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# Experimental Study on Compressive, Split Tensile and Flexural Strength 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 researchers have 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-storied buildings. To reduce cracks in concrete fibers 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 are 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 percentages of steel and polypropylene fibers like 0.5% and 1% by volume are used to make this cubes, cylinders and beams to determine the strength of concrete.
**KEYWORDS:** HPC, Steel Fibers, Polypropylene Fibers, Compressive Strength, Tensile Strength and Flexural Strength.

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## I. INTRODUCTION

Inherent micro cracks and weak in tension are the shortcomings of conventional concrete thus recent years have witnessed the extensive use of fibers like glass, steel, carbon and poly-propylene etc. in order to meet the challenges of the rapidly growing civil engineering industry. Addition of such fibers increases fire resistance, impact, compressive, erosion, split tensile and flexural strength, durability, serviceability of concrete, fatigue, fracture and shrinkage characteristics and cavitations and reduces formation and propagation of micro cracks. 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. Fibers in concrete provide a means of arresting crack growth and improving the load carrying capacity. The basic purpose in using steel fibers 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. The addition of fibers reduces the workability. Also the fibre reinforced concrete inevitably adopt lower w/c ratio and the use of ultrafine materials such as Metakaolin, fly-ash etc. in order to meet these requirements. The use of high range water reducers become essential for retaining adequate concrete workability. Fortunately with the development of a variety of chemical admixtures like super plasticizer, it is now possible to man oeuvre the properties of fresh and hardened concrete. 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 calcinations, 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 pozzolanic and latent hydraulic reactivity, suitable for use in cementing applications. When used as a partial replacement for Portland cement, Metakaolin may improve both the mechanical properties and the durability of concrete.

## II. LITERATURE REVIEW

**Dr.H.M.Somasekharaiah et.al**. In this thesis, a study had been made for the development of High Performance Concrete using mineral admixtures such as Fly-ash, Silica-fume and Metakaolin along with steel and Polypropylene fibers. The compressive strength, split tensile strength and flexural strength of the plain concrete specimens without any mineral admixture & fibers have been compared with that of compressive-strength, split-tensile strength and flexural-strength of composite concrete made up of mineral admixtures & fibers for different W/B ratios.

**Beulah M et.al**. This paper presents an experimental investigation on the effect of partial replacement of cement by Metakaolin by various percentages viz 0%, 10%, 20%, and 30% on the properties of high performance concrete, when it is subjected to hydrochloric acid attack. An aggregate binder ratio of 2 and different water binder ratios viz 0.3, 0.35, 0.40 and 0.45 was used in this investigation.

**Adanagouda et.al**. This paper deals with the strength properties of high performance concrete, on the effect of partial replacement of cement by fly ash with different percentages viz 0%, 10% and 20% was used in the concrete mix containing composite fibers (steel and polypropylene) of different percentages viz 0%, 0.50%, 0.75% and 1% steel fibers and 0.25% polypropylene fibre constant for all fly ash concrete mixes on the properties of high performance concrete. An aggregate binder ratio of 2.5 and different water binder ratio viz 0.30, 0.35 and 0.40 with super plasticizer of 0.6% by weight of binder was used in this investigation. Each series consists prisms, cylinders and cubes as per IS standard. The tests are conducted to find out the flexural strength, split tensile strength and compressive strength at the age of 7 days and 28 days.

**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 fibers 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 behaviors of the concrete were investigated such as: compressive, flexure, and bonding strength of the concretes.

## 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 2.72.
c) **Fine aggregate**: - River sand from local sources was used as fine aggregate. Specific Gravity was 2.70.
d) **Water**: used for both mixing and curing should be free from harmful amounts of harmful materials. In the present work drinkable tap water was mixed directly with concrete.
e) **Metakaolin**: it is obtained from the 20 micron limited company at Vadodara in Gujarath. The specific gravity of Metakaolin is 2.50.
f) **Super plasticizer**: To improve the workability of the mixes, a high range water reducing agent Fosroc conplast SP430 (SNF- Sulphonated Naphthalene Formaldehyde) is used. The specific gravity of Metakaolin is 1.50.
g) **Steel fibers**: Crimped steel fibers of 30mm length with a dia of 0.7mm and an aspect ratio of 42, density is 7840 Kg/m3 and specific gravity is 7.9 were used throughout the experimental program.
h) **Polypropylene fibers**: RECRON 3S TYPE–CT 2012 polypropylene fibers of density 946 Kg/m3 are used in experimental program.

## IV. MIX DESIGN

The test program considered the casting and testing of concrete specimens of cube ($100mm^3$), cylinder (100mm X 200mm) and prism (100mm X 100mm X 700mm). The specimen was cast using M60 grade concrete, Natural River sand and crushed stone with Metakaolin, Polypropylene fibers and steel fibers. Each three numbers of specimens made to take the average value. The Specimens remolded after 24hrs. The specimens were allowed to the curing periods.

**Table 1.0: Mix Proportion Table**

| Sl. No. | Mix | W/B Ratio | Steel + Polypropylene Fibre Dosage % | Cement | Metakaolin (MK) | Water | C.A | F.A | HRWR |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0% MK | 0.30 | 0% | 673.55 | - | 202.06 | 909.29 | 606.19 | 9.13 |
| | | | 0.50% | 673.60 | - | 202.06 | 909.29 | 606.19 | 9.13 |
| | | | 1.00% | 673.55 | - | 202.06 | 909.29 | 606.19 | 9.13 |
| 2 | 0% MK | 0.40 | 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 | 0.30 | 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 | 0.40 | 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 | 0.30 | 0% | 606.19 | 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% | 606.19 | 66.45 | 199.36 | 897.11 | 598.07 | 5.05 |
| 6 | 10% Mk | 0.40 | 0% | 567.94 | 62.31 | 249.25 | 841.21 | 560.80 | 3.80 |
| | | | 0.50% | 567.94 | 62.31 | 249.25 | 841.21 | 560.80 | 3.80 |
| | | | 1.00% | 567.94 | 62.31 | 249.25 | 841.21 | 560.80 | 3.80 |
| 7 | 15% MK | 0.30 | 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 | 0.40 | 0% | 536.38 | 93.46 | 246.76 | 836.18 | 557.30 | 3.56 |
| | | | 0.50% | 536.38 | 93.46 | 246.76 | 836.18 | 557.30 | 3.56 |
| | | | 1.00% | 536.38 | 93.46 | 246.76 | 836.18 | 557.30 | 3.56 |
| 9 | 20% MK | 0.30 | 0% | 538.84 | 132.90 | 195.39 | 885.36 | 590.54 | 3.98 |
| | | | 0.50% | 538.88 | 132.90 | 195.39 | 885.36 | 590.54 | 3.98 |
| | | | 1.00% | 538.84 | 132.90 | 195.39 | 885.36 | 590.54 | 3.98 |
| 10 | 20% MK | 0.40 | 0% | 504.83 | 124.62 | 244.21 | 831.43 | 553.80 | 3.32 |
| | | | 0.50% | 504.83 | 124.62 | 244.21 | 831.43 | 553.80 | 3.32 |
| | | | 1.00% | 504.83 | 124.62 | 244.21 | 831.43 | 553.80 | 3.32 |

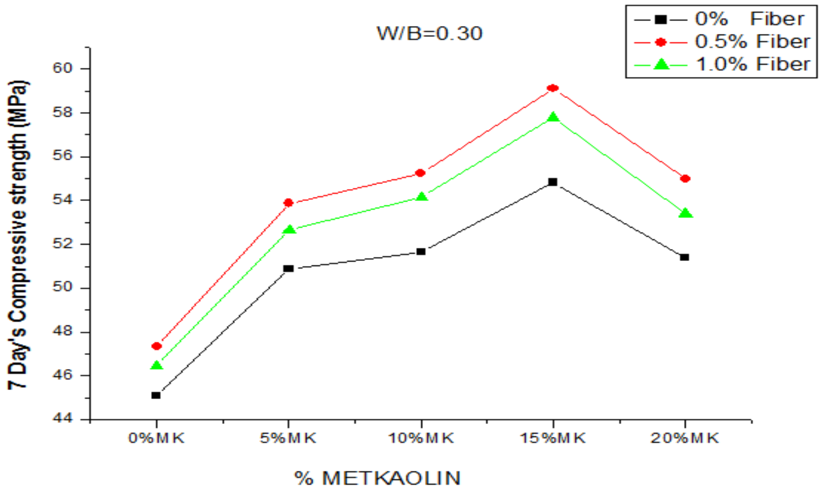
## V. RESULTS AND DISCUSSION

It is taken as an important property as it is majorly used to test hard state concrete.0.10$m^3$ 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 7 and 28 days.

**Fig 1: Testing of cubes**

**Table 2.0: 7 Days Compressive Strength Test for w/b ratio 0.30**

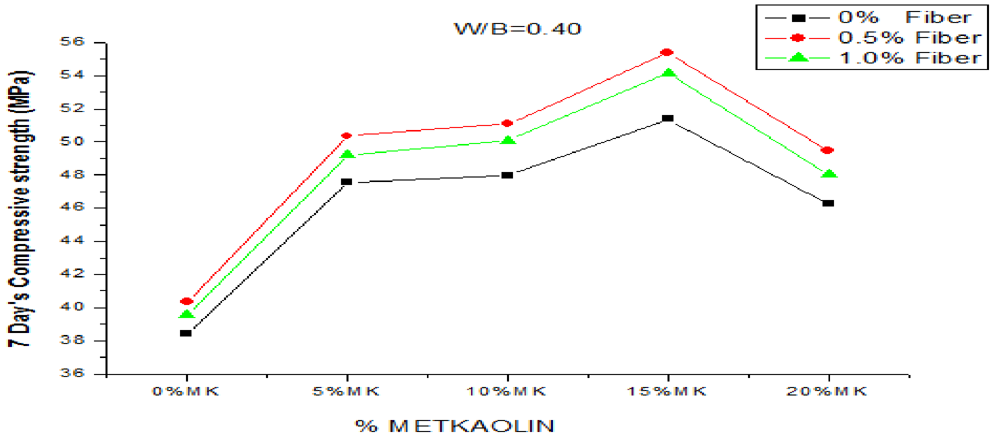
| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 7 Day cube test for w/b ratio 0.30 | 0% Metakaolin | 43.90 | 45.1 | 46.09 | 47.35 | 45.22 | 46.45 |
| | | 47.40 | | 49.77 | | 48.82 | |
| | | 44.00 | | 46.2 | | 45.32 | |
| | 5% Metakaolin | 50.20 | 50.86 | 53.16 | 53.87 | 51.96 | 52.65 |
| | | 51.50 | | 54.54 | | 53.30 | |
| | | 50.90 | | 53.90 | | 52.68 | |
| | 10% Metakaolin | 52.90 | 51.86 | 56.34 | 55.24 | 55.23 | 54.15 |
| | | 52.30 | | 55.69 | | 54.60 | |
| | | 50.40 | | 53.68 | | 52.62 | |
| | 15% Metakaolin | 52.80 | 54.83 | 56.92 | 59.11 | 55.65 | 57.79 |
| | | 56.80 | | 61.23 | | 59.87 | |
| | | 54.90 | | 59.18 | | 57.86 | |
| | 20% Metakaolin | 52.10 | 51.40 | 55.75 | 54.99 | 54.13 | 53.40 |
| | | 51.90 | | 55.53 | | 53.92 | |
| | | 50.20 | | 53.71 | | 52.15 | |




**Graph 1.0: 7 Days Compressive Strength Test for w/b ratio 0.30**

**Table 3.0: 7 Days Compressive Strength Test for w/b ratio 0.40**

| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 7 Day cube test for w/b ratio 0.40 | 0% Metakaolin | 39.51 | 38.43 | 41.48 | 40.35 | 40.69 | 39.58 |
| | | 38.39 | | 40.30 | | 39.54 | |
| | | 37.40 | | 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 | |

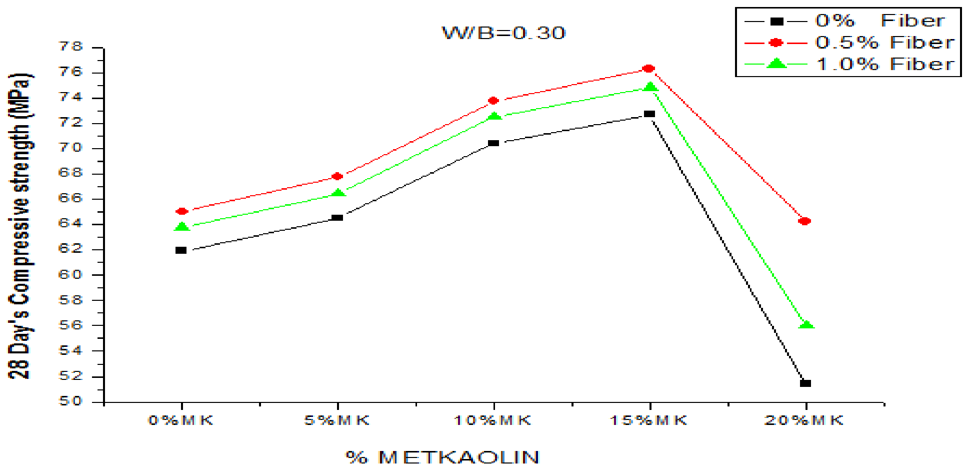



**Graph 2.0: 7 Days Compressive Strength Test for w/b ratio 0.40**

The Compressive Strength is less in control specimen compared to specimens with different w/b ratio various percentages of Metakaolin, Steel fibers and Polypropylene fibers. Compressive Strength results of specimens presented in table. 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 fibers and optimum w/b ratio is 0.3.

**Table 4.0: 28 Days Compressive Strength Test for w/b ratio 0.30**

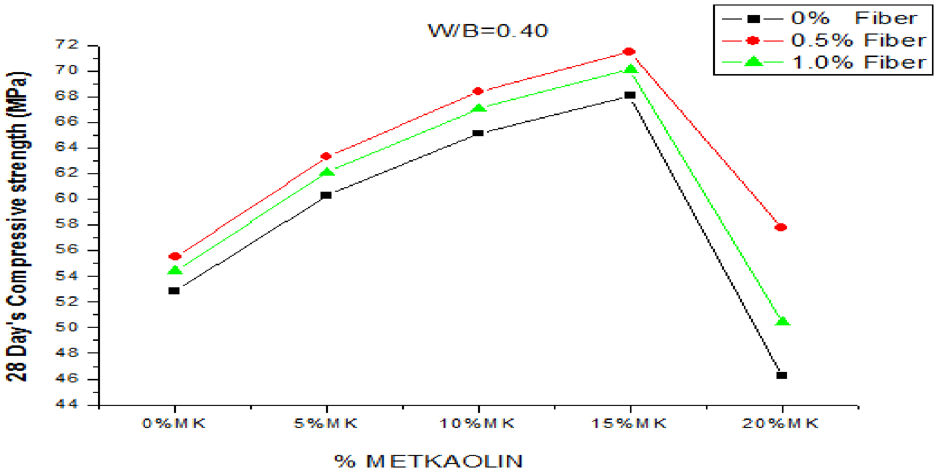
| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 28 Day cube test for w/b ratio 0.30 | 0% Metakaolin | 63.10 | 61.93 | 66.25 | 65.03 | 64.99 | 63.79 |
| | | 61.10 | | 64.15 | | 62.93 | |
| | | 61.60 | | 64.68 | | 63.44 | |
| | 5% Metakaolin | 63.50 | 64.53 | 66.67 | 67.76 | 65.40 | 66.46 |
| | | 67.50 | | 70.87 | | 69.52 | |
| | | 62.60 | | 65.73 | | 64.47 | |
| | 10% Metakaolin | 67.50 | 70.43 | 70.87 | 73.95 | 69.52 | 72.54 |
| | | 72.40 | | 76.02 | | 74.57 | |
| | | 71.40 | | 74.97 | | 73.54 | |
| | 15% Metakaolin | 72.80 | 72.70 | 76.44 | 76.33 | 74.98 | 74.88 |
| | | 71.10 | | 74.65 | | 73.23 | |
| | | 74.20 | | 77.91 | | 76.42 | |
| | 20% Metakaolin | 52.10 | 51.40 | 65.12 | 64.25 | 56.78 | 56.03 |
| | | 51.90 | | 64.87 | | 56.57 | |
| | | 50.20 | | 62.75 | | 54.71 | |




**Graph 3.0: 28 Days Compressive Strength Test for w/b ratio 0.30**

**Table 5.0: 28 Days Compressive Strength Test for w/b ratio 0.40**

| Age of test | % Metakaolin | Volume of Fibers (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 | 60.30 | 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 | |




**Graph 4.0: 28 Days Compressive Strength Test for w/b ratio 0.40**

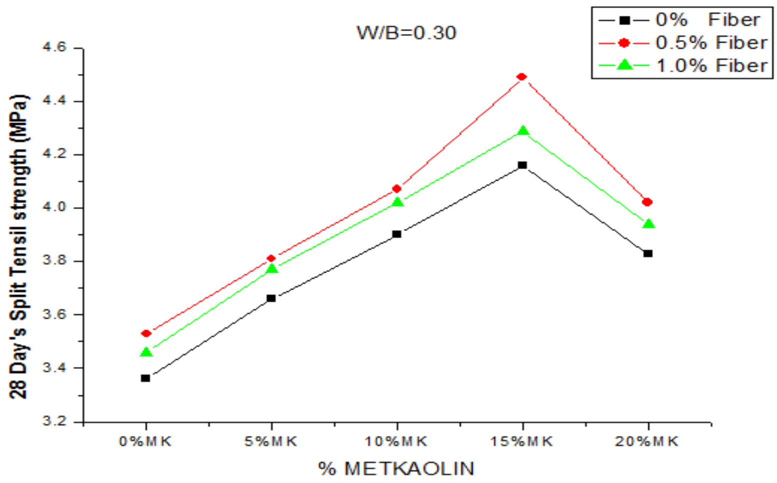
The 28 day Compressive Strength varied between 63 and 77MPa. From the above table it is clear that optimum % of Metakaolin replacement is 15% and 0.5% volume of fibre sand optimum w/c ratio is 0.3.

**Split Tensile Strength Test:** This test measures the tensile strength on 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. Tensile strength varies from 2.5 MPa to 31 MPa, about 10% of compressive strength.

**Fig 2: Split Tensile Strength Test**

**Table 6.0: 28 Days Split Tensile Test for w/b ratio 0.30**

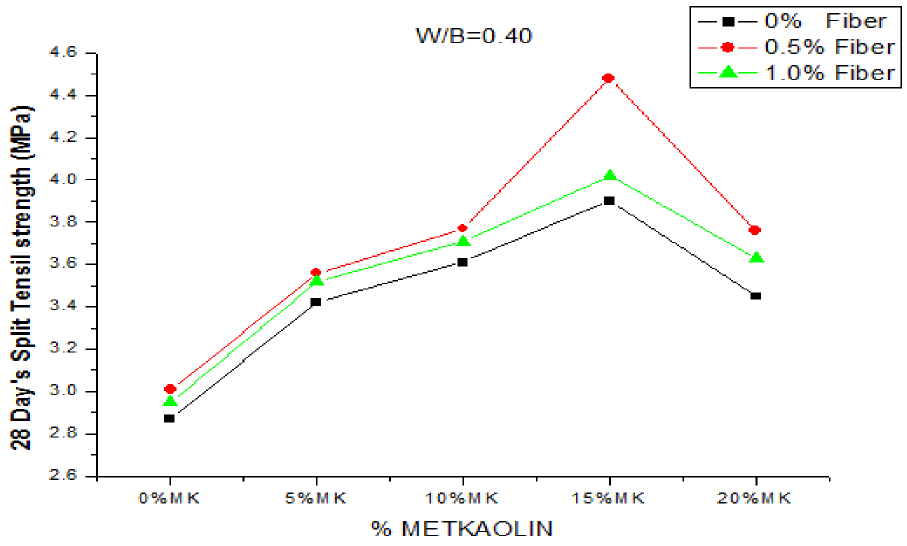
| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 28 Day Split Tensile test for w/b ratio 0.30 | 0% Metakaolin | 3.30 | 3.36 | 3.46 | 3.53 | 3.39 | 3.46 |
| | | 3.20 | | 3.36 | | 3.29 | |
| | | 3.60 | | 3.78 | | 3.70 | |
| | 5% Metakaolin | 3.50 | 3.66 | 3.62 | 3.81 | 3.60 | 3.77 |
| | | 3.80 | | 3.93 | | 3.91 | |
| | | 3.70 | | 3.88 | | 3.81 | |
| | 10% Metakaolin | 4.00 | 3.90 | 4.18 | 4.07 | 4.12 | 4.02 |
| | | 3.70 | | 3.86 | | 3.81 | |
| | | 4.00 | | 4.18 | | 4.12 | |
| | 15% Metakaolin | 4.00 | 4.16 | 4.60 | 4.49 | 4.12 | 4.29 |
| | | 4.30 | | 4.94 | | 4.42 | |
| | | 4.20 | | 4.83 | | 4.32 | |
| | 20% Metakaolin | 3.90 | 3.83 | 4.09 | 4.17 | 4.25 | 4.02 |
| | | 3.60 | | 3.78 | | 3.92 | |
| | | 4.00 | | 4.20 | | 4.36 | |




**Graph 5.0: 28 Days Split Tensile Test for w/b ratio 0.30**

**Table 7.0: 28 Days Split Tensile Test for w/b ratio 0.40**

| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 28 Day Split Tensile test for w/b 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 | |
| | | 3.60 | | 3.78 | | 3.92 | |




**Graph 6.0: 28 Days Split Tensile Test for w/b ratio 0.40**

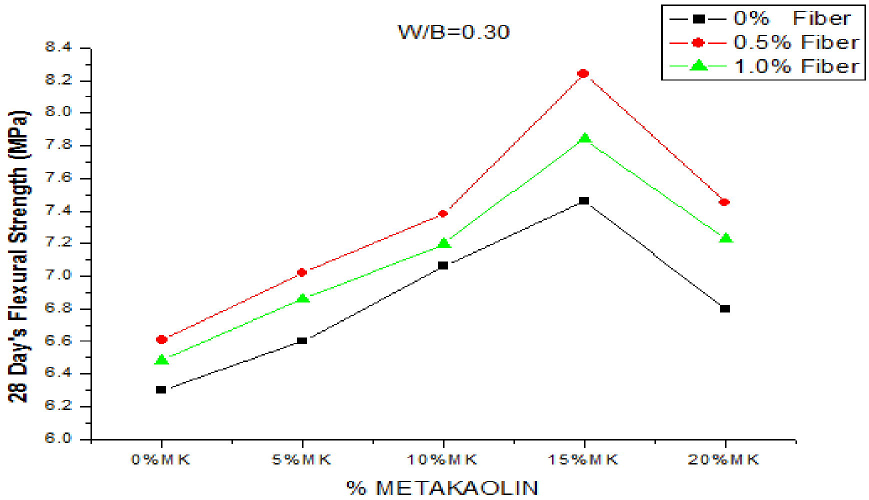
The Tensile Strength varied between 3 and 5MPa. From the above table it is clear that optimum % of Metakaolin replacement is 15% and 0.5% volume of fibre sand optimum w/c ratio is 0.3.

**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.

**Fig 3: Flexural Strength Test**

**Table 8.0: 28 Days Flexural Strength Test for w/b ratio 0.30**

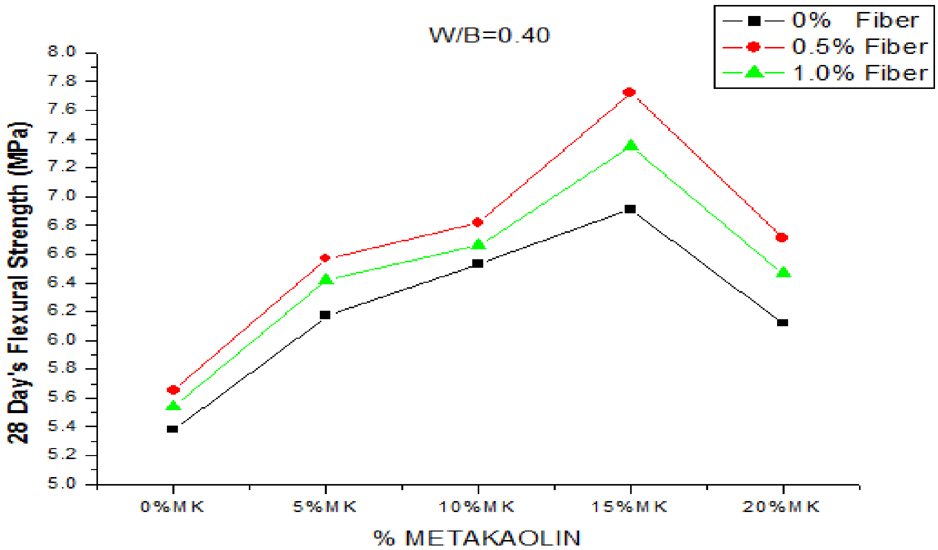
| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 28 Days Flexural Strength Test for w/b ratio 0.3 | 0% Metakaolin | 6.40 | 6.30 | 6.72 | 6.61 | 6.68 | 6.58 |
| | | 5.90 | | 6.19 | | 6.16 | |
| | | 6.60 | | 6.93 | | 6.89 | |
| | 5% Metakaolin | 6.50 | 6.60 | 6.92 | 7.02 | 6.72 | 6.86 |
| | | 6.60 | | 7.02 | | 6.83 | |
| | | 6.70 | | 7.13 | | 7.03 | |
| | 10% Metakaolin | 6.80 | 7.06 | 7.10 | 7.38 | 6.93 | 7.20 |
| | | 7.20 | | 7.52 | | 7.34 | |
| | | 7.20 | | 7.52 | | 7.34 | |
| | 15% Metakaolin | 7.00 | 7.16 | 8.05 | 8.24 | 7.66 | 7.84 |
| | | 7.20 | | 8.28 | | 7.88 | |
| | | 7.30 | | 8.39 | | 7.99 | |
| | 20% Metakaolin | 6.70 | 6.80 | 7.43 | 7.45 | 7.30 | 7.41 |
| | | 6.90 | | 7.52 | | 7.52 | |
| | | 6.80 | | 7.41 | | 7.41 | |




**Graph 7.0: 28 Days Flexural Strength Test for w/b ratio 0.30**

**Table 9.0: 28 Days Flexural Strength Test for w/b ratio 0.40**

| Age of test | % Metakaolin | Volume of Fibers (Steel + Polypropylene) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0% | Average | 0.50% | Average | 1.00% | Average |
| 28 Day Flexural Strength test for w/b 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 | |
| | | 6.80 | | 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 8.0: 28 Days Flexural Strength Test for w/b ratio 0.40**

## VI. CONCLUSIONS

From the present investigation on the effect of partial replacement of cement with Metakaolin, and addition of admixtures like Steel and Polypropylene fibers in concrete, the following conclusions were drawn;
The strength of all Metakaolin concrete mixes over shoot the strength of OPC. 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. 15% cement replacement by Metakaolin is superior to all other mixes hence it can be taken as the optimum % of Metakaolin. The results encourage the use of Metakaolin, as a pozzolanic material for partial replacement in producing high performance concrete. Increase in w/b ratio from 0.3 to 0.4 shows decrease in strength, hence optimum w/b ratio can be taken as 0.3. The increase in percentage of steel and polypropylene fibers from 0% to 0.5% shows 4.99%, 15.14%, 14.92% increase in compressive, tensile and flexural strength respectively. The increase in percentage of steel and polypropylene fibers from 0.5% to 1% shows 1.90%, 10.44%, 4.85% decrease in compressive, tensile and flexural strength respectively. Hence concluded that 15% Metakaolin with 0.3% w/b ratio and 0.5% steel and polypropylene fibers are the optimum percentages to obtain good strength.

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