International Journal For Technological Research In Engineering
Volume 4, Issue 2, October-2016 *ISSN (Online): 2347 - 4718*

EFFECT OF VARYING QUANTITIES OF METAKAOLIN AND FLY ASH ON STRENGTH CHARACTERISTICS OF CONCRETE

Bhaskara Teja Chavali[1], Perla Karunakar[2]
[1]M.Tech Student, [2]Assistant Professor,
Department of Civil Engineering, Usha Rama College of Engineering & Technology,
Telaprolu, Krishna District, Andhra Pradesh, India, 521109

ABSTRACT: Metakaolin is a revolutionary artificial pozzolana admixture obtained from thermally activated ordinary clay and kaolinitic clay which greatly enhances the properties of ordinary concrete and become the central to the research in the making of special concrete. The use of Metakaolin and various chemical admixtures have become staple in gradients in the production of concrete with designed strength in excess of 7500psi (>50Mpa) or where service environments, exposure or life cycle cost considerations dictate the use of High performance concrete (HPC). Fly Ash is another material used as cement replacement in concrete since several decades which exhibited excellent results in the mechanical properties of concrete. The overall objective of the present study is to study the effect of adding Metakaolin along with Fly Ash in concrete on its performance. It is decided to explore compressive strength, Split tensile strength, and Flexural strength of concrete on addition of different percentages of Metakaolin and Fly Ash. For this Mix proportions of OPC concrete for M40 by IS method (10262-2009) were determined. The mix proportion with partial replacement of Metakaolin and fly ash such as 0% replacement of Metakaolin and fly ash, 15% replacement of Metakaolin to Cement, 30% replacement of Fly ash to Cement and 15% Metakaolin and 30% Fly ash replacement of cement were calculated. The concrete specimens such as cubes for compressive strength, cylinders for split tensile test, prisms for flexural strength were tested in laboratory with 7 days and 28 days of curing. The compressive strength of concrete increased when cement is replaced by Metakaolin as well as fly ash for M40 grade of concrete. At 15% replacement of cement with Metakaolin in addition to 15%replacement of cement with Fly ash for M40 grade of concrete has yielded maximum strengths. This trend was observed for compressive strength, split tensile strength and flexural strength of concrete for M40 grade.
Keywords: Metakaolin, Fly Ash, Compressive strength, Split tensile strength, Flexural strength.

I. INTRODUCTION

1.1 General

Metakaolin is a manufactured pozzolanic mineral admixture which significantly enhances many performance characteristics of cement based motors, concrete and related products. The use of pozzolanic materials in the manufacture of concrete has a long, successful history. Most pozzolans used in the world today are by products from other industries, such as coal fly ash, blast furnace slag, rice husk and silica fume. As such there has been relatively little work done with regard to manufactured, optimized and engineered pozzolanic materials which are specially intended for use in Portland cement based formulations. The use of Metakaolin and various chemical admixtures have become staple in gradients in the production of concrete with designed strength in excess of 7500psi(>50Mpa)or where service environments, exposure or life cycle cost considerations dictate the use of High performance concrete (HPC).Amongst the various methods used to improve the durability of concrete, and to achieve high performance concrete the use of Metakaolin is a relatively new approach. The partial replacement of ordinary Portland cement with pozzolanic materials can be advantageous in that it can increase the durability of paste, mortar or concrete if the proper curing regime is adopted. This is due to the fact that the Calcium Hydroxide produced by the cement hydration reacts with the pozzolana and produces additional gel which has a pore blocking effect and therefore alters the pore structure and the strength. In addition there is a reduction in Calcium Hydroxide (CH) which leads to improved resistance to sulphate attack and alkali-silica reaction. Recently Metakaolin which is an ultra fine pozzolan produced from calcined clay has been added to the list of pozzolanic materials.

1.2 New Age Concrete

High Performance Concretes appeared a few years ago and now develop rapidly representing a new generation of composite materials in building and civil engineering. Without any doubt their application will be increased in many kinds of structures where special requirements are imposed. Although Portland cement demands are decreasing in industrial nations, it is increasing dramatically in developing countries. Cement demand projections shows that by the year 2050 it will reach 6000 million tons. Portland cement production leads to major CO2 emissions, results from calcination of limestone (CaCO3) and from combustion of fossil fuels, including the fuels required to generate the electricity power plant, accounting for almost 0.7 tons of CO2 per ton. Of cement which represents almost 7% of the total CO2 world emissions. This is particularly serious in the current context of climate change caused by carbon dioxide emissions worldwide, causing a rise in sea level and being responsible for a meltdown in the world economy. Since Portland cement is used mostly in concrete production, the most important building material on Earth (10,000 billion tons per year), partial replacement by pozzolanic by-products and mineral additions will allow relevant carbon dioxide emission reductions. Investigations about the pozzolanic properties of fly ash, calcined clays and calcined agriculture wastes were already carried out. Pozzolanic admixtures react with Ca (OH) generating additional CSH phases, resulting in a more compact concrete with increased durability. Some supplementary cementitious material, like fly ash has very slow hydration characteristics thus providing very little contribution to early age strength while others like Metakaolin possess a high reactivity with calcium hydroxide having the ability to accelerate cement hydration. Since current concrete structures present a higher permeability level that allows aggressive elements to enter, leading corrosion problems, usage of pozzolanic admixtures not only reduce carbon dioxide emissions but also allow structures with longer service life, thus lowering their environmental impact. Nevertheless, studies on the durability performance of concrete containing pozzolanic by-products are recent and still scarce. Even scarcer about the durability performance of concrete that contains blended reactive pozzolans. This paper presents experimental data about the strength and performance of Metakaolin, fly ash based concrete.

1.3 Metakaolin

Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous alumina silicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), Metakaolin reacts with the calcium hydroxide (Lime) by-products produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds means stronger concrete. Metakaolin, because it is very fine and highly reactive, gives fresh concrete a creamy, non-sticky texture that makes finishing easier. Efflorescence, which appears as a whitish haze on concrete, is caused when calcium hydroxide reacts with carbon dioxide in the atmosphere. Because met kaolin consumes calcium hydroxide, it reduces efflorescence. Alkali-silica reaction is a reaction between calcium hydroxide (the alkali) and glass (the silica) which can cause decorative glass embedment's in concrete to pop out. Because met kaolin consumes calcium hydroxide, it takes away the alkali and the reaction does not occur. Our experience has shown that optimal performance is achieved by replacing 10% to 15% of the cement with met kaolin. While it is possible to use less, the benefits are not fully realized until at least 10% met kaolin is used. The advantage of replacing some of the cement with met kaolin, rather than simply adding met kaolin to the mix, is that any existing colour formulas or mix designs won't change, or will only very slightly change. This is because the dosage of pigments and super plasticizers are based on the cement content in the concrete. All the other factors (good mix design, proper reinforcing, etc) must also be properly designed and accounted for in order to take advantage of the benefits met kaolin can give you. For example, making a very high compressive strength concrete is pointless if the reinforcing is inadequate. Concrete made with met kaolin can be cast, finished and cured in almost the same fashion as ordinary concrete made without met kaolin. Metakaolin complies with ASTM C618 – Specifications for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete, Class N, and is accepted under ACI 318 – Building Code Requirements for Structural Concrete and Commentary. The demand for Portland cement is increasing dramatically in developing countries. Portland cement production is one of the major reasons for CO2 emissions into atmosphere. It is due to the use of fossil fuels, including the fuels required to generate electricity during cement manufacturing process. The use of pozzolanas for making concrete is considered efficient, as it allows the reduction of the cement consumption while improving the strength properties of the concrete. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with Ca(OH)2 one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength. Metakaolin is obtained by thermal activation of kaolin clay. This activation will cause a substantial loss of water in its constitution causing a rearrangement of its structure. To obtain an adequate thermal activation, the temperature range should be established between 600 to 750ºC. Metakaolin is used in oil well cementing to improve the compressive strength of the hardened cement. Metakaolin also reduces the hardened cement permeability to liquids and gases. Hence by partially replacing Portland cement with Metakaolin not only reduces carbon dioxide emissions but also increases the service life of buildings Chemical formula of Metakaolin is Al2O3+2SiO2+2H2O.

1.4 Manufacturing of Metakaolin

Between 100–200°C, clay minerals lose most of their adsorbed water. Between 500–800°C kaolinite becomes claimed by losing water through dehydroxilization. The dehydroxilization of kaolin to Metakaolin is an endothermic process due to the large amount of energy required to remove the chemically bonded hydroxyl ions. Above this temperature range, kaolinite becomes Metakaolin, with a two-dimensional order in crystal structure. In order to produce a pozzolana (supplementary cementing material) nearly complete dehydroxilization must be reached without overheating, i.e., thoroughly roasted but not burnt. This produces an amorphous, highly pozzolanic state, whereas overheating can cause sintering, to form the dead burnt, nonreactive refractory, called mullite. Metakaolin which contains 94.88% SiO2+Al2O3 in the amorphous form is suitable for use in the cement and concrete industries. The average size of the spheroid particles is of the order of 1.5um, which is about two orders of magnitude finer than particles of Ordinary Portland Cement.

1.5 Properties of Concrete containing Metakaolin

The properties of fresh and hardened concrete containing pozzolanic admixtures are mostly dependent on their pozzolanic reaction. The effect of Metakaolin on the fresh concrete is generally viewed as a stabilizing effect in the sense that the addition of very fine particles to a concrete mix tends to reduce segregation and bleeding tendencies.

The addition of Metakaolin improves strength and durability to various types of chemical attacks, such as acidic (or) sulphate waters and the reaction causing alkali aggregate expansions. The addition of Metakaolin in small amounts (10% by weight of cement) has no significant effect on the setting time of cement. But the addition of Metakaolin is sensitive to plastic shrinkage, when exposed to drying condition at early age. However, there is no significant effect on the drying shrinkage. When used as a partial substitution for Portland cement, depending on the proportion of Metakaolin used, the early strength of concrete may be reduced by various amounts, especially when water / cementitious materials ratio is greater than 0.5 highly reactive pozzolana like Metakaolin are able to reduce there size of voids in hydrated cement pastes even at early ages with as low 10% addition of Metakaolin by weight.

1.6 Strength Parameters

Metakaolin contains similar range of silica and alumina oxides. Metakaolin has iron content as composed to other leading to lesser whiteness or reflectance, which is not of much importance for applications of material in concrete. Metakaolin contain high silica and super fineness, its reactivity is more, comparative to other pozzolanic admixtures. As a result, it contributes to strength improvement. Compressive strength of Metakaolin concrete continuous to increase with replacement levels at all ages up to optimum dosage. Ultra high strength concrete of the order of 40 to 120 N/mm2 is now possible for field peaceable concrete with Metakaolin admixture. Such high strength concrete has increased modulus of elasticity, lower creep and drying shrinkage. Another strength parameter of Metakaolin is its gain in strength at early ages.

1.7 Importance of Metakaolin

Metakaolin is often used in concrete countertop mixes to boost the physical properties of the concrete. Metakaolin is a manufactured pozzolan that is designed to be a white substitute for silica fume. Metakaolin provides higher early strengths, which allows for earlier form stripping, earlier processing and quicker turnaround. In addition, Metakaolin decreases porosity, increases compressive, tensile and flexural strengths, and it reduces drying shrinkage and adds in finish ability when it is toweled. Metakaolin can also influence the intensity and appearance of acid staining. The special characteristics of Metakaolin viz., super fineness. High silica content etc; gave the scope for enhancing the normal cement concrete when mixed with cement as partial replacement. Considered to have twice the reactivity of most other pozzolans, Metakaolin is a valuable admixture for concrete/cement applications. Replacing Portland cement with 8% - 20% (by weight) Metakaolin produces a concrete mix which exhibits favorable engineering properties.

Table: 1.1 shows the Chemical compositions of Metakaolin. The chemical composition of Metakaolin is similar to Portland cement.

TABLE 1.1 Chemical Composition of Metakaolin

CHEMICALS	PERCENTAGE (%)
SiO_2	62.62
Al_2O_3	28.63
Fe_2O_3	1.07
MgO	0.15
CaO	0.06
Na_2O	1.57
k_2O	3.46
TiO_2	0.36
LOI	2

Calcium hydroxide is one of the by-products of hydration reaction of cement. When cement is partially replaced with Metakaolin, it reacts with calcium hydroxide and results in extra C-S-H gel. C-S-H gel is the sole cause for strength development in cement and cement based concrete. The chemical reaction is given below

Cement + Water = C-S-H gel + Ca (OH) 2

Ca (OH) 2 + Metakaolin = C-S-H gel

1.8 Fly Ash

Fly ash is a burnt and powdery derivative of inorganic mineral matter that generates during the combustion of pulverized coal in the thermal power plant. The burnt ash of the coal contains mostly silica, alumina, calcium and iron as the major chemical constituents. Depending on the burning temperature of coal, the mineral phases in crystalline to non-crystalline structures such as quartz (SiO2), mullite (3Al2O3 2 H2O), hematite (Fe2O3), magnetite (Fe3O4), wustite (FeO), metallic iron, orthoclase (K2O Al2O36 SiO2) and fused silicates usually occur in the burnt coal ash2. Silica and alumina account for about 75 to 95 % in the ash. The classification of thermal plant fly ash is considered based on reactive calcium oxide content as class-F (less than 10 %) and class-C (more than10 %). Indian fly ash belongs to class-F. The calcium bearing silica and silicate minerals of ash occur either in crystalline or non-crystalline structures and are hydraulic in nature they easily reacts with water or hydrated lime and develop pozzolanic property. But the crystalline mineral phases of quartz and mullite present in the ash are stable structures of silica and silicates, and are non-hydraulic in nature. Usually the fly ash contains these two mineral phases as the major constituents. Therefore, the utilisation of fly ash in making building materials like fibre cement sheets largely depends on the mineral structure and pozzolanic property. Fly ash is broadly an aluminium-silicate type of mineral rich in alumina and silica. The usage of blended cement is growing rapidly in construction industry due to the considerations of cost saving and environmental protection. Increasing the use of by-products such as Fly Ash for partially replacing the Portland cement in concrete not only reduces the amount of cement used, but also significantly enhances the properties of concrete, reduces the emission of CO2 and conserves the existing resources. Inclusion of Fly Ash in concrete greatly improves consistency. Research work done on Metakaolin has shown that the partial replacement of Portland cement with Metakaolin in concrete significantly affects consistency and early strength. However, unlike Fly Ash increased replacement levels of Metakaolin increases water demand due to its high chemical activity and high specific surface. Concrete containing fly ash more than about 50% of total cementitious materials is classified as high volume fly ash concrete. The addition of fly ash in concrete improves certain properties such as workability, later age strength development characteristics. The major disadvantage observed in such concrete is the slower development of strength. This drawback can be addressed by adding super pozzolanic materials such as silica fume, Metakaolin and rice husk ash. This type of ternary blending of cementitious materials may improve the quality of concrete in different dimensions.

Table 1.2 Chemical Composition of Fly ash

CHEMICALS	PERCENTAGES (%)
SiO_2	60.5
Al_2O_3	30.8
Fe_2O_3	3.6
CaO	1.4
MgO	0.91
SO_3	0.14
$K_2O + Na_2O$	1.1
LOI	0.8

1.9 Advantages of using Fly ash in Concrete:

The advantages of using fly ash in concrete include the followings.

- Fly ash in the concrete mix efficiently replaces Portland cement that in turn can aid in making big savings in concrete material prices.
- It is also an environmentally-friendly solution, which meets the performance specifications. It can also contribute to LEED points.
- It improves the strength over time and thus, it offers greater strength to the building.
- Increased density and also the long-term strengthening action of flash that ties up with free lime and thus, results in lower bleed channels and also decreases the permeability.
- The reduced permeability of concrete by using fly ash, also aids to keep aggressive composites on the surface where the damaging action is reduced. It is also highly resistant to attack by mild acid, water and sulfate.
- It effectively combines with alkalis from cement, which thereby prevents the destructive expansion.
- It is also helpful in reducing the heat of hydration. The pozzolanic reaction in between lime and fly ash will significantly generate less heat and thus, prevents thermal cracking.
- It chemically and effectively binds salts and free lime, which can create efflorescence. The lower permeability of fly ash concrete can efficiently reduce the effects of efflorescence.

1.10 OBJECTIVE OF THE PRESENT WORK

The overall objective of the present study is to study the effect of adding Metakaolin and Fly Ash in concrete on its performance. The main objectives of the present project work are:

- To prepare the concrete specimens such as cubes for compressive strength, cylinders for split tensile test, prisms for flexural strength in laboratory with 0% replacement of Metakaolin and fly ash, 15% replacement of Metakaolin to Cement, 30% replacement of Fly ash to Cement and 15% Metakaolin and 30% Fly ash replacement of cement of Metakaolin and flyash with OPC for M40 grade concrete.
- To evaluate the mechanical characteristics of concrete such as compressive strength, split tensile test, flexural strength.
- To evaluate and compare the results to derive conclusions.

II. METHODOLOGY

2.1 MIX DESIGN:

The mix design was done by using the guidelines of IS Code method (IS10262-2009). The design stipulations and the data considered for mix design has been presented below.

2.2 STIPULATIONS AND TEST DATA FOR MATERIALS:

A) Type of cement	OPC 53 grade
B) Maximum size of aggregate	20 mm
C) Minimum cement content	320 Kg/m^3
D) Maximum water cement ratio	0.45
E) Workability	50mm (slump)
F) Exposure condition	Severe(RCC)
G) Method of placing concrete	by hand
H) Degree of super vision	Good
I) chemical admixture	Not used
J) Specific gravity of cement	3.15
K) Specific gravity of Metakaolin	2.6
L) Specific gravity of Fly ash	2.2
M)Specific gravity of coarse aggregate	2.8
N) Specific gravity of Fine aggregate	2.70
O) Water absorption	
1) Course aggregate	0.5%
2) Fine aggregate	Nil
P) Free surface moisture	
1) Coarse aggregate	Nil
2) Fine aggregate	1.5%

Q) Grading of coarse aggregate is conforming to table 2 of I S 383 and grading of fine aggregate is falling under zone 2.

Target Strength For Mix Proportioning:

$$f'ck = fck + 1.65\ s$$

where, f'ck = target average compressive strength at 28

days,
fck = characteristic compressive strength at 28 days, and
s = standard deviation.From Table I(IS Code), standard deviation, s =5 N/mm2
Therefore, target strength = 35 + 1.65 x 5
= 43.25 N/mm2
The mix proportion obtained from the design:
Cement: 413 kg/m3
Fine Aggregate: 681 kg/ m3
Coarse Aggregate: 1203 kg/ m3
Water : 186kg/ m3
In the normal ratio the proportion is
Cement: 1
Fine Aggregate: 1.63
Coarse Aggregate: 2.89
Water : 0.479
For a cube of dimensions 150mm x 150mm x 150mm the material proportion is taken as below
1x+1.63x+2.89x+0.479x = 8.25
5.999x = 8.25
X = 1.37
Therefore, the proportion for one cube of size 150mm x 150mm x 150mm is
Which is also called as control mix
Cement: 1.375
Fine Aggregate: 2.241
Coarse Aggregate: 3.97
Water : 0.658

III. EXPERIMENTAL WORK

3.1. MIX PROPORTIONS:

For each percentage 2 sets of cubes and 2 sets of cylinders and two sets of beams were casted i.e. For 7 days and 28 days. For 15% replacement of Metakaolin to cement the proportion for 1 cube of dimensions 150mm x 150mm x 150mm is
Metakaolin: 0.206
Cement: 1.169
Fine Aggregate: 2.241
Coarse Aggregate: 3.97
Water: 0.658

Figure 1. Ingredients used in the present work

For 30% replacement of fly-ash to cement the proportion for 1 cube of dimensions 150mm x 150mm x 150mm is
Fly Ash: 0.412
Cement: 0.962
Fine Aggregate: 2.241
Coarse Aggregate: 3.97
Water: 0.658
For 15% Metakaolin and 30% fly-ash replacement to cement the proportion for 1 cube of dimensions 150mm x 150mm x 150mm is
Metakaolin: 0.206
Fly Ash: 0.412
Cement: 0.757
Fine Aggregate: 2.241
Coarse Aggregate: 3.97
Water: 0.658

3.2 TESTING:

Test for Compressive Strength of Concrete
On the date of testing i.e., after 7 days and 28 days of using the cube specimens were removed from the water tank and placed on flat surface for 10 minutes to wipe off the surface water and grit, and also removes the projecting fines on the surface of the specimens. Before placing the specimen in the testing machine the bearing surfaces of the testing machine was wiped clean, and the cube specimen also cleaned. The cube specimen was placed in the machine, of 2000kN capacity. The load was applied at a rate of approximately 140 kg/cm /min until the resistance of the specimen to the increasing load can be sustained. The compressive strength of the specimen was calculated by dividing the maximum load applied on the specimen during the test by the cross sectional area of the specimen for which average of three values of three cubes and the individual variation is more than ±15% of the average was observed. The test results for compressive strength are presented for M40 grades of concrete at room temperature for 7 and 28 days respectively.
Immediately after removal of cylinder specimens kept on the surface, water and grit shall be removed from the surfaces, which are to be in contact with the packing strips and the bearing surfaces of the testing machine was wiped clean.
The cylinder specimen was placed horizontally in the cantering with packing skip (wooden strip)/or loading pieces carefully positioned along the top and bottom of the plane of loading of the specimen. The wooden pieces were placed on top of the cylinder and bottom of the cylinder, so that the specimen is located centrally, all these arrangements are shown in Plate 3.4 .The load was applied without shock and increased continuously at a nominal rate within the range 1.2 N/mm2/min to 2.4 N/mm2/min until failure of the specimen. The maximum load applied was recorded at failure. The test results for split tensile strength are presented M40 grades of concrete at room temperature for 7 and 28 days respectively.
Then the split tensile strength fct of the specimen was calculated by using the following formula.

$$fct = \frac{2P}{(\Pi x L x d)}$$

Where P = Maximum load in Newton's applied to the specimen.
L = Length of the specimen in mm
d = Cross sectional dimension of the specimen in mm
The prism specimens were removed from the water tank on 7th day and 28th days placed for 10 minutes to wipe off the

surface water. The dimensions of each specimen were noted before testing. Before placing the specimen in the testing machine the bearing surfaces of the supporting and loading rollers were wiped off clean and any loose sand or other material was removed from the surfaces of the specimen. The specimen was placed in the machine in such a manner that the load was applied to the uppermost surface as cast in the mould, along two lines spaced 13.33cm apart. The axis of the specimen was carefully aligned with the axis of the loading device. The load was applied through two similar steel rollers, 38mm in diameter, mounted at the third points of the supporting span that is spaced at 13.33cm centre to centre. The load was applied without shock and increased continuously at a rate of 180 kg/min until the specimen failed. The maximum load applied to the specimen during the test was recorded. The appearance of the fractured faces of concrete and unused features in the type of failure was noted.

(i) if a> 13.33 cm

$$fb = \frac{(p\,x\,l)}{(b\,x\,d^2)}$$

(ii) if a< 13.33 cm

But a < 11.0 cm

$$fb = \frac{(3p\,x\,a)}{(b\,x\,d^2)}$$

Where b = measured width in cm of specimen.

d = length in cm of the span on which the specimen

L = length in cm of the span on which the specimen, and

P = maximum load in kg applied to the specimen.

IV. RESULTS AND DISCUSSIONS

In this section the results obtained from the test procedures are presented in tabular form as well as in graphical representation for deriving proper conclusions

Table 4.1 Average compressive Strength for both 7 days and 28 days

MATERIAL	AVERAGE COMPRESSIVE STRENGTH OF CUBES FOR 7 DAYS(N/mm^2)	AVERAGE COMPRESSIVE STRENGTH OF CUBES FOR 28 DAYS(N/mm^2)
Control Mixing	25.24	46.01
15% replacement of MK to Cement	31.56	51.84
30% replacement of Fly ash to Cement	19.6	40.39
15% MK and 30% Fly ash replacement of cement	24.24	44

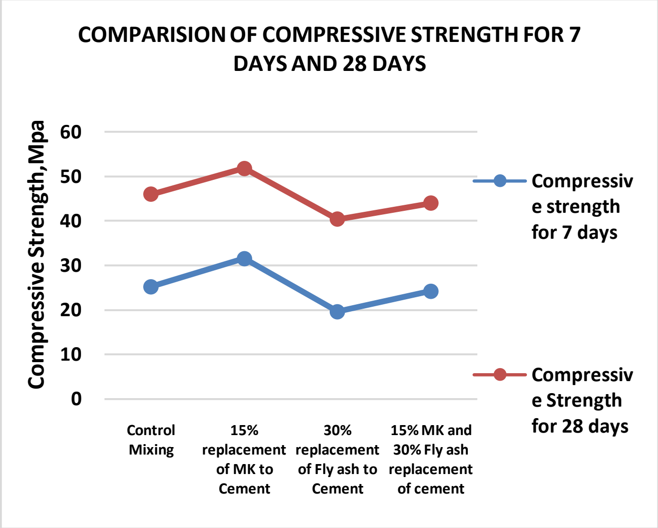

Figure 4.1 Comparison of Compressive Strength for 7 and 28 days

Table4.2 Average split tensile Strength for both 7 days and 28 days

MATERIAL	AVERAGE SPLIT TENSILE STRENGTH OF CYLINDERS FOR 7 DAYS(N/mm^2)	AVERAGE SPLIT TENSILE STRENGTH OF CYLINDERS FOR 28 DAYS N/mm^2)
Control Mix	2.2	3.5
15% replacement of MK to Cement	2.55	4
30% replacement of Fly ash to Cement	1.7	3.2
15% MK and 30% Fly ash replacement of cement	2.1	3.3

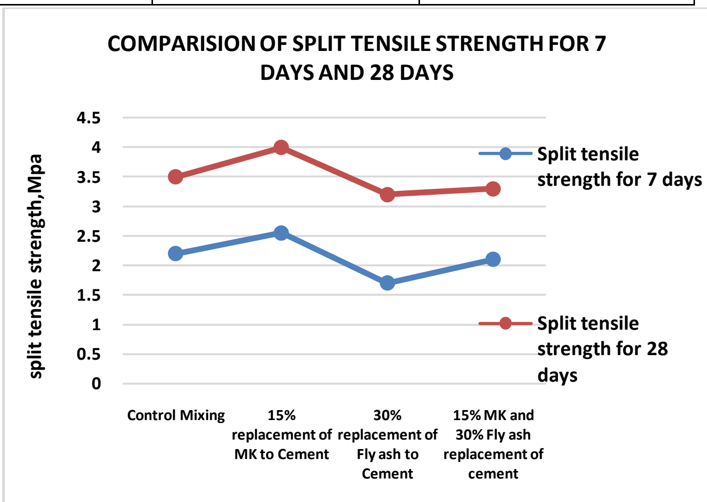

Figure 4.2 Comparison of Split tensile Strength for 7 and 28 days

Table 4.3 Average flexural Strength for both 7 days and 28 days

MATERIAL	AVERAGE FLEXURAL STRENGTH FOR 7 DAYS(N/mm2)	AVERAGE FLEXURAL FOR 28 DAYS N/mm2)
Control Mixing	3.11	4.86
15% replacement of MK to Cement	3.44	5.16
30% replacement of Fly ash to Cement	2.70	4.55
15% MK and 30% Fly ash replacement of cement	3	4.75

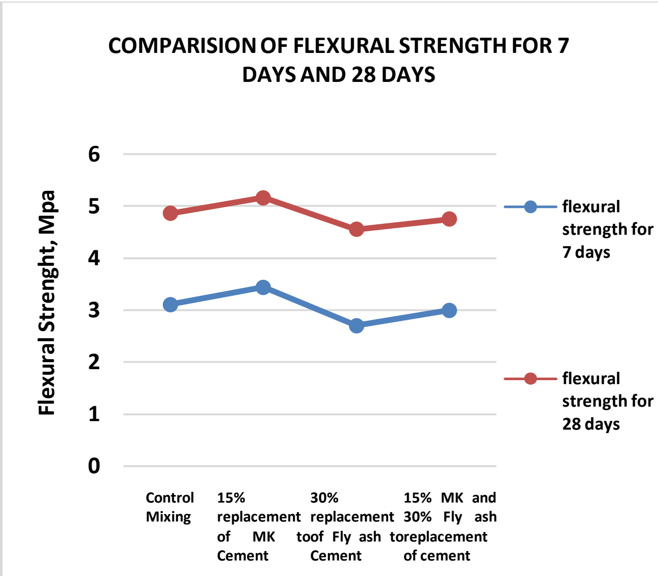

Figure 4.3 Comparision of flexural strength for both 7 days and 28 days

From the above tables and graphs it was clearly understood that at 15% replacement of cement with Metakaolin in addition to 15%replacement of cement with Fly ash for M40 grade of concrete has yielded maximum strengths. This trend was observed for compressive strength, split tensile strength and flexural strength of concrete for M40 grade

V. CONCLUSIONS

The concrete specimens such as cubes for compressive strength, cylinders for split tensile test, and prisms for flexural strength were tested in laboratory with 7 days and 28 days of curing with varying percentages of Metakaolin and Fly ash. The compressive strength of concrete increased when cement is replaced by Metakaolin as well as fly ash for M40 grade of concrete. At 15% replacement of cement with Metakaolin in addition to 15%replacement of cement with Fly ash for M40 grade of concrete has yielded maximum strengths. This trend was observed for compressive strength, split tensile strength and flexural strength of concrete for M40 grade. This paper confirms that partial replacement of Portland cement by 30% fly ash leads to serious decrease in compressive strength when compared to a reference mix of 100% Portland cement. The use of 30% fly ash and 15% Metakaolin based mixtures are responsible for minor strength loss.

REFERENCES

[1] IS 10262 – 2009, for mix design procedure
[2] IS 456 – 2000, Indian standard guidelines for information on concrete
[3] M.S.SHETTY concrete technology
[4] Mandel, J. A. and Said, S. (1990), Effect of the addition of an acrylic polymer on the mechanical properties of mortar, ACI Materials journal, 87(1), 54-61.
[5] Kim, J.-H., Robertson, R. E. and Naaman, A. E.(1995), Structure and properties of poly (vinyl alcohol)-modified mortar and concrete, Journal of Cement and Concrete research, 29, 407-415.
[6] Aggarwal, L. K., Thapliyal, P.C. and Karade, S. R.(2007), Properties of Polymer modified mortars using epoxy and acrylic emulsion, Journal of Construction and Building Materials, 21(2), 379-383.
[7] Muthukumar, M. and Mohan D.(2005), Studies on furan polymer concrete, Journal of Polymer Research, 12, 231–241.
[8] Joshua, B.K.(1997),Polymer modified concrete: Review, Journal of materials in Civil Engineering, ASCE,85-92.
[9] Wahby, W. S.(2003), Fifty years' history of polymer in concrete in Review, ACI International, Publication-SP 214-2, 13-14.

