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An Experimental Study on Compressive Stength of Composite Fiber Reinforced Concrete with Metakaolin as Admixture

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***Abstract:** In the field of construction industry there are lot of materials that widely used and play different and important roles one of these materials is cement concrete. Undoubtedly, cement concrete has a vibrant role in maintenance and repair of structures however it also contributes to the expenditures. Through extensive research around the globe, it has been possible to treat the material to meet higher performance requirements, particularly in terms of long-term durability. HPC is the latest development in concrete. It has become very popular and is used in many prestigious projects, such as nuclear power projects, multi-storey flying buildings. HPC introduces in concrete fibres to reduce cracks. While use HPC, the addition of additional materials in the cement has increased significantly, along with the development of the concrete industry, due to reduced costs, energy savings and environmental concerns, both in terms of damage caused by the extraction of raw materials than carbon dioxide. Emissions during cement manufacturing pushed to reduce cement consumption. Metakaolin appears to be a promising additional cement material for high performance concrete. The properties of concrete containing metakaolin are mainly preferred additives in high performance concretes. A possibly lower cost, due to the high availability of our country, could be an advantage for the use of metakaolin in high performance computing. The proportion of metakaolin substitution to be used was 5%, 10%, 15%, 20% by weight of cement and various percentages of steel and polypropylene fibres, such as 0.5% and 1% by volume, are used to make these cubes, beams to establish the strength of the concrete.*

I. INTRODUCTION

With the introduction of plasticizers and super plasticizers, it is now possible to produce a concrete of resistance much higher, than that of normal concrete. A strength concrete of about 138 Mpa is commercially available as High Performance Concrete. HPC is widespread in America, Europe and Japan and other countries. High performance, high strength concrete is very commonly used in structural columns, super bridge structures and bridges. In India, the first pre-stressed concrete bridge was built in 1949 for Assam Rail Link in Silliguri. Of the fifty, a number of pre-stressed concrete structures were constructed with concrete with strength ranging from 35 MPa to 45 MPa. But concrete strength greater than 35 MPa was not commonly used in general construction practices. Resistance concrete greater than 35 MPa was likely used extensively in the Konkan railway project in the early 1990s and in road construction at the Mumbai Municipal Corporation. Fibre Reinforced Concrete (FRC) is often used in the structures to restrict cracks that originate from stresses caused by volume changes in combination with structural restraint. Cracking is a problem-especially when high strength concrete, which is inherently brittle, is used. Fibres in concrete provide a means of arresting crack growth and improving the load carrying capacity. The basic purpose in using steel fibres is to control cracks at different size levels, in different zones of concrete (cement paste or interface zone between paste and aggregate), at different curing ages, at different temperatures and at different loading stages.

A. Introduction to fibres

Fibers increase the structural integrity of concrete. Fibers are typically used in concrete to control cracking due to plastic shrinkage and shrinkage drying. It produces greater resistance to shocks and abrasion. The use of microfibers offers better impact resistance. Fiber concrete (CRF) is a new structural material that is becoming increasingly important. CRF is a relatively new composite material composed of hydraulic cement, aggregates and discrete fibers. The FRC system has been used for a variety of purposes.

1) *Types of Fibres*

Following are the different type of Fibres generally used in the construction industries.

a) Steel Fibres
b) Polypropylene Fibres
c) Glass Fibres
d) Asbestos Fibres
e) Carbon Fibres
f) Organic Fibres

2) *Steel Fibres:* Steel fibers are the most commonly used fibers. Steel fiber reinforced concrete is basically a cheaper and easier way to use as a reinforced concrete form of rebar. Reinforced rebar uses steel bars that are laid in the liquid cement, which requires a lot of preparation work but makes the concrete much more resistant.

Fig 1.1: Steel Fibres

The fibres dia can vary from 0.25 mm to 0.75 mm. Fibreglass fibre concrete. Fiber of Risk-to-Risk-Prefixes. It has already been seen that fiber rust was not present on the surface. It was very resistant to traction of 1700N / m2.

B. Polypropylene Fibres

C. Metakaolin

The use of calcined clay in the form of Metakaolin (MK) as a puzzolonic additive for mortar and concrete has attracted considerable interest in recent years. Much of this interest has been focused on the elimination of CH, which is produced by cement hydration. The decrease of CH makes the concrete and mortars more resistant to sulphate attack and reduces the effect of the alkaline-silica reaction. This provides increased strength that results from additional cement phases generated by the reaction of CH with MK. MK is processed from high purity kaolin clay by calcination at a moderate temperature (650 ° C to 800 ° C). Silica and alumina in MK react effectively with CH. The main reasons for using clay-based puzzolonas in mortar and concrete are due to the availability of materials and improved durability. In addition, it depends on the calcinations temperature and the type of clay. It is also possible to obtain an improvement of the resistance, in particular during the hardening resistance. The very early increase in resistance is due to the combination of the load effect and the acceleration of cement hydration.

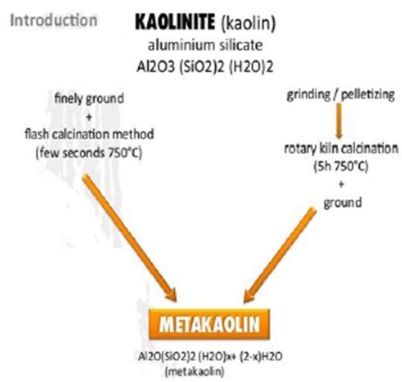

Fig 1.3: Formation of Metakaolin

Fig 1.4: Metakaolin

II. LITERATURE REVIEW

Dr.H.M. Somasekharaiah et.al. a study was carried out for the development of high-performance concrete using mineral additives such as fly ash, silica fume and metakaolin, as well as steel and polypropylene fibers. The compressive strength, tensile strength, and bending strength of simple concrete specimens, without any adjuvant or mineral fiber, were compared with those of compressive, tensile, tear, and tensile strengths. bending of a composite concrete composed of adjuvant and fibers different W / B ratios.

Yasir Khan et.al. This paper focuses on research in the field of fiber-reinforced concrete, which includes experimental studies, strength and durability properties, effects on fibers, etc. The literature articles collected focus mainly on the review of papers published after 2010. This article presents a comprehensive collection of studies in the field of fiber-reinforced composites. The review article would provide updated material for researchers in the field of fiber reinforced concrete. This helps them research fiber, composite fibers, etc., and can integrate them into their studies and help them achieve realistic results.

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G.Durga Uma Maheswari et.al. This project deals with the replacement of both the binder and fine aggregates by Industrial waste. Various strength parameters are studied and compared with the standard results of conventional concrete. Further, Micro structure analysis using TEM was also carried out in this study.

S. Kesavraman et.al. This paper investigates the effect of using high reactivity metakaolin on the properties of Banana fibre reinforced concrete. Compressive strength, splitting tensile strength, flexural strength, and Impact resistance test were investigated. HRM content used in this study was 5%, 10%, 15% and 20% with 0.5%, 1%, 1.5% and 2% of Banana fibres by volume of concrete.

Barham Haidar Ali et.al. This paper deals with the outcomes of an experimental research on mechanical properties of conventional concrete and a concrete incorporated metakaolin (MK) with and without steel fibre. One of the ingredients of the concrete mixture was metakaolin; Portland cement was partially substituted with metakaolin (MK) as 10% by weight of the total binder content. Steel fibres with length/aspect ratios of 60/80 and hook ended was embedded into the concrete to make fibre reinforced concretes. Value of water/binder ratios (w/b) was 0.35. To know the impacts of MK and steel fibre, the mechanical behaviours of the concrete were investigated such as: compressive, flexure, and bonding strength of the concretes.

III. MATERIALS CHRACTERIZATION AND METHODOLOGY

A. Introduction

B. Materials Required for Preparing Concrete

The various types of materials used for concrete are,

1) Cement x
2) Fine xaggregate.
3) Coarse xaggregate.
4) Metakaolin.
5) Superplasticizer.
6) Steel xfibres
7) Polypropylene xfibres.
8) Water.

C. Mix Proportions

Sl. No.	Mix	W/B Ratio	Steel + Polypropylene Fibre Dosage %	Cement	Metakaolin	Water	C.A	F.A	HRWR
1	0% MK	0.3	0%	673.3	-	202.05	909.28	606.18	9.14
			0.50%	673.6	-	202.05	909.28	606.18	9.14
			1.00%	673.56	-	202.05	909.28	606.18	9.14
2	0% MK	0.4	0%	631.03	-	252.43	851.92	567.95	4.26
			0.50%	631.03	-	252.43	851.92	567.95	4.26
			1.00%	631.03	-	252.43	851.92	567.95	4.26
3	5% MK	0.3	0%	639.87	33.22	201.39	903.83	602.47	7.58
			0.50%	639.92	33.22	201.39	903.83	602.47	7.58
			1.00%	639.87	33.22	201.39	903.83	602.47	7.58
4	5% MK	0.4	0%	599.48	31.15	251.78	855.79	564.44	4.05
			0.50%	599.48	31.15	251.78	855.79	564.44	4.04

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			1.00%	599.48	31.15	251.78	855.79	564.44	4.05
5	10% Mk	0.3	0%	606.195	66.45	199.36	897.11	598.07	5.06
			0.50%	606.24	66.45	199.36	897.11	598.07	5.06
			1.00%	606.195	66.45	199.36	897.11	598.07	5.06
6	10% Mk	0.4	0%	567.936	62.31	249.25	841.21	560.8	3.9
			0.50%	567.936	62.31	249.25	841.21	560.8	3.9
			1.00%	567.936	62.31	249.25	841.21	560.8	3.9
7	15% MK	0.3	0%	572.52	99.68	197.42	891.05	594.26	4.58
			0.50%	572.56	99.68	197.42	891.05	594.26	4.58
			1.00%	572.52	99.68	197.42	891.05	594.26	4.58
8	15% MK	0.4	0%	536.38	93.46	246.76	836.18	557.3	3.57
			0.50%	536.38	93.46	246.76	836.18	557.3	3.57
			1.00%	536.38	93.46	246.76	836.18	557.3	3.57
9	20% MK	0.3	0%	538.84	132.9	195.39	885.36	590.54	3.98
			0.50%	538.88	132.9	195.39	885.36	590.54	3.98
			1.00%	538.84	132.9	195.39	885.36	590.54	3.98
10	20% MK	0.4	0%	504.83	124.62	244.21	831.43	553.8	3.32
			0.50%	504.83	124.62	244.21	831.43	553.8	3.32
			1.00%	504.83	124.62	244.21	831.43	553.8	3.32

IV. RESULTS AND DISCUSSION

Initially several trail mixes of concrete were done and for these trail mixes the optimum percentage of superplastizers is calculated. After getting the result fresh concrete test like slump cone test is conducted to know the workability and then cubes werecasted andcured for28 days. After curing period tests like compressivestrength, SplitTensile Strength, FlexuralStrength were conducted.

A. Compressive Strength Test

It is taken as a important property as it is majorly used to test hard state concrete.0.15m^3 test specimens which are cured at room temperature are tested in Compressive Testing Machine of 2000KN capacity and this test is done as per Indian Standard 516:1959. The concrete cubes were tested at 7days. 28days.

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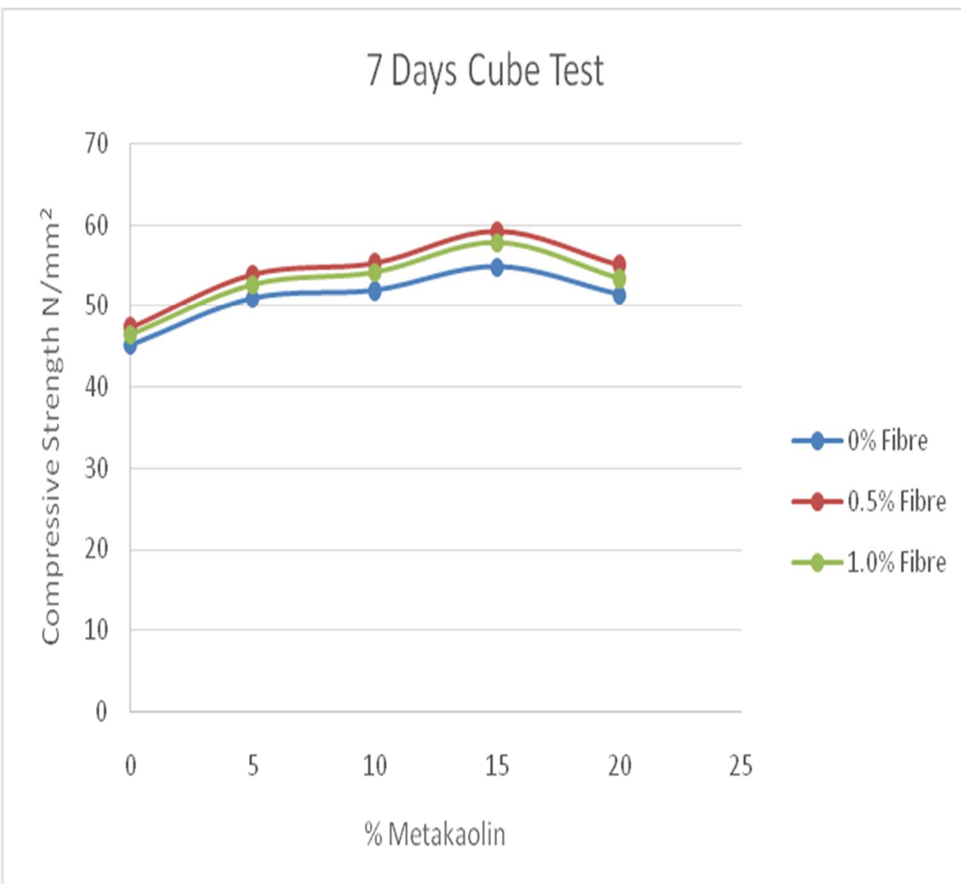
Table 4.1 (a): 7 Days Comp. Strength Test for water cement ratio is 0.3

Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
7 Day cube test for w/c ratio 0.3	0% Metakaolin	43.9	45.1	46.09	47.35	45.22	46.45
		47.4		49.77		48.82	
		44		46.2		45.32	
	5% Metakaolin	50.2	50.86	53.16	53.87	51.96	52.65
		51.5		54.54		53.30	
		50.9		53.90		52.68	
	10% Metakaolin	52.9	51.86	56.34	55.24	55.23	54.15
		52.3		55.69		54.60	
		50.4		53.68		52.62	
	15% Metakaolin	52.8	54.83	56.92	59.11	55.65	57.79
		56.8		61.23		59.87	
		54.9		59.18		57.86	
	20% Metakaolin	52.1	51.4	55.75	54.99	54.13	53.40
		51.9		55.53		53.92	
		50.2		53.71		52.15	



Graph 4.1(a): 7 Days Comp. Strength Test for water cement ratio 0.3

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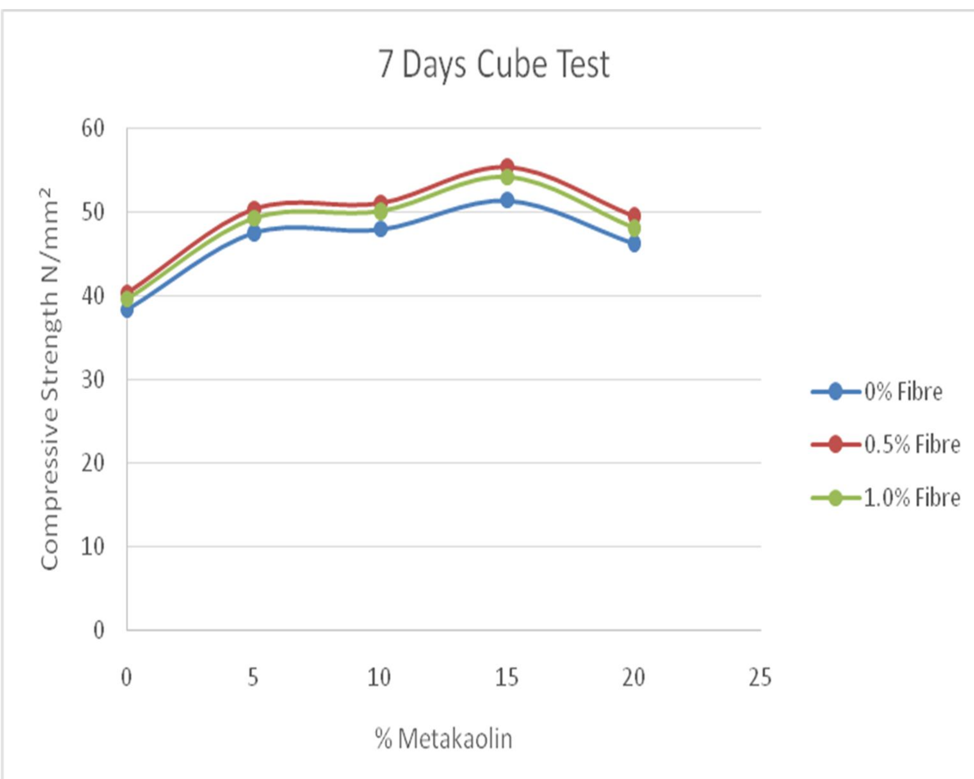
Table 4.1 (b): 7 Days Compressive Strength Test for water cement ratio 0.4

Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
7 Day cube test for w/c ratio 0.4	0% Metakaolin	39.51	38.43	41.48	40.35	40.69	39.58
		38.39		40.30		39.54	
		37.4		39.27		38.52	
	5% Metakaolin	46.69	47.56	49.44	50.36	48.32	49.22
		47.12		49.90		48.76	
		48.86		51.74		50.57	
	10% Metakaolin	49.19	47.96	52.39	51.08	51.35	50.07
		47.07		50.13		49.14	
		47.63		50.73		49.73	
	15% Metakaolin	49.37	51.38	53.22	55.38	52.03	54.15
		54.53		58.78		57.47	
		50.23		54.14		52.94	
	20% Metakaolin	46.89	46.26	50.17	49.49	48.72	48.06
		46.71		49.97		48.53	
		45.18		48.34		46.94	



Graph 4.1(b): 7 Days Compressive Strength Test for w/c ratio 0.4

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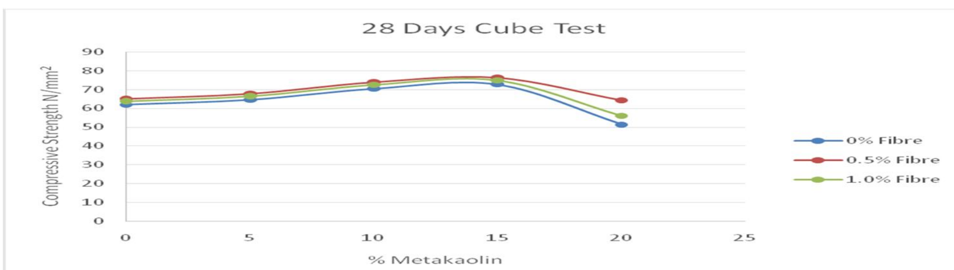
Table 4.2 (a): 28 Days Compressive Strength Test for w/c ratio 0.3

Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
28 Day cube test for w/c ratio 0.3	0% Metakaolin	63.1	61.93	66.25	65.03	64.99	63.79
		61.1		64.15		62.93	
		61.6		64.68		63.44	
	5% Metakaolin	63.5	64.53	66.67	67.76	65.40	66.46
		67.5		70.87		69.52	
		62.6		65.73		64.47	
	10% Metakaolin	67.5	70.43	70.87	73.95	69.52	72.54
		72.4		76.02		74.57	
		71.4		74.97		73.54	
	15% Metakaolin	72.8	72.7	76.44	76.33	74.98	74.88
		71.1		74.65		73.23	
		74.2		77.91		76.42	
	20% Metakaolin	52.1	51.4	65.12	64.25	56.78	56.03
		51.9		64.87		56.57	
		50.2		62.75		54.71	



Graph 4.2 (a): 28 Days Compressive Strength Test for w/c ratio 0.3

Table 4.2 (b): 28 Days Compressive Strength Test for w/c ratio 0.4

Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
28 Day cube test for w/c ratio 0.4	0% Metakaolin	56.79	52.88	59.63	55.52	58.49	54.46
		49.49		51.96		50.97	
		52.36		54.98		53.93	
	5% Metakaolin	59.05	60.3	62.00	63.31	60.82	62.10
		61.76		64.85		63.61	
		60.09		63.09		61.89	
	10% Metakaolin	62.78	65.14	65.91	68.39	64.66	67.09
		65.16		68.41		67.11	
		67.47		70.84		69.49	
	15% Metakaolin	68.07	68.07=	71.47	71.47	70.11	70.11
		68.26		71.67		70.30	
		67.89		71.28		69.92	
	20% Metakaolin	46.89	46.26	58.61	57.82	51.11	50.42
		46.71		58.38		50.91	
		45.18		56.47		49.24	

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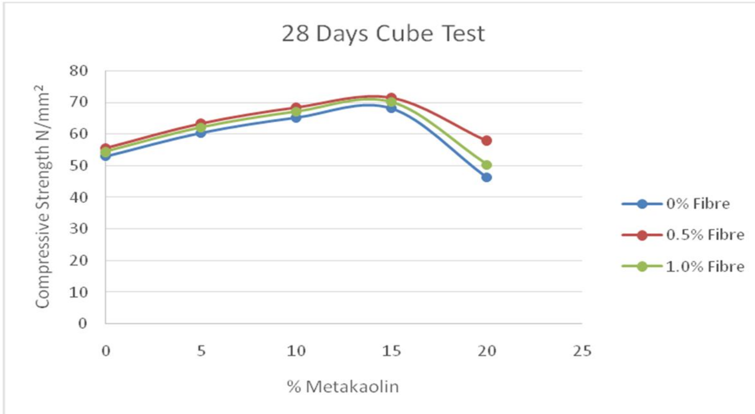

Graph 4.2 (b): 28 Days Compressive Strength Test for w/c ratio 0.4

The 28 day Compressive Strength varied between 63 and 77MPa. From the above table it is clear that optimum % of metakaolin replacement is 15% and 0.5% volume of fibresand optimum w/c ratio is 0.3.

B. Split Tensile Strength

Fig 4.2: Split Tensile Strength Test

Table 4.3 (a): Split Tensile Strength Test for water cement ratio 0.3

Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
28 Day Split Tensile test for w/c ratio 0.3	0% Metakaolin	3.3	3.36	3.46	3.53	3.39	3.46
		3.2		3.36		3.29	
		3.6		3.78		3.70	
	5% Metakaolin	3.5	3.66	3.62	3.81	3.60	3.77
		3.8		3.93		3.91	
		3.7		3.88		3.81	
	10% Metakaolin	4	3.9	4.18	4.07	4.12	4.02
		3.7		3.86		3.81	
		4		4.18		4.12	
	15% Metakaolin	4	4.16	4.6	4.79	4.12	4.29
		4.3		4.94		4.42	
		4.2		4.83		4.32	
	20% Metakaolin	3.9	3.83	4.09	4.02	4.25	4.17
		3.6		3.78		3.92	
		4		4.2		4.36	

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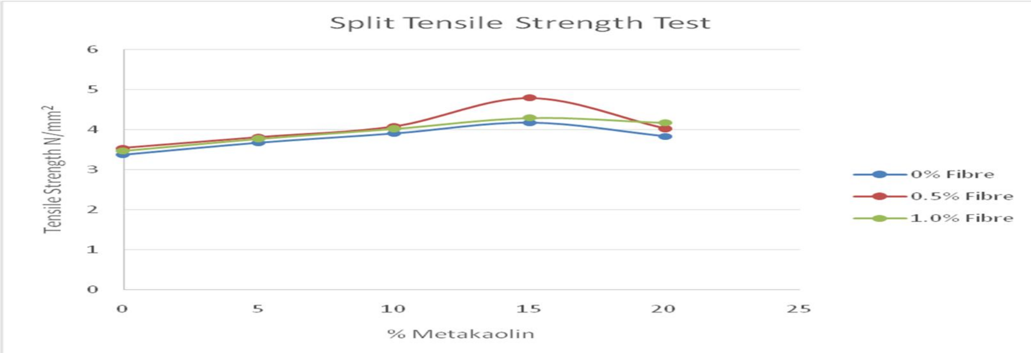
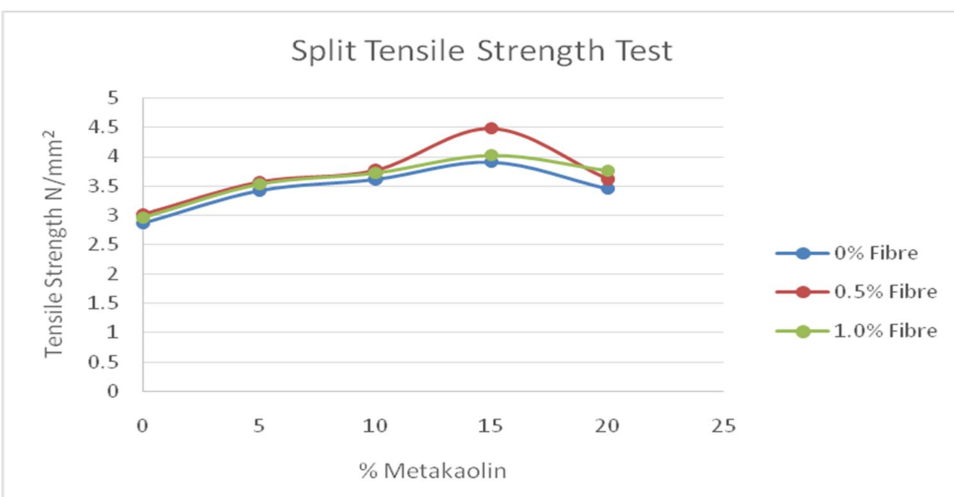


Graph 4.3 (a): Split Tensile Strength Test for water cement ratio 0.3

Table 4.3 (b): Split Tensile Strength Test for water cement ratio 0.4

Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
28 Day Split Tensile test for w/c ratio 0.4	0% Metakaolin	2.97	2.87	3.12	3.01	3.05	2.95
		2.59		2.72		2.66	
		3.06		3.21		3.15	
	5% Metakaolin	3.25	3.42	3.36	3.56	3.34	3.52
		3.47		3.59		3.57	
		3.55		3.73		3.65	
	10% Metakaolin	3.72	3.61	3.88	3.77	3.83	3.71
		3.33		3.47		3.42	
		3.78		3.95		3.89	
	15% Metakaolin	3.74	3.90	4.30	4.48	3.85	4.02
		4.13		4.75		4.25	
		3.84		4.42		3.95	
	20% Metakaolin	3.51	3.45	3.68	3.62	3.82	3.76
		3.24		3.40		3.53	
		3.6		3.78		3.92	



Graph 4.3 (b): Split Tensile Strength Test for water cement ratio 0.4

V. CONCLUSIONS

The following conclusions were drawn from the present study on the effect of partial replacement of cement with Metakaolin and the addition of admixtures such as steel and polypropylene fibers in concrete;

A. The strength of all Metakaolin concrete mixes on CPO strength.
B. Increasing the metakaolin content improves the compressive strength, flexural strength and tensile strength divided by up to 15% cement replacement, and a further increase indicates lower strength.
C. The replacement of 15% of the cement by Metakaolin is superior to all other mixtures, so it can be considered as the optimal percentage of Metakaolin.
D. The results encourage the use of Metakaolin as a puzzolonic material for partial replacement in the production of high performance concrete.
E. Increase in w/c ratio from 0.3 to 0.4 shows decrease in strength, hence optimum w/c ratio can be taken as 0.3.
F. The increase in percentage of steel and polypropylene fibres from 0% to 0.5% shows 4.99%, 15.14%, 14.92% increase in compressive, tensile and flexural strength respectively.
G. The increase in percentage of steel and polypropylene fibres from 0.5% to 1% shows 1.90%, 10.44%, 4.85% decrease in compressive, tensile and flexural strength respectively.
H. Hence concluded that 15% Metakaolin with 0.3% w/c ratio and 0.5% steel and polypropylene fibres are the optimum percentages to obtain good strength.

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