

# **A Study on Mechanical Properties of Concrete using Fly Ash and Metakaolin**

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**ABSTRACT:** In this study, effects of metakaolin on strength were experimentally investigated. The Study focus on partial replacement of cement by metakaolin in M<sub>40</sub> grade concrete . They were incorporated into concrete at the levels of 0%, 5%, 10%, 15% and 20%. This paper presents a detailed experimental study on compressive strength, split tensile strength and flexural strength at an age of 7,14and28 days. Test results shows that use of metakaolin in concrete has improved the performance of concrete in strength at a 15% percentage replacement. Although the highest compressive strength of concrete was observed was 15% metakalolin replacement for ordinary Portland cement and were reduced as the increase in the replacement ratios.

**KEYWORDS:** metakaolin, fly ash, compressive strength.split tensile strength, flexural strength

## **I.INTRODUCTION**

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The usage, behavior as well as the durability of concrete structures, built during the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the ease of procuring the constituent materials (whatever may be their qualities) of concrete and the knowledge that almost any combination of the constituents leads to a mass of concrete have bred contempt.The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Met kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing.

## **II.MATERIAL PROPERTIES**

### **2.1 Materials**

In the design of high performance concrete the selection of proper ingredients evaluating their properties and understanding the interaction between different materials plays a major role in performance of the concrete. The

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 11, November 2017

ingredients used are cement, metakaolin, natural sand, manufacture sand, coarse aggregate, super plasticizer. The performance requirements of concrete enhancements of the following

1. Ease of placement and compaction by no segregation.
2. Long term mechanical properties.
3. Early strength.
4. Toughness.
5. Volume stability.
6. Long term durability properties.
7. Longer service life.
8. The efficiency of high performance concrete is improved by proper selection controlling and proportioning the ingredients of high performance concrete.

## 2.2 Metakaolin

Metakaolin is a pozzolanic material which is manufactured from selected kaolin, after refinement and calcinations under specific conditions. It is a highly efficient pozzolana and reacts rapidly with the excess calcium hydroxide resulting from OPC hydration, via a pozzolanic reaction, to produce calcium silicate hydrates and calcium alumina silicate hydrates. It differs from other supplementary cementations materials like fly ash, slag or metakaolin, in that it is not a by-product of an industrial process. The properties of metakaolin as shown in Table 2.1

**Table 2.1: Properties of Metakaolin**

S.No	Physical properties	Result
1.	Specific gravity	2.41
2.	Physical form	Powder
3.	Size (Micron)	0.089
4.	Color	light creamy-white



**Figure 2.1 Metakaolin**

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## 2.3 Fly ash

Fly ash is like a slag an industrial waste that is widely used as mineral admixture in the cement and concrete industry the chemical composition of fly ash depends on the composition of the original coal ash. Fly ash improves concrete's workability, pump ability cohesiveness, finish, ultimate strength as well as solves many problems experienced with concrete today and all for less cost. The properties of fly ash are shown in Table 2.2.

**Table 2.2: Properties of fly ash**

S.No	Physical properties	Result
1.	Specific gravity	2.12
2.	Physical form	Powder
3.	Size (Micron)	0.1
4.	Colour	Dark grey



**Fig. 2.2 Fly ash**

## 2.4 Super plasticizers

Super plasticizer named Conplast SP430 is used. It helps in dispersing cement particles, and they can reduce mixing water requirements by up to 30%, thereby increasing the concrete compressive strength. The Sulphonated Naphthalene Formaldehyde based super plasticizer (Conplast Super Plasticizer – SP 430) u. The properties super plasticizer are shown The in Table 2.3.

**Table 2.3 Properties of super plasticizer**

S.NO	PhysicalProperty	Value
<b>I.</b>	Solid content	42%
<b>II.</b>	Specific gravity	1.22

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**Fig. 2.3 Super plasticizer**

## III. MIX DESIGN

### 3.1 GENERAL

The process of selection suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability therefore becomes of vital importance.

### 3.2 MIX PROPORTIONS

Cement	= 270 kg/m <sup>3</sup>
Fly Ash	= 115 kg/m <sup>3</sup>
Water	= 140 kg/m <sup>3</sup>
Fine aggregate	= 869 kg/m <sup>3</sup>
Coarse aggregate	= 1106kg/m <sup>3</sup>
Chemical admixture	= 7.7 kg/m <sup>3</sup>

The table 3.1 shows the mix proportion of concrete.

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**Table 3.1 Mix proportion.**

Mix proportions	Cement kg/m <sup>3</sup>	Fine Aggregate kg/m <sup>3</sup>	Coarse Aggregate kg/m <sup>3</sup>	Water kg/m <sup>3</sup>	Chemical Admixture kg/m <sup>3</sup>	Fly ash kg/m <sup>3</sup>	Metakaolin kg/m <sup>3</sup>
Mix 1(0%)	270	869	1106	140	7.7	115	0
Mix 2(5%)	270	869	1106	140	7.7	109.25	5.75
Mix 3(10%)	270	869	1106	140	7.7	103.5	11.5
Mix 4(15%)	270	869	1106	140	7.7	97.75	17.25
Mix 5(20%)	270	869	1106	140	7.7	92	23

## IV. EXPERIMENTAL PROGRAM

### V.

#### 4.1 MECHANICAL PROPERTIES

##### 4.1.1 Compression Test (Ref: IS: 516-1959)

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Compressive strengths were attained as a result of the compressive tests conducted on the cube specimens of size 100mm x 100mm x 100mm . Cube was placed on the platform of the compression testing machine. The load was applied gradually till the concrete cubes get failed. The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted which gives the compressive strength of that cube. The compressive strength is the ratio of crushing load to the surface area of the specimens expressed in N/mm<sup>2</sup>. Similarly the compression strength values of all the cubes are found.



**Fig 4.1 Test Set up for Compressive Strength Test**

##### 4.1.2 Flexure Test (Ref: IS: 516-1959)

The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol  $f_{cr}$ . The flexural strengths of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 100mm x 100mm x 500mm. The flexural strength are tested using a two point loading frame machine as per standard as shown in figure 5.2.

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**Fig 4.2 Test Set Up for Flexural Strength**

The modulus of rupture can be determined by using the formula given below

$$f_{cr} = (P_{max} \times l) / bh^2$$

where,

$f_{cr}$	= Flexural strength
$P_{max}$	= maximum load in (N) kg.
$b$	= width of the prism in mm
$h$	= depth of the prism in mm
$l$	= span of the prism in mm

The loading must be applied centrally and without subjecting the specimen to any tensional stresses and restraints. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without any shock and increasing continuously at specified rate.

### 4.1.3 Split tensile strength Test (Ref: IS: 5816-1999)

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150mm x 300 mm were casting using M<sub>25</sub> grade concrete. Specimens with Conventional Concrete and SCC of two different percentages were casted. During casting the conventional concrete cubes were manually compacted using tamping rods. After 24hours, the specimens were removed from the mould and subjected to water curing for 7, 14, 28 days. After curing, the specimens were tested for compressive strength as per IS: 5816-1999 using a calibrated compression testing machine of 2000KN capacity.

Two packing strips of plywood 3mm thick were provided between the specimen one at top and another at bottom. The specimen was placed on the plywood strip and aligned so that, the central horizontal axis of the specimen is exactly perpendicular to the load applying axis. The second plywood strip was placed length wise on the cylinder and the top platen was brought down till it touched the plywood. The load was applied without shock and increased continuously until the resistances of the specimen to the increasing load broke down and no greater load can be sustained.

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Tensile strength of concrete  $f_t = \frac{2p}{\pi dl}$

Where ,  
 $P =$  Maximum load in N applied to the specimen  
 $L =$  Measured length in cm of the specimen  
 $D =$  Measured diameter in cm of the specimen

## V.RESULTS AND DISCUSSION

### 5.1 GENERAL

This chapter deals with the results obtained from the various experiments conducted to access mechanical properties. The aim of the study is to determine the compressive strength, flexural strength and split tensile strength. so the results of test specimens are presented. The discussion on the results also presented in this chapter.

### 5.2 MECHANICAL PROPERTIES

The mechanical properties of concrete such as compressive strength, flexural strength and split tensile strength are determined from the standard experiments. They are as follows.

#### 5.2.1 Compressive Strength

The compressive strength of replacement of metakaolin is arrived. The compressive strength value for replacement of metakaolin Table 5.1 Shows compression test results.

**Table 5.1: Compressive Strength of Cubes with Partial Replacement of metakaolin**

Curing days	COMPRESSIVE STRENGTH N/mm <sup>2</sup>				
	Mix 1(0%)	Mix 2(5%)	Mix 3(10%)	Mix 4(15%)	Mix 5(20%)
<b>7 days</b>	26.34	26.90	27.2	29.42	28.4
<b>14 days</b>	32.11	32.12	35.42	38.51	36.2
<b>28 days</b>	41.46	43.52	45.68	49.14	46.11

#### 5.2.2 FLEXURAL STRENGTH

The flexural strength of replacement of metakaolin is arrived.. Table 5.2 shows flexural strength test results

**Table 5.2: Flexural Strength of beams with Partial Replacement of metakaolin**

Curing days	FLEXURAL STRENGTH N/mm <sup>2</sup>				
	Mix 1(0%)	Mix 2(5%)	Mix 3(10%)	Mix 4(15%)	Mix 5(20%)
<b>7 days</b>	1.98	2.12	2.36	2.58	2.41
<b>14 days</b>	2.69	2.76	3.28	3.62	3.58
<b>28 days</b>	3.76	3.80	4.17	4.44	4.36

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## 5.2.3 SPLIT TENSILE STRENGTH

The variation of split tensile strength at the age of 28 days with different percentage of metakaolin, and fly ash from the test results, it was observed that the maximum split tensile strength was obtained for mix of 15% replacement of fly ash by metakaolin. Table 5.3 flexural strength test results

**Table 5.3: split tensile strength of Cylinder with Partial Replacement of metakaolin**

Curing days	SPLIT TENSILE STRENGTH N/mm <sup>2</sup>				
	Mix 1(0%)	Mix 2(5%)	Mix 3(10%)	Mix 4(15%)	Mix 5(20%)
<b>7 days</b>	2.78	2.86	2.93	3.21	3.19
<b>14 days</b>	3.21	3.48	3.54	3.79	3.62
<b>28 days</b>	3.92	4.21	4.43	4.89	4.62

## VI. CONCLUSION

The compressive strength of concrete increased when cement is replaced by metakaolin for M40 grade of concrete at 15% replacement of cement by metakolin the concrete attained maximum compressive strength for M40 grade of concrete. The split tensile strength of concrete is also increased when cement is replaced by metakaolin. The split tensile strength is maximum at 15% of replacement. The flexural strength of the concrete is also increased when the cement is replaced by metakaolin. at 15% replacement, the flexural strength is maximum.

## REFERENCES

- Shetty M.S.(2010) "concrete technology" S.Chand and company Ltd, Delhi
- IS 10262:2009 Concrete Mix proportion guidelines
- Gambhir.M.L concrete technology" Tata McGraw-Hill publishing company Ltd, NewDelhi,2004.
- Santhakumar. A.K.S, "concrete technology" Oxford Publication, New Delhi,2006.
- IS 456: 2000 code of practice for plain and reinforced concrete(third revision)
- IS 516:1959 method of test for strength of concrete (Jan-99)
- IS 2386 (PT3): 1963 method of test for aggregates for concrete Part 3 specific gravity, density, voids, absorption and bulking (Feb-97)
- IS 5816:1999 methods of tests for splitting tensile strength of concrete (first revision)
- IS:1199 -1959.Indian Standards methods of sampling and analysis of concrete. Bureau of Indian standard, new Delhi.
- IS :3812-1981, Indian standard specification for fly ash for use as pozzolana and admixture, 1<sup>st</sup> revision, bureau of Indian standard, New Delhi, June 1981.
- IS: 8112-1981, Specifications for 53 grade Portland cement, Bureau of Indian Standards, New Delhi
- IS: 3812-2003, Specifications for Pulverized fuel ash, Bureau of Indian Standards, New Delhi, Indian.
- IS: 383-1970, Specifications for Coarse and Fine aggregates from Natural sources for Concrete, Bureau of Indian Standards, New Delhi, Indian.
- ACI, 234R-96, "guide for the use of silica fume in concrete," reported by ACI Committee, 234,pp.1-51,1996
- Aitein p.c "high performance concrete, E & FN spon, London 1998