.55	54.66	52.88	50.44	51.33	47.55	46.33
4	1.00	0.25	1.25	56.88	54.44	51.11	59.33	56.88	54.22	55.11	52.66	50.44

The variation of 7 Days Cube Compressive Strength on Percentage of Composite fibres for different W/B Ratio are presented in fig 1,2 and 3 for 0% metakaolin, 10% metakaolin, and 20% metakaolin respectively.

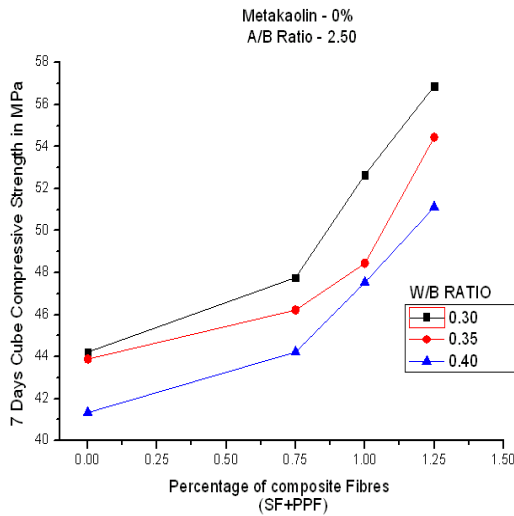


Fig 1

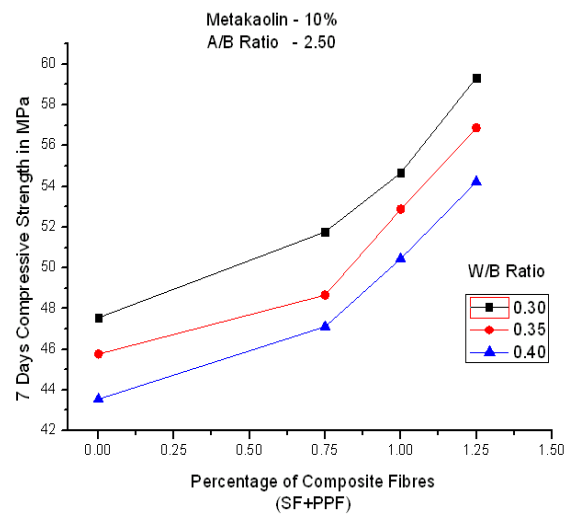


Fig 2

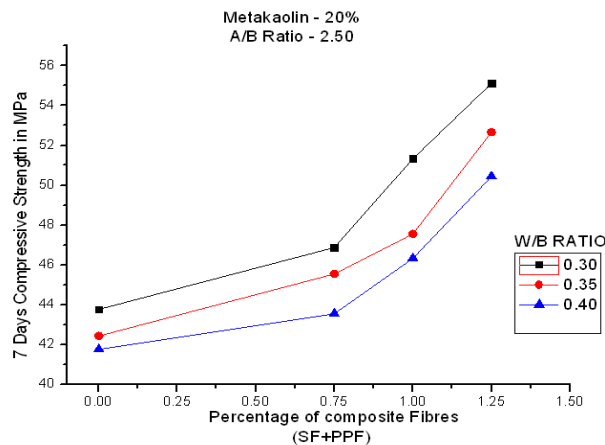


Fig 3
CUBE COMPRESSIVE STRENGTH AT 28 DAYS IN N/mm²

S. No	% of steel Fibre	% of ppf	Total % of composite fibres	Cube Compressive strength (MPa)								
				0% Metakaolin w/c Ratio			10% Metakaolin w/c Ratio			20% Metakaolin w/c Ratio		
				0.3	0.35	0.40	0.3	0.35	0.40	0.30	0.35	0.40
1	0.0	0	0	50.25	49.22	47.48	54.66	53.11	51.55	49.77	48.22	46.88
2	0.50	0.25	0.75	55.10	53.12	50.15	59.44	57.33	54.88	53.55	52.66	49.33
3	0.75	0.25	1.0	58.90	57.11	55.48	63.55	60.88	58.66	56.88	54.44	53.11
4	1.00	0.25	1.25	63.66	62.67	60.62	66.22	64.22	61.55	61.33	58.66	56.88

The variation of 28 Days Cube Compressive Strength on Percentage of Composite fibres for different W/B Ratio are presented in fig 4,5 and 6 for 0% metakaolin, 10% metakaolin and 20% metakaolin respectively.

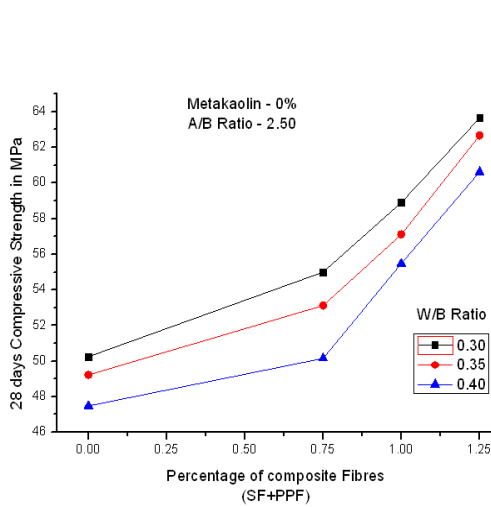


Fig 4

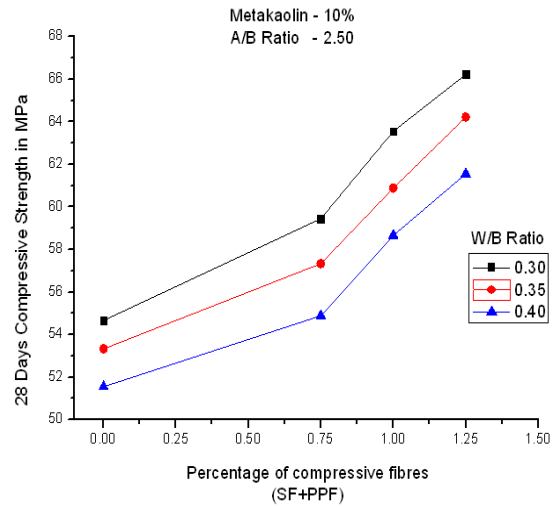


Fig 5

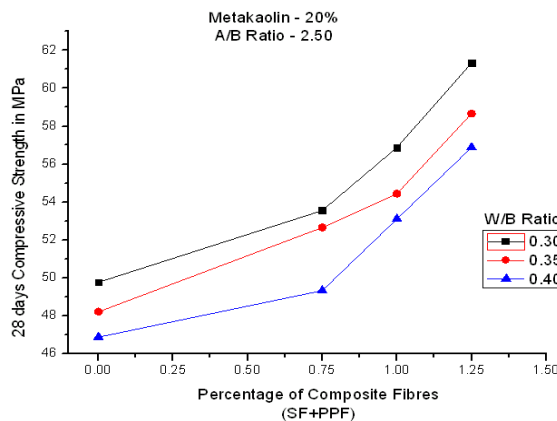


Fig 6

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TABLE 3 **SPLIT TENSILE STRENGTH AT 7 DAYS IN N/mm²**

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	Split Tensile strength (MPa)								
				0% Metakaolin w/c Ratio			10% Metakaolin w/c Ratio			20% Metakaolin w/c Ratio		
				0.3	0.35	0.40	0.3	0.35	0.40	0.30	0.35	0.40
1	0.0	0	0	4.31	4.25	4.11	4.51	4.38	4.13	4.27	4.21	4.07
2	0.50	0.25	0.75	4.58	4.38	4.31	4.72	4.63	4.42	4.44	4.32	4.27
3	0.75	0.25	1.0	4.75	4.62	4.44	4.93	4.81	4.75	4.65	4.57	4.36
4	1.00	0.25	1.25	4.92	4.81	4.70	5.25	5.10	4.92	4.75	4.70	4.62

The variation of 7 Days Split Tensile Strength on Percentage of Composite fibres for different W/B Ratio are presented in fig 7,8 and 9 for 0% metakaolin, 10% metakaolin and 20% metakaolin respectively.

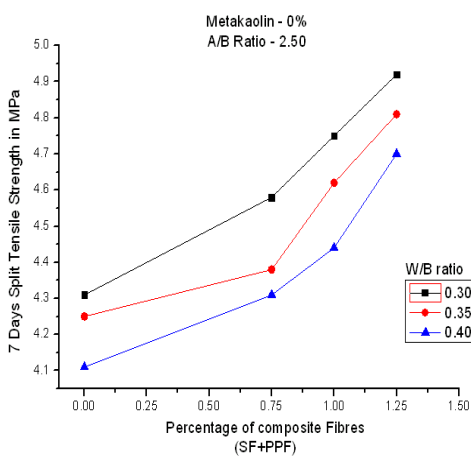


Fig 7

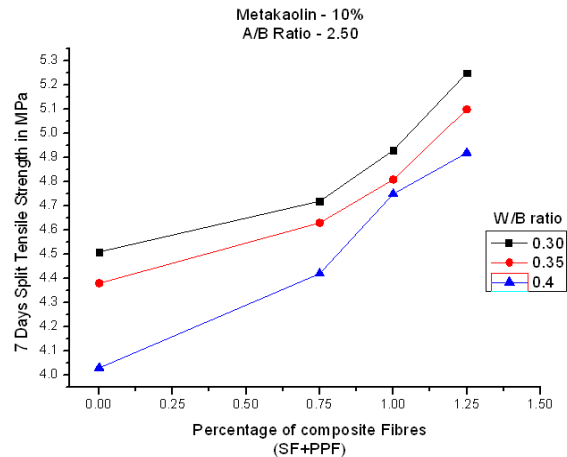


Fig 8

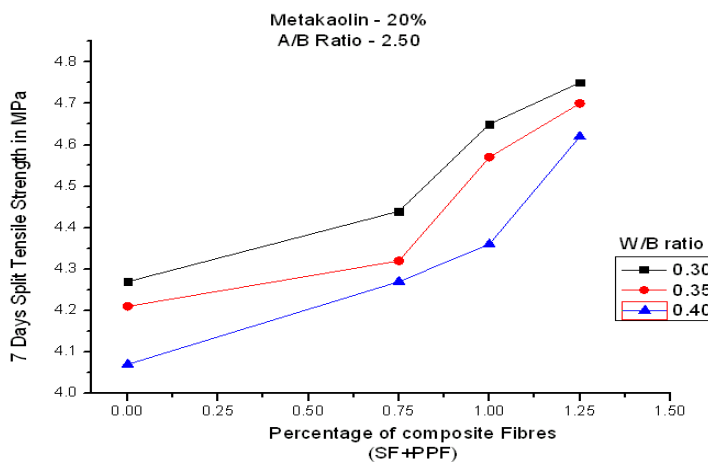


Fig 9

TABLE 4 **SPLIT TENSILE STRENGTH AT 28 DAYS IN N/mm²**

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	Split Tensile strength (MPa)								
				0% Metakaolin w/c Ratio			10% Metakaolin w/c Ratio			20% Metakaolin w/c Ratio		
				0.3	0.35	0.40	0.3	0.35	0.40	0.30	0.35	0.40
1	0.0	0	0	4.92	4.83	4.64	5.15	4.95	4.78	4.87	4.75	4.66
2	0.50	0.25	0.75	5.21	4.98	4.91	5.37	5.24	5.12	5.18	4.92	4.88
3	0.75	0.25	1.0	5.31	5.26	5.21	5.47	5.41	5.36	5.29	5.21	5.06
4	1.00	0.25	1.25	5.56	5.42	5.33	5.73	5.56	5.48	5.48	5.36	5.28

The variation of 28 Days Split Tensile Strength on Percentage of Composite fibres for different W/B Ratio are presented in fig 10,11 and 12 for 0% metakaolin, 10% metakaolin and 20% metakaolin respectively.

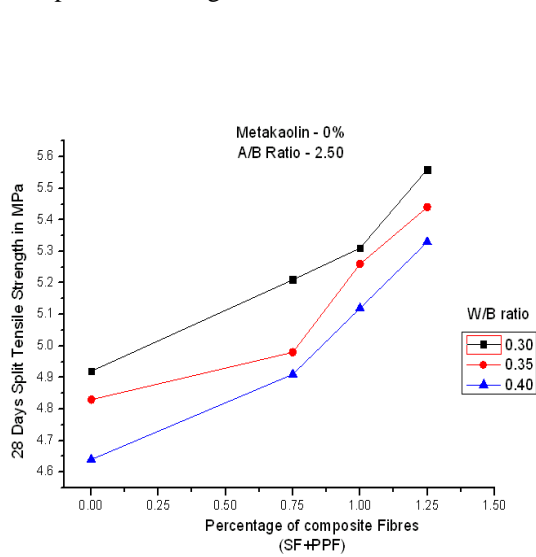


Fig 10

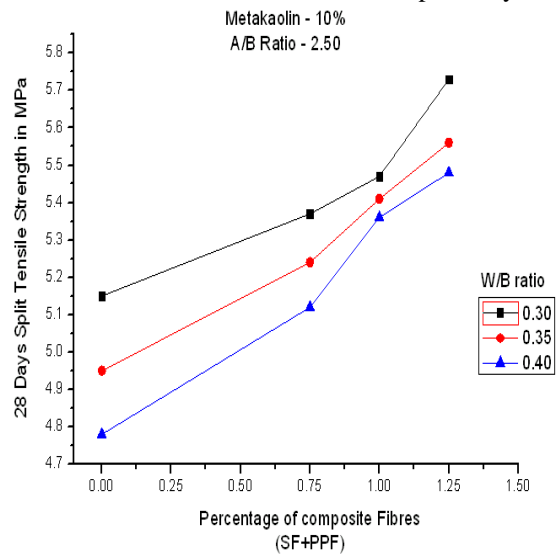


Fig 11

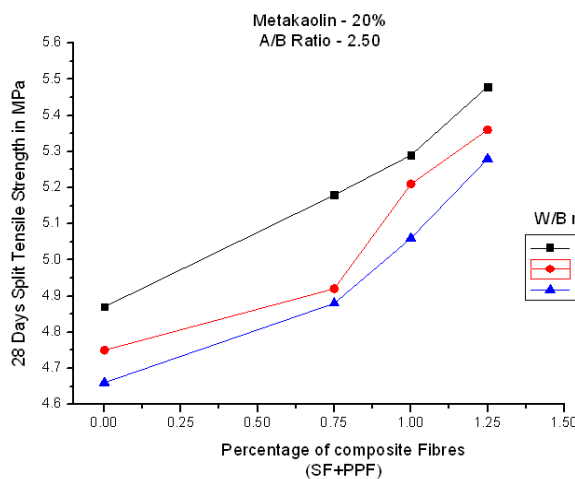


FIG 12

TABLE 5 **FLEXURAL STRENGTH AT 7 DAYS IN N/mm²**

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	Flexural strength (MPa)								
				0% Metakaolin w/c Ratio			10% Metakaolin w/c Ratio			20% Metakaolin w/c Ratio		
				0.3	0.35	0.40	0.3	0.35	0.40	0.30	0.35	0.40
1	0.0	0	0	5.07	4.78	4.67	5.21	4.98	4.75	4.94	4.66	4.52
2	0.50	0.25	0.75	5.27	5.19	4.85	5.39	5.24	5.12	5.12	5.07	4.86
3	0.75	0.25	1.0	5.38	5.31	5.24	5.56	5.41	5.33	5.27	5.21	5.16
4	1.00	0.25	1.25	5.57	5.48	5.36	5.76	5.62	5.57	5.38	5.31	5.27

The variation of 7 Days Flexural Strength on Percentage of Composite fibres for different W/B Ratio are presented in fig 13,14 and 15 for 0% metakaolin, 10% metakaolin and 20% metakaolin respectively.

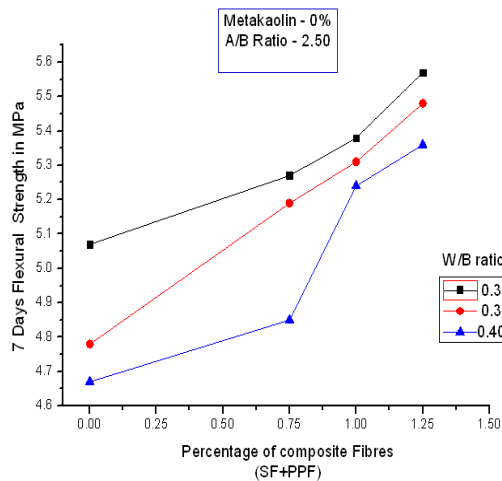


Fig 13

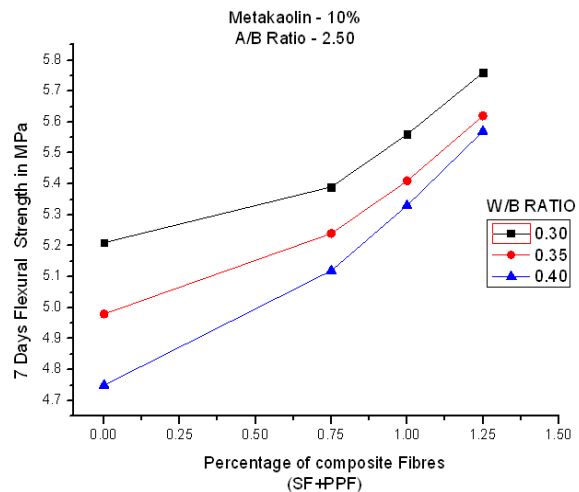


Fig 14

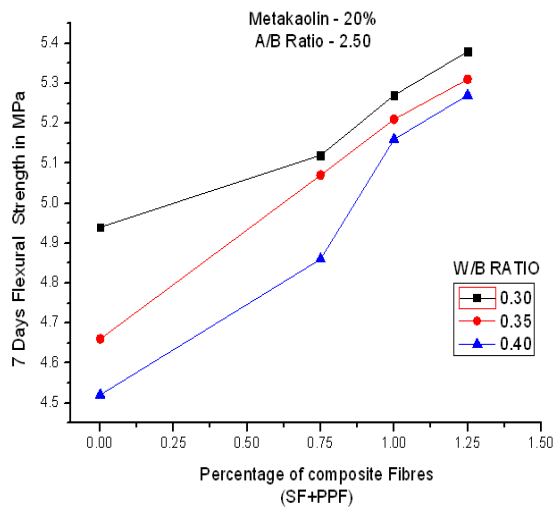


Fig 15

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TABLE 6 FLEXURAL STRENGTH AT 28 DAYS IN N/mm²

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	Flexural strength (MPa)								
				0% Metakaolin w/c Ratio			10% Metakaolin w/c Ratio			20% Metakaolin w/c Ratio		
				0.3	0.35	0.40	0.3	0.35	0.40	0.30	0.35	0.40
1	0.0	0	0	5.75	5.43	5.27	5.92	5.65	5.45	5.71	5.35	5.12
2	0.50	0.25	0.75	5.92	5.77	5.48	6.19	5.98	5.71	5.84	5.75	5.41
3	0.75	0.25	1.0	6.18	5.96	5.82	6.32	6.24	6.03	5.98	5.86	5.75
4	1.00	0.25	1.25	6.31	6.24	6.11	6.54	6.37	6.28	6.11	6.07	5.91

The variation of 28 Days Flexural Strength on Percentage of Composite fibres for different W/B Ratio are presented in fig 16,17 and 18 for 0% metakaolin, 10% metakaolin and 20% metakaolin respectively.

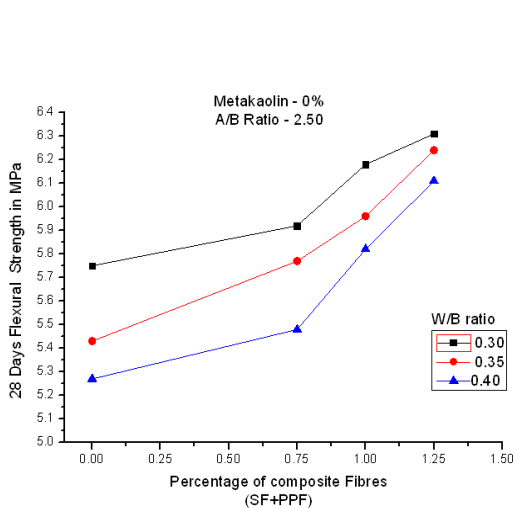


Fig 16

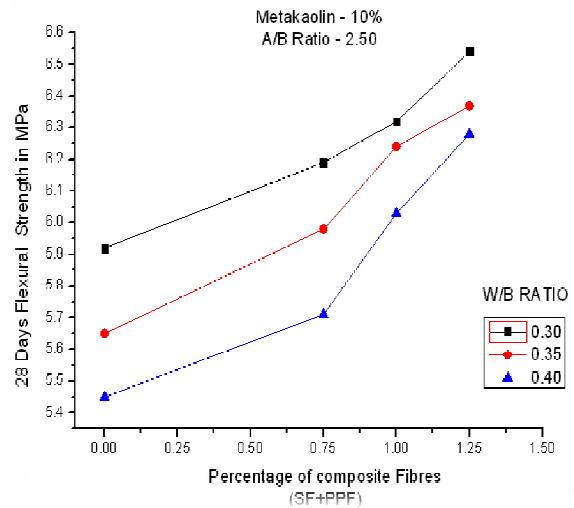


Fig 17

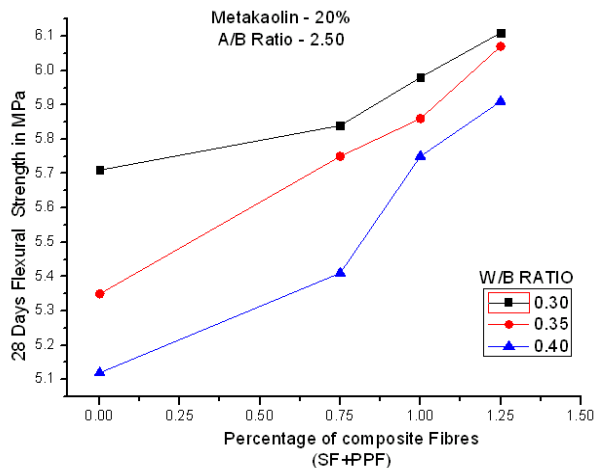


Fig 18

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VII CONCLUSIONS

Based on the present experimental investigation the following conclusions can be drawn

- The cement can be replaced maximum by 10% with metakaolin as admixture to achieve maximum compressive strength at 7 days or 28 days for composite fiber (Steel and PPF) reinforced high performance concrete
- The percentage increase in compressive strength at 28 days of 1.25% composite (Steel and PPF) fiber volume with 10% metakaolin high performance concrete over plain high performance concrete without fiber and metakaolin is 26.68% Also from experimental results it has been observed that the compressive strength of composite (Steel and PPF) fiber reinforced high performance concrete of 20% metakaolin are on the lower side when compared with that of plain high performance concrete mixes.
- There is a increase of 11.26% in split tensile strength at 28 days of 1.25% composite (Steel and PPF) fiber volume with 10% metakaolin high performance concrete over plain high performance concrete without fiber and metakaolin. The split tensile strength is on lower side for 20% metakaolin when compared with that of plain high performance concrete mixes.
- There is a increase of 10.47% in flexural strength at 28 days of 1.25% composite (Steel and PPF) fiber volume with 10% metakaolin high performance concrete over plain high performance concrete without fiber and metakaolin.
- From experimental results it has been observed that the flexural strength of composite (Steel and PPF) fiber reinforced high performance concrete of 20% metakaolin are on the lower side when compared with that of plain high performance concrete mixes
- From results obtained, the optimum percentage recommended as 1.25% composite (Steel and PPF) fiber volume with 10% metakaolin for achieving maximum benefits in compressive strength, split tensile strength and flexural strength.

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