

# An Investigation of Partial Replacement of Cement with Metakaolin in Association with Super Plasticizer

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**ABSTRACT:** These day's natural issues are increasingly noteworthy. The modern region creates loads of waste materials and CO<sub>2</sub>, respectably. A champion among the best approaches to take care of these issues is the usage of these waste materials. Metakaolin is non conventional materials obtained from the calcinations of kaolin clay. Metakaolin seems to be a auspicious additional cementitious material for superior cement. Properties of cement with metakaolin are for the most part favoured added substances in superior cement. A conceivable lower cost, because of huge accessibility in our nation itself might be points of interest to metakaolin use in making superior concrete. The metakaolin consolidations increment the quality of the concrete specimens. In this work, the impact of various contents of Metakaolin included to concrete containing super plasticizer its compressive quality strength and workability has been contemplated. Samples with 0%, 5%, 10%, 15%, 20% and 25% content of metakaolin replacing the cement have been evaluated for M30 grade. The outcomes have been contrasted and those for the control test and practicality of adding metakaolin to concrete has been examined. It was watched that up to 15% of concrete can be supplanted with metakaolin blended with superplasticizer. 15% substitution is the ideal rate at which expanded quality of test sample is seen from the base sample test.

**KEYWORDS:** Metakaolin, Super plasticizer, Compressive strength, Workability, Cement concrete.

## I. INTRODUCTION

Advancement is truly necessary to take care of the expanding demand for the new and quality material. In the previous years, many research and alterations has been performed to create concrete with craved qualities. Cement is commonly utilized and adaptable building material having high compressive quality, by augmentations of certain Pozzolanic materials, the different properties of solid wiz, workability, solidness ,quality can be moved forward. Metakaolin is a thermally initiated alumina silicate material gotten by calcining kaolin dirt inside the temperature scale 650–800 °C, which is a moderately new material in the solid business, is successful in expanding quality, diminishing sulfate assault and enhancing air-void system. Pozzolanic responses change the microstructure of cement and science of hydration items by devouring the discharged calcium hydroxide and creation of extra calcium silicate hydrate gel (C-S-H), bringing about an expanded quality and lessened porosity and in this manner enhanced strength.

Metakaolin is a profoundly proficient pozzolona and responds quickly with the overabundance calcium hydroxide coming about because of OPC hydration, by means of a pozzolanic response, to deliver calcium silicate hydrates and calcium alumino silicate hydrates Luc et al. [1]. It is very helpful for enhancing solid quality, by upgrading quality and lessening setting time, and may in this way end up being a promising material for assembling superior solid Li and Ding, 2003 [2]. Utilization of metakaolin is attaining popularity because of its genuine effect on various properties of concrete. Metakaolin causes lessening of workability. So expanding measure of perceptual extent of Metakaolin in concrete blend appears to require higher dose of super plasticizer to guarantee longer time of workability Sanjay N. Patil et.al. [3]. Replaced cement with metakaolin causes extraordinary change in the concrete structure and give imperviousness to unsafe arrangement B.B. Sabir et.al. [4]. Other customary bond substitution materials including

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GGBS and fly ash can be used in conjunction with metakaolin to bring on additional pore refinement [5, 6, 7]. Experimental work on utilization of metakaolin in concret demonstrates that exitance of metakaolin in cement enhances its mechanical properties and toughness properties [8, 9, 10, 11].

In this work of research the main emphasis is imparted to investigate the impact of replacement of cement partially in concrete with different proportion of metakaolin and to evaluate the compressive strength of concrete at 7 days and 28 days respectively. Also the results of normal concrete are compared with the concrete having different percentage of metakaolin.

## II. RELATED WORK

J.M. Khatib et al., [12] in this work studied the parameter of strength i.e. ultrasonic pulse velocity, compressive strength and density of mortar containing extent of metakaolin as partial replacement of cement is evaluated. Metakaolin was replaced up to 50% with cement in an increment of 10. For each replacement total 6 cubes specimens were casted that were demoulded for curing in water at 20°C for a total duration of 28 .The results observed that the higher strength of mortar cube specimen occurs at 20% replacement with metakaolin. Compressive strength started decreasing when metakaolin is replaced with cement more than 30 %.

Jian-Tong Ding and Zongjin Li, [13] in this study, analyzed the impact of metakaolin on the workability, quality, shrinkage and imperviousness to chloride entrance of cement were assessed and thought about. For the given blend extents, metakaolin offer preferable workability over does silica fume. As the replacement(cement level was expanded, the Strength of the metakaolin – altered cement expanded at all ages. The expansion in the quality was like that of the silica fume – changed cement. The fuse of the both metakaolin and silica fume in cement can diminish the free drying the free drying shrinkage and controlled shrinkage splitting width. The underlying breaking seemed before in the silica fume and metakaolin in cement can decrease the chloride dispersion rate altogether, with the silica rage solid performing to some degree better.

Paiva.H et al., [14] concentrated the influence of Metakaolin on quality and workability of cement. The exploratory outcomes demonstrated that the utilization of Metakaolin diminished the workability and to get the required droop, High range water decreasing admixtures (HRWRA) were basic. HRWRA brought about deflocculation of Metakaolin particles and in this manner a well scattering of Metakaolin particles were accomplished. The work reasoned that utilization of HRWRA was extremely fundamental in cement containing fine particles like Metakaolin to accomplish well scattering and better.

Dojkov.I et al., [15] experimentally concentrated the response between Metakaolin-Ca (OH) □-water and Fly fiery debris Ca (OH) □-water. Obviously amid the underlying time of curing (up to 7 days), Metakaolin joined lime with a high rate. This showed the general rate of the response occurring in early period of Portland bond - Metakaolin cements and concrete mortars was restricted by the hydration of the bond stages. The response between Fly fiery debris Ca (OH)□-water was occurring at a direct rate in the underlying age as contrasted and Metakaolin-Ca(OH)□-water. The exploratory outcomes supported the conceivable joined utilization of Metakaolin-Fly fiery remains Portland bond in solid industry.

## III.EXPERIMENTAL METHODOLOGY

### 3.1 MATERIALS SELECTED:

**Cement:** The ordinary Portland cement (OPC) having 53 grade produced by the Ultra Tech Cement Company was utilized as a part of the study, which is as per IS 12669:1987. Properties of this cement were examined and listed with its results in table-1.

Table □ Physical properties of OPC 53 grade cement

Setting time in minutes		Normal consistency (%)	Specific gravity
Initial	Final		
45	305	30	3.15

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**Fine aggregate:** In this study fine aggregate is taken from locally available supplier which is free from organic matter. Sieve analysis result Confirms to zone-II sand that is defined in IS: 383-1970. The other properties of fine aggregate are evaluated that are listed with its results in table 1.

**Table 1 Properties of Fine aggregate**

Specific Gravity	Water Absorption	Fineness Modulus
2.62	1.20%	3.01

**Coarse aggregate:** In this study Crushed aggregate of 20 mm size is brought from locally available supplier. Aggregates which are having size more than 20mm size are separated by sieving method. Various Tests on aggregate are performed in order to find out its properties. The test performed on coarse aggregate and their corresponding results are represented in table 2.

**Table 2 Properties of Coarse aggregate**

Specific Gravity	Water Absorption	Fineness Modulus
2.67	0.92%	6.92

**Metakolin:** Indeed Metakaolin is not a by-item. It is gotten by the calcination of immaculate or refined Kaolinite dirt at a temperature between 650°C and 850°C, trailed by pounding to accomplish an artfulness of 700-900 m<sup>2</sup>/kg. It is a great pozzolanic material, which is replaced with cement at various percentages so as to enhance the strength of cement. At the point when utilized as a part of solid it will fill the void space between cement particles bringing about a more impermeable concrete.its chemical composition are listed in table 3.

**Table 3 Chemical composition of Metakaolin**

Chemical composition	Silica	Alumina	Calcium oxide	Iron oxide	Magnesium oxide	Potassium Oxide	Loss on ignition
<b>Metakaolin %</b>	53.7	37.2	0.38	4.28	0.15	0.12	0.7

**Super-Plasticizer:** Sika ViscoCrete 4203 NS obtained from Sika India private ltd. was used in this study as a water reducing admixture that confirms to IS 9103-1999 ASTM C494.it is light brown in color having relative density of 1.11 and Ph>6.

**Design Mix Proportions:** In this study a design mix is performed for M30 grade of concrete as per IS 10262-2009. The concrete mix proportion was 1:1.34:2.91 with water cement ratio of 0.45.the slum obtained was 43 mm .in order to make more workable concrete super plasticizer of 1.3 % by weight of cement is added that provide 82 mm slump which is satisfactory .Total 42 cubes were casted to perform compressive strength test at 7 days and 28 days along with their workability. List of various proportion of percentage replacement with metakaolin are listed in table 4.

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**Table □ Mix proportions of concrete for M30 grade replaced with metakaolin**

% REPLACEMENT	Cement Kg/m <sup>3</sup>	Metakaolin (M.K.) Kg/m <sup>3</sup>	Fine aggregate Kg/m <sup>3</sup>	Coarse aggregate Kg/m <sup>3</sup>	Super plasticizer lit/m <sup>3</sup>	Water lit/m <sup>3</sup>
M.K. 0%	413.3	0	555.68	1203.35	5.37	186
M.K. 5%	392.64	20.66	555.68	1203.35	5.37	186
M.K. 10%	371.97	41.33	555.68	1203.35	5.37	186
M.K. 15%	351.305	61.995	555.68	1203.35	5.37	186
M.K. 20%	330.64	82.66	555.68	1203.35	5.37	186
M.K. 25%	309.975	103.325	555.68	1203.35	5.37	186

### 3.2 EXPERIMENTAL PROGRAM:

#### Test for fresh concrete:

For each mix 6 cubes are casted and their workability is measured with the help of slump cone test as suggested by Indian Standard code of practice. This test is designed to perform on fresh concrete to check its workability.

#### Test for hardened concrete:

The major valuable property of concrete is the compressive strength because it predicts the overall quality of concrete in hardened state. The hardened concrete test in this study was compressive strength test.

## IV. EXPERIMENTAL RESULTS & DISCUSSION

### 4.1 Compressive Strength Test:

The strength test was performed on 150 mm size cubes in order to find its compressive strength at an interval of 7 and 28 days. The compressive strength was evaluated using 2000 KN compression testing machine as per IS 516-1959. The value of compressive strength for M30 grade concrete at different percentage of metakaolin are shown in table □ after 7 & 28 days.

**Table □ Compressive strength test results in MPa for M30 Grade**

CEMENT REPLACEMENT AT DIFFERENT PERCENTAGE BY METAKAOLIN (M.K.)				
Concrete mix proportion	Compressive strength in MPa			
	Compressive strength in (N/mm <sup>2</sup> ) at 7 days	Percentage strength increment or decrement from M.K. 0% at 7 days	Compressive strength in (N/mm <sup>2</sup> ) at 28 days	Percentage strength increment or decrement from M.K. 0% at 28 days
M.K. 0%	26.22	0	38.81	0
M.K. 5 %	29.9	14.04	43.11	11.08
M.K. 10 %	32.07	22.31	45.84	18.11
M.K. 15 %	34.36	31.05	47.77	23.09
M.K.20 %	31.36	19.6	45.16	16.36
M.K. 25 %	26.04	-0.69	36.35	-6.34

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Compressive strength at 7 days varied between 26 MPa to 35 MPa and 25 % replacement exhibit the minimum compressive strength with respect to other replaced by metakaolin and 15 % replacement gives the maximum compressive strength as noticed in figure 1.

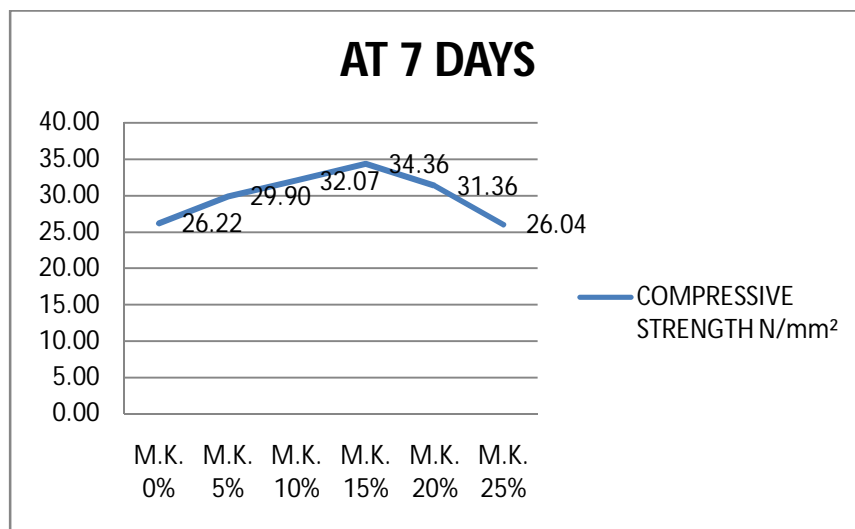


Figure 1: 7 days Compressive strength of M30 grade of concrete

Compressive strength at 28 days varied between 39 MPa to 48 MPa and 25 % replacement exhibit the minimum compressive strength with respect to other replaced by metakaolin 15 % replacement gives the maximum compressive strength that can be noticed in figure 2.

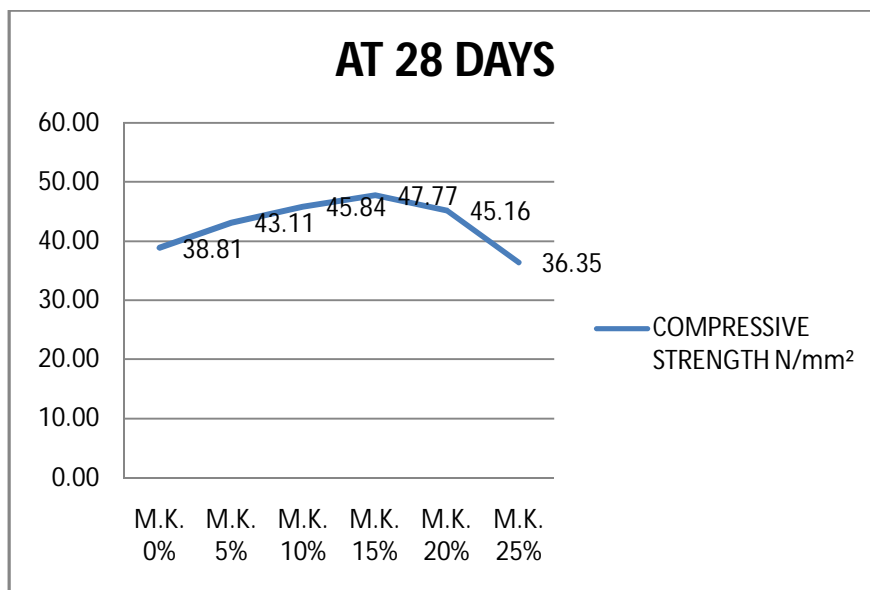


Figure 2: 28 days Compressive strength of M30 grade of concrete

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Experimental setup for compressive strength test shown in following figure 3 was used for conducting this test under compression testing machine of capacity of 2000KN with a loading rate of 140 Kg/cm<sup>2</sup>/minute. The cube is placed between the two bearing plate and load is applied through the mechanism of compression testing machine.



Figure 3: Experimental Setup for compressive Strength test

Failure of concrete cube specimen under compression testing machine (CTM) when loading was applied on it can be noticed in the figure 4.



Figure 4: Failure of concrete specimen under CTM

The highest strength at 15 % replacement by metakaolin is observed at 7 & 28 days that can be called as optimum percentage replacement even satisfactory results are found up to 20 % replacement after which decreased in strength with respect to target mean strength of M30 is taken place. At 15 % replacement with metakaolin provides increase in 31.05% strength in 7 days & 23.09 % increase in strength at 28 days.

### 4.2 Workability:

In order to find the workability of different concrete mix proportions slump test is performed for each percentage replacement mix with metakaolin.

Following results of slump cone test were obtained for different mixes of concrete prepared by replacement of cement with metakaolin .All the results of slump cone test can be noticed in table □.

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Table □ Slump value of different concrete mix

Concrete Mix Proportions	Super plasticizer dosage	Slump value (mm)
M.K. 0%	1.30%	82
M.K. 5 %	1.30%	80
M.K. 10 %	1.30%	83
M.K. 15 %	1.30%	78
M.K.20 %	1.30%	77
M.K. 25 %	1.30%	75

Maximum slump value is obtained at 10 % replacement of cement with inclusion of metakaolin and further increment in replacement with metakaolin causes slump value to decrease by small amount. It was noticed with the experiment of slump cone that metakaolin decreases workability so that inclusion of metakaolin in concrete results workability was slightly compromised

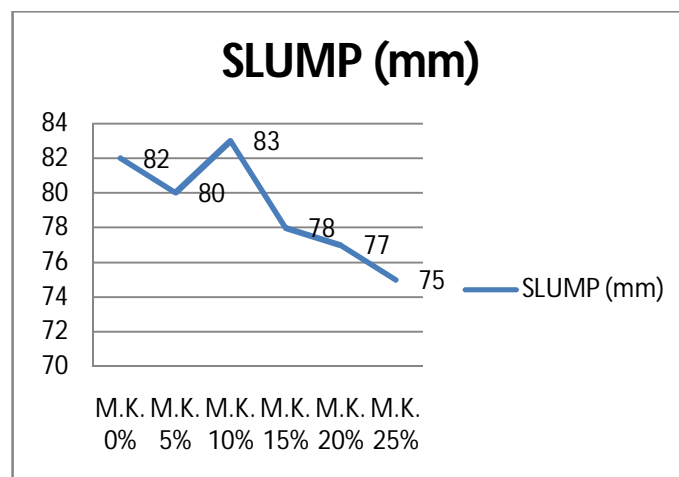


Figure 5: Slump value of different concrete mix

## V. CONCLUSION

On the basis of the test performed in this study following conclusions are listed below:-

- The strength of metakaolin modified cement concrete mixes shoot the strength of ordinary Portland cement (OPC).
- The strength of concrete in compression increases up to 15 % replacement of cement in concrete by metakaolin and further increasing of metakaolin leads to decrease in strength of concrete.
- Thus it is evaluated that optimum percentage replacement of metakaolin with cement in concrete and it is almost 15% for cubes.
- Metakaolin diminishes workability. Be that as it may, in specific cases with proper dosages of plasticizers the impact is very little.

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