AN EXPERIMENTAL STUDY ON COMPRESSIVE STENGTH OF COMPOSITE FIBER REINFORCED CONCRETE WITH METAKAOLIN AS ADMIXTURE.

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ABSTRACT - Cement concrete is the most extensively used construction material. Maintenance and repair of concrete structures is a growing problem involving significant expenditure. As a result many researches has been carried out worldwide, it has been made possible to process the material to satisfy more stringent performance requirements, especially long–term durability. HPC is the latest development in concrete. It has become very popular and is being used in many prestigious projects such as Nuclear power projects, flyovers multi-storeyed buildings. To reduce cracks in concrete fibres are introduced in HPC. When using HPC, the addition of supplementary materials in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental concerns both in terms of damage caused by the extraction of raw materials and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption. Metakaolin looks to be a promising supplementary cementitious material for high performance concrete. Properties of concrete with metakaolin is mostly preferred additives in high performance concrete. A possible lower cost, due to large availability in our country itself may be advantages to metakaolin usage in HPC. The substitution proportion of metakaolin is to be used was 5%, 10%, 15%, 20% by the weight of cement and various percentage of steel and polypropylene fibres like 0.5% and 1% by volume are usedto make this cubes, cylinders and beams to determine the strength of concrete.

Keyword: Concrete, Metakaolin, Steel fibres, Plastic fibres, HPC

1. INTRODUCTION

It is during 90, s use of high strength concrete has taken its due place in Indian construction scenario. Of late concrete of strength from 45MPa to 60MPa has been used in high rise buildings at Mumbai, Delhi and other metropolitan cities. High strength concrete was also employed in bridges and fly overs. Presently in India concrete of strength 75MPa is being used for the first time in one of the flyovers at Mumbai. Other notable example of high strength concrete in India is in the construction of Containment Dome at Kaiga power project. They have used high performance concrete of strength 60MPa with silica fume as one of the constituents.

Metakaolin differs from other supplementary cementitious materials (SCMs), like fly ash, silica fume, and slag, in that it is not a by-product of an industrial process; it is manufactured for a specific purpose under carefully controlled conditions. Metakaolin is produced by heating kaolin, one of the most abundant natural clay minerals, to temperatures of 650-900°C. This heat treatment or calcination, serves to break down the structure of kaolin. Bound hydroxyl ions are removed and resulting disorder among alumina and silica layers yields a highly reactive, amorphous material with puzzolonic and latent hydraulic reactivity, suitable for usein cementing applications. When used as a partial replacement for Portland cement, metakaolin may improve both the mechanical properties and the durability of concrete.

1.1 Types of Fibres

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

1. Steel Fibres
2. Polypropylene Fibres
3. Glass Fibres
4. Asbestos Fibres
5. Carbon Fibres
6. Organic Fibres

1.2 Mineral Admixture

The basic components of cement mortar are cement, water and aggregates. But, often, other substances are added to these three in preparing the cement mortar. The purpose of these additional substances is to improve the quality of the mortar. These substances are collectively called admixtures. Admixtures can be broadly classified into two types – chemical admixtures and mineral admixtures. Mineral admixtures are basically derived from other substances and not chemically manufactured.

Popular examples of mineral admixtures are:

1. Metakaolin
2. Fly ash
3. Silica fumes
4. Carbon black powder
5. Anhydrous gypsum based mineral additives
6. Blast Furnace lag

1.3 Chemical Admixtures

Unlike mineral admixtures, which may be introduced as blended cements, chemical admixtures are typically added during the mixing process of concrete production. Depending upon the requirement admixture may alter workability, pumping qualities, strength development, appearance etc. in fresh concrete and permeability, strength, durability etc. in hardened concrete. But use of chemical admixture is a must for producing high grade concrete.

Different types of chemical admixtures are:

- Plasticizers
- Super plasticizers
- Retarders
- Air entraining agents

1.4 Uses of M60 grade concrete

Today's concrete, with the help of innovative peripherals, has developed following capacities:

It can remain in liquid state for a longer duration,

1. It can be prepared with very small quantity of water, and
2. Addition of mineral admixtures like Metakaolin gives good strength and increased life.

2. Aim and Objectives:

2.1 Aim

The major aim of this work is to study and evaluate the strength characteristics of concrete (M60) containing Metakaolin, Polypropylene fibres, Steel fibres and superplasticizer.

2.2 Objectives.

The major objectives are as follows:

1. To study the strength properties of conventional concrete initially concrete is casted with 0% MK, Steel fibres, Polypropylene fibres.
2. To study the effect of partial replacement of metakaolin with additives as steel fibres, polypropylene fibres and superplasticizers on strength of concrete.
3. To fix optimum w/c ratio for M60 grade concrete.
4. To fix optimum dosage of Metakaolin propositions for M60 grade concrete.
5. To fix the optimum dosage of steel fibres and polypropylene fibres for M60 grade concrete.

3. MATERIALS CHRACTERIZATION AND METHODOLOGY

This particular chapter deals with the experimental studies carried out on M-60 grade concrete. It mainly includes the different materials required, mix design of concrete, mixing, casting and curing of test specimens.

The various types of materials used for concrete are,

1. Cement

2. Fine aggregate.

3. Coarse aggregate.

4. Metakaolin.

5. Superplasticizer.

6. Steel fibres

7. Polypropylene fibres.

8. Water.

4. 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%	673.55	-	202.06	909.29	606.19	9.13
			0.50%	673.6	-	202.06	909.29	606.19	9.13
			1.00%	673.55	-	202.06	909.29	606.19	9.13
2	0% MK	0.4	0%	631.04	-	252.42	851.91	567.94	4.27
			0.50%	631.04	-	252.42	851.91	567.94	4.27
			1.00%	631.04	-	252.42	851.91	567.94	4.27
3	5% MK	0.3	0%	639.87	33.23	201.39	903.83	602.47	7.59
			0.50%	639.92	33.23	201.39	903.83	602.47	7.59

			1.00%	639.87	33.23	201.39	903.83	602.47	7.59
4	5% MK	0.4	0%	599.48	31.15	251.78	855.79	564.44	4.04
			0.50%	599.48	31.15	251.78	855.79	564.44	4.04
			1.00%	599.48	31.15	251.78	855.79	564.44	4.04
5	10% Mk	0.3	0%	606.195	66.45	199.36	897.11	598.07	5.05
			0.50%	606.24	66.45	199.36	897.11	598.07	5.05
			1.00%	606.195	66.45	199.36	897.11	598.07	5.05
6	10% Mk	0.4	0%	567.936	62.31	249.25	841.21	560.8	3.8
			0.50%	567.936	62.31	249.25	841.21	560.8	3.8
			1.00%	567.936	62.31	249.25	841.21	560.8	3.8
7	15% MK	0.3	0%	572.52	99.68	197.42	891.05	594.26	4.54
			0.50%	572.56	99.68	197.42	891.05	594.26	4.54
			1.00%	572.52	99.68	197.42	891.05	594.26	4.54
8	15% MK	0.4	0%	536.38	93.46	246.76	836.18	557.3	3.56
			0.50%	536.38	93.46	246.76	836.18	557.3	3.56
			1.00%	536.38	93.46	246.76	836.18	557.3	3.56
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

5. Experimental Program

5.1 Casting of Specimens

The test program considered the casting and testing of concrete specimens of cube (150mm^3), cylinder (100mm X 200mm) and prism (100mm X 100mm X 1000mm). The specimens was cast using M60 grade concrete, Natural River sand and crushed stone with Metakaolin, Polypropylene fibres and steel fibres. Each three numbers of specimens made to take the average value. The Specimens remoulded after 24hrs.The specimens were allowed to the curing periods. 3.5 Test conducted on fresh concrete

5.2 Slump Cone Test

The slump test is generally used as the required test on the construction to decide/figure out the consistency and evenness and equality of the concrete mix. The mould forth slump test is 300mm high, 200mm base diameter and 100mm top diameter. It is placed on a smooth surface with the 100mm diameter opening at the top and filled with concrete in three layers. Each layer is tamped 25 times with standard 16mmdiameter tamping rod. The cone must not be tilted at the time of lifting and it must be lift straight up and down. The decrease in the height of the slumped concrete is called slump admeasured using scale of 30cm.The Slump value obtained = 75 mm, hence ok.

6. 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 compressive strength, Split Tensile Strength, Flexural Strength were conducted.

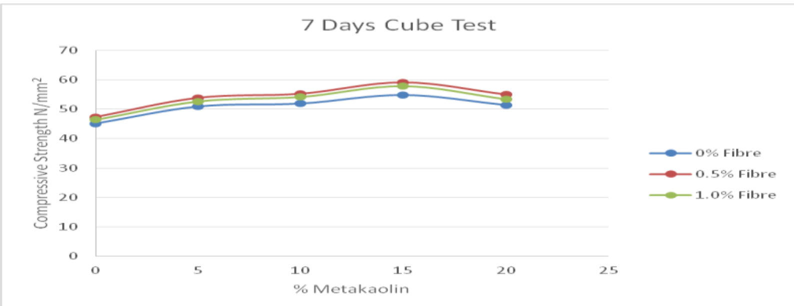
6.1 Compressive Strength Test

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.

$$\text{Compressive strength} = \frac{\text{Failure load}}{\text{cross sectional area of specimen}}$$

Table 1: 7 Days Compressive Strength Test for w/c ratio 0.3

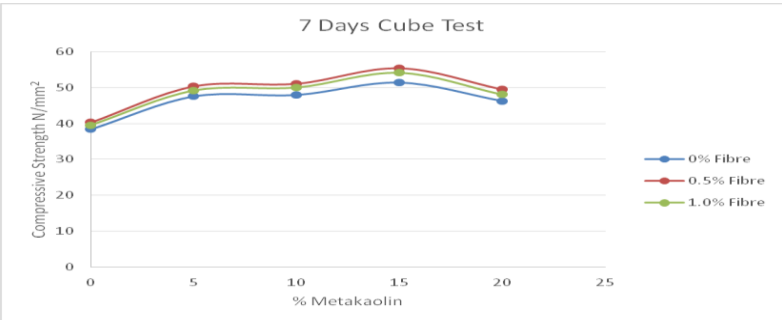
Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
7 Day cube test for w/c ratio 0.3	0% Metakaolin	43.9	45.1	46.09	47.35	45.22	46.45
		47.4		49.77		48.82	
		44		46.2		45.32	
	5% Metakaolin	50.2	50.86	53.16	53.87	51.96	52.65
		51.5		54.54		53.30	
		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 1: 7 Days Compressive Strength Testfor w/c ratio 0.3

Table 2: 7 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
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	



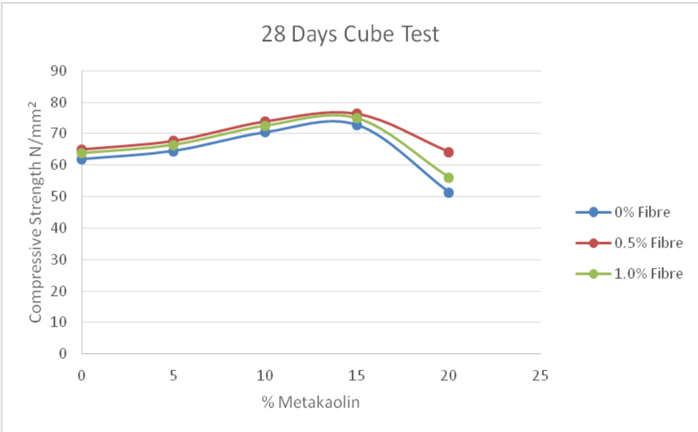
Graph 2 : 7 Days Compressive Strength Test for w/c ratio 0.4

The Compressive Strength is less in control specimen compared to specimens with different w/c ratio various percentages of Metakaolin, Steel fibres and Polypropylene fibres. Compressive Strength results of specimens presented in Table 4.1. The seven day Compressive Strength varied between 43 and 59MPa. From the above table it is clear that optimum % of metakaolin replacement is 15% and 0.5% volume of fibres and optimum w/c ratio is 0.3.

Table 3: 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	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	

ratio 0.3	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	

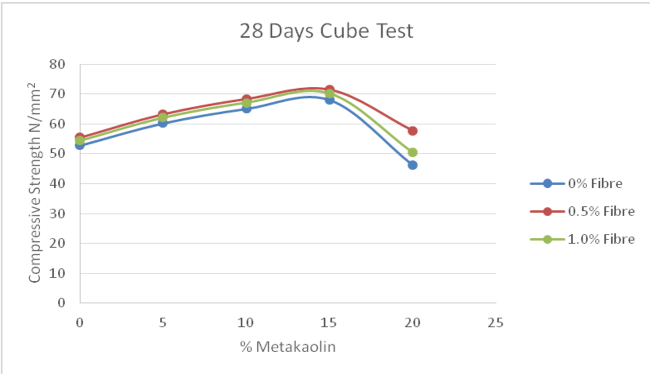


Graph 3: 28 Days Compressive Strength Test for w/c ratio 0.3

Table 4: 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%	68.07	68.07=	71.47	71.47	70.11	70.11

	Metakaolin	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	



Graph 4: 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 fibres and optimum w/c ratio is 0.3.

4.2 Split Tensile Strength Test

This test measures the tensile strengthen concrete and this test is done as per Indian Standard 5816:1999. Cylindrical specimen of dia. 150mm and height 300 mm is subjected to compressive load along vertical diameter at a constant rate until fatigue. Failure occurs along vertical diameter due to tension developed in transverse direction.

Split tension is computed by T =2P/πLD

T = tensilestrength, MPa

p= load atfailure, N

L = length ofspecimen, mm

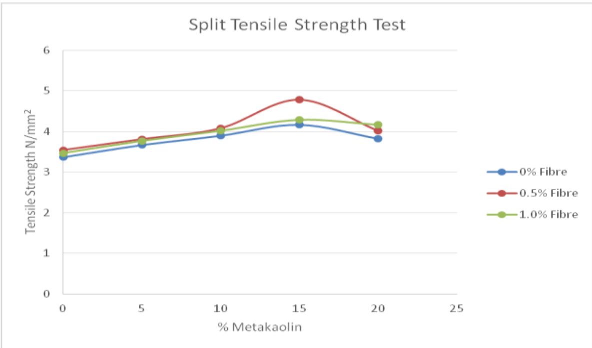
D = diameterof specimen, mm

Tensile strength varies from 2.5 MPa to 31 MPa, about 10% of compressive strength

Fig 4.2: Split Tensile Strength Test

Table 5: Split Tensile 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 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	

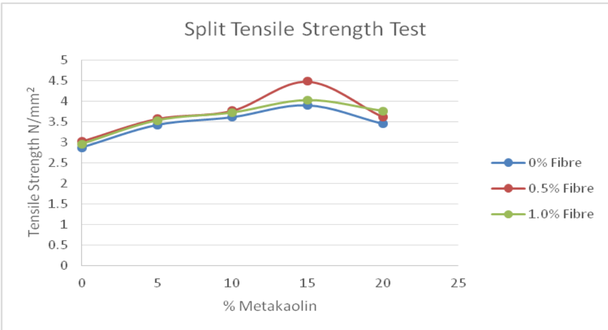


Graph 5: Split Tensile Strength Test for w/c ratio 0.3

Table 6: Split Tensile 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 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 6: Split Tensile Strength Test for w/c ratio 0.4

The Tensile Strength varied between 3 and 5MPa. From the above table it is clear that optimum % of metakaolin replacement is 15% and 0.5% volume of fibres and optimum w/c ratio is 0.3.

4.3 Flexural Strength Test

This test is used for measuring Modulus of Rupture and this test is done as per Indian Standard 516:1959. It is an important test for road and airport concrete pavements. Beam specimen of 100X100X1000mm is loaded into a 2-point loading apparatus.

Calculation of Modulus of Rupture

If the fracture occurs in the middle 1/3 of the span

$$R = PL/(bd^2)$$

R = flexure strength, MPa

P = maximum load applied, N

L = span length, mm

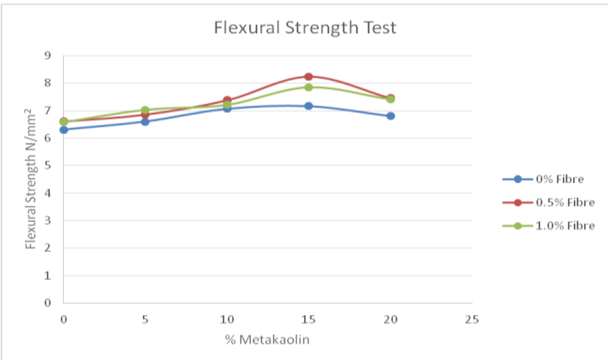
b = average width of specimen, mm

a = average depth of specimen, mm

Fig 4.3: Flexural Strength Test

Table 7: Flexural Strength Test for w/c ratio 0.3

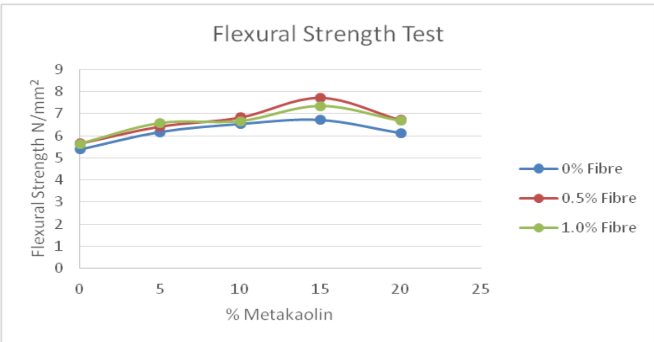
Age of test	% Metakaolin	Volume of Fibres (Steel + Polypropylene)					
		0%	Average	0.50%	Average	1.00%	Average
28 Days Flexural Strength Test for w/c ratio 0.3	0% Metakaolin	6.4	6.3	6.72	6.61	6.68	6.58
		5.9		6.19		6.16	
		6.6		6.93		6.89	
	5% Metakaolin	6.5	6.6	6.72	6.86	6.92	7.02
		6.6		6.83		7.02	
		6.7		7.03		7.13	
	10% Metakaolin	6.8	7.06	7.10	7.38	6.93	7.20
		7.2		7.52		7.34	
		7.2		7.52		7.34	
	15% Metakaolin	7	7.16	8.05	8.24	7.66	7.84
		7.2		8.28		7.88	
		7.3		8.39		7.99	
	20% Metakaolin	6.7	6.8	7.43	7.45	7.30	7.41
		6.9		7.52		7.52	
		6.8		7.41		7.41	



Graph 7: Flexural Strength Test for w/c ratio 0.3

Table 8: Flexural 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 Flexural Strength test for w/c ratio 0.4	0% Metakaolin	5.76	5.38	6.04	5.65	6.01	5.62
		4.78		5.02		4.99	
		5.61		5.89		5.86	
	5% Metakaolin	6.05	6.17	6.26	6.42	6.44	6.57
		6.04		6.25		6.43	
		6.43		6.75		6.84	
	10% Metakaolin	6.32	6.53	6.60	6.82	6.44	6.66
		6.48		6.77		6.60	
		6.8		7.10		6.93	
	15% Metakaolin	6.55	6.71	7.53	7.72	7.17	7.35
		6.91		7.94		7.56	
		6.68		7.68		7.31	
	20% Metakaolin	6.03	6.12	6.69	6.71	6.57	6.67
		6.21		6.76		6.76	
		6.12		6.67		6.67	



Graph 8: Flexural Strength Testfor w/c ratio 0.4

The Flexural Strength varied between 6 and 9MPa. From the above table it is clear that optimum % of metakaolin replacement is 15% and 0.5% volume of fibres and optimum w/c ratio is 0.3.

7. CONCLUSIONS

From the present investigation on the effect of partial replacement of cement with Metakaolin, and addition of admixtures like Steel and Polypropylene fibres in concrete, the following conclusions were drawn;

1. The strength of all Metakaolin concrete mixes over shoot the strength of OPC.

2. The increase in Metakaolin content improves the compressive strength, flexural strength and split tensile strength up to 15% cement replacement and further increase shows lesser strength.

3. 15% cement replacement by Metakaolin is superior to all other mixes hence it can be taken as the optimum % of Metakaolin.

4. The results encourage the use of Metakaolin, as a puzzolonic material for partial replacement in producing high performance concrete.

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.

Type of Test	Ageof Test With w/c Ratio	Metakaolin %	% of fibres		
			0%	0.50%	1%
Compressive Test	28 days, 0.3 w/c ratio	15%	72.7	76.33	74.88
Split Tensile Test	28 days, 0.3 w/c ratio	15%	4.16	4.79	4.29
Flexural Test	28 days, 0.3 w/c ratio	15%	7.17	8.24	7.84

1. 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.

2. 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.

3. 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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