EFFECT OF METAKAOLIN AND FLY ASH ON PROPERTIES OF CONCRETE

A

PROJECT REPORT

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Under the supervision

Of

Dr. ASHISH KUMAR

(Professor)

by

PANKAJ SANKHYAN (141658)

RAHUL VERMA (141659)

SUMIT DHANKHAR (151649)

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

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STUDENT'S DECLARATION

We hereby declare that the work presented in the Project report entitled "EFFECT OF METAKAOLIN AND FLY ASH ON THE PROPERTIES OF CONCRETE" submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of our work carried out under the supervision of (**Dr. Ashish Kumar**). This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

Pankaj Sankhyan

141658

Signature of Student

Rahul Verma

141659

Signature of Student

Sumit Dhankhar

151649

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

Date: __ May 2019

CERTIFICATE

This is to certify that the work which is being presented in the project report title " EFFECT OF METAKAOLIN AND FLY ASH ON THE PROPERTIES OF CONCRETE" in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Wakhnaghat** is an authentic record of work carried out by **Pankaj Sankhyan (141658), Rahul Verma (141659) and Sumit Dhankhar (151649)** during a period from July, 2018 to May 2019 under the supervision of **Dr. Ashish Kumar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date:

Signature of Supervisor	Signature of HOD	Signature of
Dr. Ashish Kumar	Dr. Ashok Kumar Gupta	External
Professor	Professor and Head	
Department of Civil Engineering	Department of Civil Engineering	
JUIT, Waknaghat	JUIT, Waknaghat	

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Abstract

Concrete is the construction material which is used frequently all over the world. It is widely used in infrastructure projects. It is made by mixing cement, water, inert matrix of sand and gravel undergoes several operations such as transportation, placing, compacting, finishing and curing. The ingredients contains active materials like cement, water and inactive materials comprising of fine and coarse aggregates. Metakaolin is used instead of cement in the year 1960 and working with this material has increased in recent years .It has has various pozzolanic properties which brings positive effects on resulting properties of concrete. These properties cause chemical reaction of active components with calcium hydroxide, which is formed as a product of cement hydration. Fly ash and Metakaolin are used as replacement of OPC

Keywords: - Ordinary Portland cement, Metakaolin ,Fly ash.

Chapter 1
Introduction

1.1 General

Concrete is the most usually used construction material. Concrete is substantially used in infrastructure projects. The concrete received with the aid of mixing cement, water and an inert matrix of sand and gravel undergoes several operations which include transportation, placing, compacting, finishing and curing. The ingredients consist of active materials like cement, water and inactive materials comprising of fine and coarse aggregates.

A nicely designed concrete mix ought to have minimum feasible cement content without sacrificing the strength to make it a cost-effective blend. The water-cement ratio is the most crucial factor in concrete mix design which directly affects the strength of concrete. Other important factors are aggregate to cement ratio, grading of aggregate, shape, and texture of aggregate particle and amount of entrained air. The properties like durability, workability, etc. are vital performance parameters of concrete. This has brought about the paintings which turned into first of all restrained to high strength Concrete (HSC), then extended to Concrete (HPC). HPC mix is designed with mineral and chemical admixtures along with different everyday components of concrete having a low water-cement ratio.

Pozzolanic materials basically includes fly ash, Metakaolin, slag, Rice Husk Ash and silica fume which are used from past many years instead of cement to improve the workability and strength. Metakaolin helps in reduction of sulphate attack and helps in improving air void network. It helps in improving very small structures of concrete and it's chemistry of hydration products by consumption of calcium hydroxide (CH) which is released and production of additional calcium silicate hydrate (C-S-H). It results in more strength and helps in improving durability.

Metakaolin is used instead of cement in the year 1960 and working with this material has increased in recent years. It has various pozzolanic properties which brings positive effects on resulting properties of concrete. These properties cause chemical reaction of active components with calcium hydroxide, which is formed as a product of cement hydration. Fly ash and Metakaolin are used as replacement of OPC

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Metakaolin

Metakaolin is the effective pozzolanic that is used in concrete. This product is produced when china clay, is heated at very high temperature i.e.- 600 to 800 degree Celsius. The size of Metakaolin is smaller than cement particles which has range from 1 to 2 µm. Metakaolin increase flexural and compressive strength. It increases durability and resistance to chemical attack. It is used for high performance, high strength and lightweight concrete. Metakaolin basically reduces the shrinkage due to packing of the particle to make concrete more dense.

Fly ash

Fly ash is the coal combustion product which is made up of particulates that is compelled out of coal fired boilers with flue gases. It is the fine powder which is by-product of burning pulverized coal in electric generation power plants. When the fly ash is used in concrete mixture then it improves the strength of the concrete makes it more easier to pump. It is the prime material used in cement based products. There are two type of fly ash i.e.- class F and class C. Fly ash can be used as an admixture and has great workability. It is the non shrink material and helps in reducing crack problems.

Fig. 1.1 Different material used for casting

1.2 Use of mineral admixtures in concrete

- The mineral admixtures like fly ash and Metakaolin have been used in production of concrete from sustainability viewpoint in the recent years. In the present study flyash and Metakaolin have been used as additional materials and their effect on mechanical properties of concrete has been examined.
- Metakaolin is white, amorphous, extraordinarily reactive aluminium silicate pozzolan forming stable hydrates after mixing with limestone in water and supplying concrete with hydraulic properties.
- Fly ash is used to achieve various benefits:

- Reducing cement content to reduce costs
- Improving workability
- Reducing heat of hydration
- Improving durability
- achieving required levels of strength

1.3Need and Objective of the Present Study

1.3.1 Need

The review of literature presented in the chapter 2 reflects that the various studies had been mainly confined to use of fly ash in concretes. A review of previous studies shows that the individual effect of addition of either fly ash or Metakaolin on strength properties of concrete. The look at handling mixed effect of addition of fly ash and Metakaolin only on the flexural and compressive strength of concrete are scarce. Thus, a need was felt for carrying out the present study by using the above material.

1.3.2 Objectives

The basic idea is to discover the effect of partial replacement of cement by Metakaolin and fly ash in different percentage proportions. This help in maintaining assets and retaining ecological stability to fulfil present want of production material in infrastructure improvement region which is growing at alarming rate. Thus the reduction of natural aggregates and cement is very important to meet the future demand which will amplify the utility of waste materials and at the same time minimize the demand for natural aggregates and cement.

The following specific objective has been identified for the present study:

- To analyze the impact of partial alternative of cement through fly ash on compressive and flexural energy of concrete and to examine them with outcomes of plain cement concrete.

1.4 Organisation of Thesis

The entire thesis has been presented in Five chapters. The organization of thesis is as given below:

- **Chapter 1** deals with the introduction to concrete in general, Metakaolin and fly ash as materials, environmental aspect of reducing cement content and strength characteristics. The need, objectives and the scope of work are also stated in this chapter. Finally, the organization of the thesis is presented.
- **Chapter 2** presents the literature reviews related to the present study. The available literature on concrete containing Metakaolin and fly ash is presented in this chapter to establish the need for present study.
- **Chapter 3** presents the experimental program carried out to develop the mixture proportions, various laboratory tests conducted on the materials used in the investigation, Concrete mix design to select the reference mix, Proportioning methods of Metakaolin and fly ash concrete mixes in the form of tables, the mixing procedure, and the curing of concrete cubes and beams and then the testing of hardened concrete are also discussed in this chapter.
- **Chapter 4** deals with the results obtained from the experiment which are presented and discussed in detail in the form of tables and graphs. Discussion on effects of fly ash and Metakaolin on compressible strength is also mentioned.
- **Chapter 5** deals with the summary and the conclusions drawn from present study, followed by future work. The list of references has also been appended with.

Chapter 2

Literature Review

2.1 General

This chapter deals with the review of the published literature on concrete containing fly ash. Its hazards, disposal, environmental aspects, and utilization are also discussed. Structural properties of fly ash concrete and quaternary concrete containing fly ash and Metakaolin have been reviewed in brief and emphasis has been laid on flexural strength of concrete containing fly ash and Metakaolin.

Fly ash concrete is obtained by replacing a part of cement by an appropriate amount of fly ash in the concrete. In area of high performance concrete (HPC), major advancements have been largely observed with the incorporation of mineral admixture like fly ash. The use of Metakaolin in addition with fly ash has proved effective in enhancing the mechanical properties of fresh and hardened concrete to a great extent. Addition of Metakaolin improves the strength, durability and packing density of concrete, which leads to its improvement in resisting chemical attack, permeability etc.

2.2 Review of previous studies on properties of fly ash concrete

Davis (1937) investigated different properties of fly ash as Pozzolans and found that:

(i) Fly ash varies in detailed chemical composition the main difference, as far as effect on concrete is concerned being its carbon content. It was also found that particles of fly ash are spherical and finer than that of cement particles.

(ii) Fly ash exhibits Pozzolanic properties. Also fly ash of low carbon content and high fineness is used as a 30% replacement of cement in concrete which is standard moist cured at a temperature of 27+ /- 2 degree Celsius and 60% relative humidity. (iii) Fly ash under moist curing conditions may be in as high as 50% replacement. (iv) The results obtained are most favourable, if fly ash with cement of normal or high fineness or high lime content is used.

(v) If fly ash is integrated with cement, very good results are obtained and higher early strength concrete is obtained.

(vi) Fly ash retard the setting time, but this remains within specified limits & water reducing agents are more effective in concrete with fly ash than without it.

(vii) Fly ash can be used in excess of amount of cement replaced and as such, excess can then be considered as replacing the sand, thus permitting a reduction in the amount of sand.

Davis further found the properties of concrete containing fly ash with relatively less carbon content and high fineness as compared to concrete which contains no fly ash are affected as follows:

(i) With the decrease in carbon content and increase of fineness of fly ash, the water demand decreases.

(ii) Improved workability and reduced tendency to segregation and bleeding.

(iii) For a 30% replacements and standard curing, the early strength is less than control concrete but becomes higher after 3 months.

(iv) Under moist curing conditions. The strength of fly ash concrete is higher than that of plain concrete even at the age of 28 days.

(v) Increased final compressive energy isn't laid low with growth in cement content of blend. Also, modulus of elasticity is not affected much. It is lower at lower ages and higher at later ages.

(vi) Shrinkage and autoclave expansion is reduced.

(vii) Resistance to sulphate and also to freezing thawing is increased.

(viii) Heat of hydration is reduced.

(ix) Permeability and leaching arc reduced.

(x) Plastic flow at early ages is more and is less at later.

Berry et al. (1986) said that the fly ash concrete enables in reducing bleeding and segregation and is extra nice whilst located with the aid of pumping than undeniable concrete placed underneath comparable situations. In keeping with Singh, et al."Diffusion received from fly ash changed into solid. Because the water content material changed into low in HVFC the bleeding become more low and insignificant.

Ravina & Mehta (1986) investigated the reaction of changing 35 to 50 % of cement through fly ash, on the compressive strength of bare concrete mixes the usage of ASTM class F and ASTM class c fly ash. Exams consequences showed that, in comparison concrete with 35 to 50% replacement with fly ash reached the required power at 35 to 170 days, depending at the replacement percent along with various properties of fly ash.

Berry et al. (1986) suggested that each the strength at a specified age and the rate of electricity advantage of fly ash concrete have been stricken by the characteristics of the fly ash (properties, chemical composition, particle length, reactivity), the use of cement, amount of each used in the concrete along with the temperature and sanative situation and existence of different components.

Parrott (1987) Suggested the specific rate where concrete carbonates become a function of the many factors such as level of compaction, CO2 awareness, time of wet curing, permeability, and the mass of calcium hydroxide available for response of the central element which is further used to restriction the carbonation rate which is W/CM. W/CM further reduces the depth of carbonation. The system which are sluggish including fly ash have greater benefit than prolonged moist curing because the cement in inner surface layers stop hydrating if inner humidity will drop to 80%. It results in porosity and permeability and further, expands the cost of CO2 diffusion.

Lame (1989) investigated the impact of changing cement (0 to fifty five percent) via the fly ash, he took 3 types of concrete mixes along with water- cementations cloth ratio of zero.3, zero. four, zero.5 respectively and came to the point that fly ash provided little strength very fast. At three days, in comparison to Portland cement concrete, the compressive strength decreased in way of sixteen% in average for a fifteen percent fly ash substitute, 66% for fifty five% fly ash replacement. At twenty eight days, the strength of fly ashes mixes was little lower (four% in common) than Portland cement mixes,55% fly ash substitute nonetheless resulted in a 44% reduction in strength. Later, fly ash contributed to compressive energy development became giant.

Reddy et al. (1994) suggested the various results of fly ash, received by Nellore Thermal strength Station, on 6 sparse concrete mixes substitute tiers of ten, twenty, thirty, forty and fifty percent and concluded that if the strength of fly ash concrete was much less than reference concrete in course of the starting length of twenty days, it become more at some stage in the following length reaching ninety percent of the reference blend at the age of ninety days.

Naik et al. (1994) investigated the result of supply and quantity of fly ash on strength and endurance houses of concrete. Mechanical houses are known to have been compressive strength, tensile electricity, flexural electricity, and modulus of elasticity. They concluded that during preferred power and durability residences of concrete had been appreciably stricken by two of fly ash source and amount of fly ash. in addition, electricity and sturdiness properties for the forty% fly ash mixture have been both similar or superior to the no fly ash concrete. "The salt scaling resistance of fly ash concrete turned into either akin to or better than no —fly ash concrete"; besides for source of fly ash at 60% cement alternative degree. Every combination, with and without fly ash, examined in this investigation confirmed to the power and durability requirements of terrific exceptional structural grade concretes. They also investigated the compressive energy and abrasion resistance of concrete by means of replacing cement with fly ash upto 70%. They mentioned that compressive strength as well as the abrasion resistance of the concrete decreased with increase in proportion of fly ash.

Malhotra et al. (1994) said that the particular amount of water is needed for working of mortar and concretes, is dependable on carbon content material of fly ashes; Better the carbon content material, better the need of water for production of a paste of everyday firmness and better carbon content material (two-ten%) was very commonplace for low – calcium fly ashes. they have got explained that the homes of fly ash had been suffering from the great of coal fire inside furnace and combustion manner. The result declared that the carbon which was not burnt carbon in fly ash (with the aid of loss on ignition), changed into the critical guidelines of the evaluation of the excellent fly ash. Langley and Leaman, (1998) elaborated Plastic shrinkage changed into a capability problem of HFVA concrete. quantity of bleed water accessible for evaporation of HVFA concrete changed into low because of low unit water content material, consequently it was considered that the curing of HVFA concrete will be started very fast when concrete was put to restriction the amount of evaporable water and decrement in plastic shrinkage.

Mehta (1998) investigated that as a way to recognize the usage of fly ash in concrete, the physical manifestations of various types of chemical reactions that should be taken into consideration. There are various properties of concrete which are prompted by means of many things. one very important element was turned into the power residences at interfacial bond became the area of transition in the Portland cement turned in weak due to large and big crystals of Ca(0H)2, which locate area here because of effect of wall next to the coarse debris.

Rangaswamy (1999) investigated in India country wide mission on fly ash utilization and disposal have been initiated underneath the aegis of department of technology and technology. The Andhra Pradesh authorities had directed all thermal power vegetation in the kingdom to deliver fly ash free of price to cement and constructing cloth manufacturers. Reclamation of deserted ash ponds undertaken with the aid of numerous international locations to convert them as parking lots, grazing fields, playgrounds and so forth

Rao et al. (1999) pronounced that the work of fly ash concrete changed into more than that of managed concrete at sixty percent fly ash content. But, the work extended as much as forty% fly ash and then showed moderate lower for fly ash contents onwards. They had in addition suggested that compressive electricity of HVFC for a particular aggregates cement ratio reduced whenever the fly ash extended.

Gopalakrishanan et al.(2001) suggested the energy characteristics of fly ash concrete along with distinctive fly ash alternative tiers and pronounced that fly ash concrete up to twenty five percent substitute degree might deliver the concrete extra durable and corrosion resistant, beside the electricity necessities.

Krishna et al. (2002) suggested that constructive efforts have been made everywhere to use the fly ash regardless of several avenues recognized for ability use of fly ash and attractive incentives provided by means of the authorities, most effective less than five% of ash become placed to use in India , leaving large quantity of flyash in lagoons leading to air water and land pollutants. 10% of modern concrete produced worldwide utilizes flyash . Inchina rate of usage of flyash in hongkong and a few ecru countries like Netherlands and Denmark was very excessive. thus there has been huge potential for the multiplied use of flyash in concrete within the global (Malhotrav. m. . several research institutions like CBRI –Roorkee, CBRI- New Delhi , CPWD, IIT's and so on. Are launching demonstrative projects on flyash usage to create self belief within the attitude customers to promote its bulk utilization. It turned into felt that bulk usage of fly ash turned into possible through the usage of it inside the creation of roads and embankments. Wide unfold reluctance in use of flyash in civil engineering. Applications can be because of the truth that thermal energy plants in India have now not but accorded recognition to backside ash and fly ash as two enormously distinct useful resource materials for different industries.

Singh et al. (2003) said that because of low cement content material there was less heat of hydration, therefore very green in lowering temperature rise and disposing of thermal cracks. He has in addition recommended that fly ash, for the reason that thirty percent lighter than cement, it made concrete greater doable. Normal Portland cement grains have been decumbent to show off few coagulation ensuing non-uniform non-homogeneous structure. In Addition of fly ash dispersed the cement flocks consequently makes greater paste and improving the workability.

Siddique (2003) Mentioned the effects of various research by studying the outcomes of alternative of clement (using mass) with throe % of fly ash and the effects of addition of herbal san fibers at the stoop. Vee Bee time, compressive strengths, Split tensile electricity, flexural power and strength of fly ash fibrous concrete San fibres belong to category of 'natural best fibers" It was typically grown in the Indian subcontinent, Brazil, jap & Southern Africa and some parts of the united states (Hawaii and Florida). A manipulate mixture of proportions 1:1.4.2.19 with W/C of 0.47 and tremendous plasticizer, cementations ratio of 0.1/2 became designed Cement turned into replaced with 3 possibilities (35%, 45% and 55%) of class F fly ash. three percentages of san fibers (zero.25%. 0 50%, zero.75%) having 250mm length were used. The check end result indicated that the alternative of cement with fly ash expanded the workability (stoop and Vee-Bee time), reduced compressive electricity, splitting tensile strength and flexural power and had no massive effect on the impact energy of simple (manage) concrete. Addition of san fibers decreased the workability, did not substantially affect the compressive power, and multiplied the break up tensile and flexural electricity and tremendously massive-impact on energy of fly ash concrete as the percentage of fibber became elevated.

Siddique (2004) mentioned the outcomes of an experimental investigation that was done for sparkling concrete residences; slump, air content, unit weight and changed with three probabilities (forty%, forty five and fifty percent) of sophistication fly ash exams have been performed for fresh concrete residences; droop, air content, unit weight and temperature. Portland cement modulus of t incorporating with concrete alternative of cement in concrete which is further reduced by 28 days compressive test end result proved that the usage of excessive quantity of class F fly ash as a partial elasticity and abrasion resistance had been determined up to 365 days temperature, Compressive strengths, splitting tensile and flexural strengths, modulus of elasticity and abrasion resistance of concrete. however a lot of these electricity properties and abrasion resistance showed consequences non-stop and good sized development at the ages of 91 and 365 days, concrete which was maximum in all likelihood due to the pozzolanic response of fly ash., based on the assessments, it was concluded that magnificence F fly ash can be suitably used upto 50% stage of cement substitute in concrete to be used in precast factors and bolstered cement concrete construction.

Bremner et al.(2004) suggested that concrete mixture which contains fly ash helps in gaining strength at very little/slower rate. In case of concrete without fly ash the strength is higher. When the rate of strength gain of hydraulic cement slows, then continued pozzolanic activity of fly ash helps in providing strength gain later on if the concrete was kept moist; During early ages concrete which contains lower strength have higher strength at later age in comparison to concrete without fly ash as long as concrete is moist to to required quantity. The gained strength gets continued with time and results in much higher age strength. However, by using accelerators, activators, water reducers, or by changing the mixture proportions, equivalent 3 or 7-day strength may be achieved as per (ACI Committee 232, 2003). High calcium fly ashes (Class C) showed a more rapid strength gain at early ages than concrete made with a lower calcium fly ash (Class F) because Class C ashes often exhibited a higher rate of reaction at early ages than Class F ashes.

Mohammed et al.(2011) stated that devouring of regular Portland Cement (OPC) induced pollution in surroundings because of the emission of CO2. The alternative cloth has delivered to update OPC within the concrete. Fly ash changed into spinoff from the coal industry, which was available in large amount inside the world. furthermore, using fly ash changed into extra environmental friendly and stored cost in comparison to OPC. Fly ash turned into wealthy in silicate and alumina, subsequently it reacted with alkaline solution which produced aluminosilicate gel that bind the aggregate to generate a very good concrete. The compressive energy multiplied with the growing of fly ash fineness and accordingly the reduction in porosity could be received. Fly ash based totally geopolymer additionally supplied better resistance against competitive surroundings and expanded temperature in comparison to regular concrete. As a conclusion, the residences of fly ash-based totally geopolymer have been enhanced with few factors that prompted its performance in lots of elements together with compressive strength, publicity to aggressive surroundings, workability and publicity to high temperature.

Gunavant et al. (2013) investigated and said that excessive electricity Concrete changed into made by way of partial replacement of cement by means of fly ash. The shrinkage of excessive electricity Concrete have been studied using the distinct mixes from at least 10% to maximum of 70 %.. The price of boom in shrinkage with time changed into uniform for low fly ash content material, whereas it typically will increase after 28 days for high volume of fly ash and the excessive volume fly ash concrete yielded gradual power development at an early age.

2.3 Previous studies on the properties of Metakaolin based concrete

Wild et al. (1996) investigated the workability of Metakaolin concretes. substitute degrees of "ordinary Portland cement"(OPC) by means of Metakaolin (MK) were 0, 5, 10, 15, 20, 25, and 30% and water-binder ratio (w/b) was 0.45. The proportion of OPC concrete mixture was1:2.3:3.4.Results of working (slump, compacting factor and vebe time are given in Table 2.1

Table 2.1 Workability of Metakaolin concretes

Metakaolin (%)	Super plasticizer (%)	Slump (mm)	Compacting Factor	Vebe time (sec)
0	0	5	0.81	26
5	0.6	10	0.84	15
10	1.2	15	0.88	10
15	1.8	25	0.89	9
20	2.4	75	0.89	7
25	3.0	75	0.89	4
30	3.6	90	0.90	5

Wild et al. (1996) searched about the impact of changing probabilities of Metakaolin on the compressive electricity of concrete combinations. Replacement ranges of ordinary Portland cement (OPC) by way of Metakaolin (MK) have been 0, 5, 10, 15, 20, 25, and 30% and water-binder ratio (w/b) was 0.45. OPC concrete mixture share become 1:2. three: three. four. Compressive electricity exams have been performed till 90 days, and various results are determined in table. The conclusion was drawn that MK as partial alternative of cement enhanced the compressive power of concrete at every age, however the most effective alternative stage of OPC with the aid of MK to provide most long term power enhancement became approximately 20%.

Table 2.2 Compressive strengths and densities of Metakaolin concretes

MK (%)	Density (kg/	Compressive strength (MPa)				
		1 day	7 days	14 days	28 days	90 days
0	2490	19.07	50.23	57.10	62.60	72.43
5	2440	21.50	53.80	58.97	63.50	71.63
10	2460	22.43	62.30	69.23	71.00	80.07
15	2470	20.23	64.80	74.67	76.00	83.70
20	2480	19.33	66.47	75.73	82.47	85.13
25	2470	15.73	62.50	69.77	73.93	82.23
30	2480	14.53	60.53	72.33	76.73	81.80

Brooks et al.(2001) investigated the compressive energy of concretes containing zero, five, ten, and fifteen% Metakaolin (MK). Mixing percentage of OPC concrete became 1:1.5:2.5 along with a water-to-cement ratio of zero.28. 28-day Compressive electricity outcomes of MK concretes are mentioned in table 2.3 it is obtrusive from the table that compressive strength accelerated with the growth inside the Metakaolin content.

Table 2.3 Compressive strengths of MK concrete mixes

Concrete mixes	Compressive strength (MPa)
OPC	87.0
MK5	91.5
MK10	104.0
MK15	103.5

Brooks et al. (2001) reported the slump and setting times of concretes containing 0, 5, 10, and 15% Metakaolin (MK). Control concrete mixture share became 1:1.5:2.five with water binder ratio of zero.28. Droop and putting times consequences are given in table 2.four. It may be visible that hunch decreased and setting instances expanded with the increase in MK content.

Table 2.4 Workability, setting times of MK concretes

Concrete mixes	Slump (mm)	Initial setting time (hours)	Final setting time (hours)
OPC	100	5	7.7
MK5	30	6.42	8.82
MK10	20	6.98	9.42
MK15	5	6.45	9.31

Sabir et al. (2001) investigated the usage of Metakaolin is used as pozzolanic material for urban and referred to as the extensive range software of Metakaolin in various production industries .According to them using Metakaolin as a pozzolana will help inside the improvement in strength and long time power. Metakaolin helps in altering the pore shape in cement paste mortar and concrete and helps in improving the resistance against transportation of water and further diffusion of dangerous ions which results in degradation of given matrix.

Bai et al. (2001) suggested that the effect of composition of Portland cement– pulverized fuel ash–Metakaolin binders on power improvement of computer–PFA–MK concrete helps in curing both in air and water simultaneously. Concrete combinations have been designed with four exceptional cement substitute stages (10, 20, 30 and 40 percent) for laptop–PFA–MK concrete with numerous MK/PFA proportions and helps in curing in water and air as much as eighteen months. In water-cured concrete made with laptop–PFA–MK binder, the MK stronger early (28 days) energy, and PFA retarded early energy. Air-cured concrete confirmed a loss in energy relative to equivalent concrete that became water cured and the power distinction increased with curing duration. The distinction turned into more suitable in concrete that is prepared with pc–PFA binder at excessive replaced with various levels, which showed a miles decreased power benefit with time while air cured, while for computer–PFA–MK concrete, this distinction was reduced because the MK content material increases.

Muthupriya et al. (2011)investigated an experimental investigation on the conduct of excessive performance bolstered Concrete column (HPRC) to assess the suitability of HPRC columns for the structural programs. high overall performance concrete became prepared by partial alternative of everyday Portland cement with Metakaolin and Fly ash. The take a look at outcomes showed improvements in electricity, brittleness and sturdiness. The premier replacement degree for Metakaolin and Fly ash was suggested as 7.five%.they reported that the compressive electricity of high performance concrete containing 7.five% of Metakaolin turned into 12% better than the everyday concrete.

John (2013) Investigated the power residences of Metakaolin admixed Concrete. The outcomes of a have a look at achieved to research the outcomes of Metakaolin on energy of concrete were offered. The referral concrete M30 was made using 53grade OPC and the other mixes have been organized by replacing part of OPC with Metakaolin. The substitute tiers had been five%, 10%, 15% up to twenty %(via weight) for Metakaolin. The diverse effects which imply the impact of replacement of cement by Metakaolin on concrete are provided in this paper to attract beneficial conclusions. The results have been as compared in regards blend. take a look at results suggest that use of substitute cement via Metakaolin in concrete has stepped forward performance of concrete up to 15%.

Chapter 3

Test programme

3.1 General

In the present study an experimental study was undertaken to analyze the impact of partial replacement of cement through fly ash and Metakaolin on flexural strength of concrete. The basic properties of various constituents of concrete such as cement, fly ash, Metakaolin has been presented in this chapter. Concrete mixes detail along with method of casting, curing and testing has also been reported.

3.2 Test programme

The main objective was to check the performance of ternary mix concrete in terms of above parameters and do the comparison with results of plain cement concrete. The testing consisted of following activities

- To decide the properties of constituent materials of concrete like cement, quality mixture, coarse combination as in line with relevant Indian well known Codes of exercise, anywhere relevant used on this investigation.
- To design concrete mix (M30) for selecting reference mix as per IS 10262-2009.
- To proportion ternary concrete mixes incorporating varying percentages of fly ash and Metakaolin.
- To cast and cure specimens.
- To conduct flexural strength test on reference mix and ternary concrete mix containing both fly ash and Metakaolin.

3.3Physical Properties of Materials

The homes of materials that is used in making concrete are driven in lab as according to applicable codes of practice. The various material which are used were cement, fine aggregate, coarse aggregate, water, fly ash and Metakaolin. Laboratory tests were conducted on these materials and their properties were stated in the following sections:

3.3.1 Cement

Ordinary Portland cement (OPC) of 43 Grade (Ultratech) from a single batch turned into used for all the concrete mixes. Cement taken changed into clean and with none lumps with uniformity in its colour. The cement become tested as per IS: 8112-2013 for its normal consistency, preliminary and Finals placing time, specific gravity and compressive energy for three, seven and twenty eight days, the results of various tests conducted are reported in the table 3.1.

Table 3.1 Physical Properties of Cement

Sr. No.	Properties	Experimental value	Specified Value as per IS: 8112-2013
1	Consistency of Cement	30%	-
2	Specific gravity	3.12	3.15
3	Initial setting time	110 minutes	>30 minutes
4	Final setting time	265 minutes	< 600 minutes
5	Compressive Strength (N/mm^2) 3 days 7days 28 days	 30.4 41.16 48.82	 >23 >33 >43

Fig. 3.1 vicat apparatus

3.3.2 Aggregates

“Aggregates are the most valuable elements in concrete. It helps in giving frame to the concrete and helps in reducing and influences financial system. The combination include inert and course materials. first-class combination in concrete helps in generating working and uniformity in aggregate. Further the great combination also helps the paste made of cement to grasp the coarse aggregate particles in suspension. This motion advance plasticity inside the mixture and helps in preventing the segregation of the paste and coarse aggregates. Further, The coarse aggregates are useful usually due to the reason of offering bulk to the concrete. IS: 383-2011 says that the high-quality aggregate are aggregates mostly bypass thru four. Seventy five mm IS sieve. The definition of coarse aggregate is aggregates most of which can be retained on four.75 mm IS sieve".

3.3.2.1 Fine Aggregates

Sand is taken from a neighbourhood quarry near domehar used as best mixture. The sand changed into thoroughly washed to take away dirt and the dried to be used .The sieve evaluation and other tests have been done in the laboratory. The results of sieve analysis are listed in table 3.2, The physical properties of sand are presented in table 3.3.

Table 3.2 Sieve Analysis of Fine Aggregates

IS Sieve Designation	Wt. Retained on Sieve (g)	Cumulative Wt. Retained (g)	Cumulative Percentage Wt. Retained	%age Passing	IS 383-2011 requirement for Zone II
10mm	-	-	0	100	100
4.75 mm	0	0	0	100	90-100
2.36 mm	30	30	3	97	75-100
1.18 mm	100	130	13	87	55-90
600 µ	280	410	41	59	35-59
300 µ	290	700	70	30	8-30
150 µ	210	910	91	09	0-10
Pan	90	1000	-	-	-

Cumulative percentage weight retained =218

Fineness Modulus (F.M.) = $\frac{218}{100}$ = 2.18

Table 3.3 Physical Properties of Fine Aggregates

Characteristics	Results Obtained
Grading	Grading Zone II (IS: 383-2011)
Fineness Modulus	2.18
Specific Gravity	2.63
Water Absorption (%)	0.52 %
Free Moisture Content (%)	2 %

3.3.2.2 Coarse Aggregates

Fraction of size of coarse aggregates, 20mm down and 10mm down obtained from a stone crusher near Domehar are used to make concrete mixtures. The coarse aggregates fractions have been wash to eliminate dust, dirt and then dried to floor dried conditions. Sieve evaluation and other tests were performed in the laboratory overwhelmed stone mixture of 20mm and 10mm length are mixed in 60 :40 equilibrium to meet various requirements of IS 383-2011. The results of sieve analysis are listed given below the physical properties are listed in table 3.4.

Table 3.4 Sieve Analysis of Proportioned Coarse Aggregates

IS Sieve Designation	Wt. Retained on Sieve (10mm Agg.) (g)	Wt. Retained on Sieve (20mm Agg.) (g)	Proportioned Wt. Retained (g)	Cumulative Wt. Retained (g)	Cumulative %age Wt. Retained (g)	%age Passing
80mm	0.00	0.00	0.00	0.00	0.000	100.00
40 mm	0.00	0.00	0.00	0.00	0.000	100.00
20 mm	0.00	9.00	5.40	5.40	0.108	99.890
10 mm	738.00	4891.00	3229.80	3235.20	64.704	35.290
4.75 mm	4200.00	92.00	1735.20	4970.40	99.408	0.5920
Pan	62.00	8.00	29.60	5000.00	-	-

Fineness Modulus (F.M.) = $\frac{108 + 64.704 + 99.408 + 500}{100}$ 0.= 6.64

Table 3.5 Physical Properties of Coarse Aggregates

Characteristics	Value
Colour	Grey
Type	Crushed
Shape	Angular
Specific gravity	2.65
Water absorption	1%
Fineness modulus	6.64
Moisture Content (%)	Nil

3.4 DESIGN OF CONCRETE MIX

The concrete mix must be designed to offer the maximum low-priced and sensible proportions of the substances, on the way to produce essential workability in sparkling concrete and required qualities inside the hardened concrete. for this reason, the combination design become executed to rationalize diverse parameters in the application of concrete. mix design allows to know correct enter of cement, aggregates, and water to cement ratio to reap the preferred workability and energy, all culminating in techno-monetary optimization associated with feasibility. In pursuit of the purpose of acquiring concrete with positive preferred performance traits, the choice of element materials is the first step; the subsequent step is a method known as mix design with the aid of which one arrives on the proper aggregate of the additives.

3.4.1 Mix Design by Indian Standard Recommended Guidelines

Present examine consists of design of concrete mix (non-air entrained) for medium electricity concrete. Precise relationships, charts, graphs which can be given on this approach of blend layout had been evolved from widespread experimental research on the cement research institute of India as well as on the premise of data on concrete being designed and produced within the country. The guidelines given in various codes like IS: 10262-2009 and IS: 456-2000 have been adopted for mix design of concrete.

3.4.1.1 Design Stipulation

- Characteristic strength of concrete at 28 days (f_{ck}) 30 N/mm^2
- Maximum Nominal Size of Crushed Aggregate 20 mm
- Degree of Workability (Slump value) 75 mm
- According to IS: 456-2000 the value of Statistical coefficient (k) 1.65
- According to IS: 456-2000 the value of Standard Coefficient (S) 5.00
- Type of Exposure Moderate

3.4.1.2 Characteristics of the materials

- Cement Used OPC
- Specific Gravity of Cement 3.12
- Specific Gravity of Coarse Aggregate 2.65
- Specific gravity of Fine Aggregate 2.63
- Water Absorption of Coarse Aggregate. 1 %
- Water absorption of Fine Aggregate 0.52 %
- Free Surface Moisture of Coarse Aggregate 0.00 %
- Free Surface Moisture of Fine Aggregate 2 %
- Sieve Analysis of Coarse Aggregate Conforming to Table 2 of IS: 383-2011
- Sieve Analysis of Fine Aggregate Conforming Grading Zone II of IS: 383-2011

3.4.1.3 Target Mean Strength of Concrete

Target mean strength is given by $ft = fck + KS$ eq. (1)

Where ft = Target mean strength at 28 days. fck = Characteristics compressive strength at 28 days.

S = Standard coefficient.

K= statistical coefficient.

Target Mean Strength of Concrete, ft = 30 + 1.65 x 5.00 = 38.25 N/mm^2

3.4.1.4 Selection of Water Cement Ratio:

- Water Cement Ratio for Target Mean Strength 0.43
- Maximum Water Cement Ratio from Durability consideration
  (As per code IS 456-2000) 0.50
- The lower value of above two W/C ratios is selected 0.43
- To fix the Right W/C Ratio, Preliminary Trails has to made by
  Varying the W/C Ratio 10%
- Therefore W/C Ratio for trails is 0.43

3.4.1.5 Selection of Water:

- Water Content for per Cubic meter of Concrete 186 kg
- From table 2 of IS: 10262:2009 maximum water content for 20mm aggregates is 186kg

Estimated water content for 75mm slump is $=186 + \frac{3}{100} \times 186$=191.58 L

3.4.1.6 Determination of Cement Content:

- Water Cement Ratio = 0.43
- Quantity of Water = 191.58 L
- Cement Content = 162.84 / 0.43

  = 379 kg/m^3
- Minimum Cement Content Required for Moderate Exposure = 300 kg/m^3

  (As per code IS 456-2000) Hence okay.

3.4.1.7 Proportion of volume of coarse aggregate and fine aggregate.

From table 3 of IS: 10262:2009, volume of coarse aggregate corresponding to 20mm size aggregate (zone II) for water- cement ratio = 0.5 is 0.62

Volume of coarse aggregate has to increase to decrease fine aggregate content at the rate of -/+ 0.01 for every +/- 0.05 change in water-cement ratio.

Therefore corrected volume of coarse aggregate is 0.634

And volume of fine aggregate is = 1- 0.634 = 0.366

3.4.1.8 Mix Calculations

The mix calculations per unit volume of concrete is as follows

1. Volume of concrete = $1m^3$
2. Volume of cement $\frac{\text{Mass of cement}}{\text{Specific gravity} \times 1000} =$ eq. (2)

   =379/(3.15x1000)=0.1203 m^3

   $= \frac{\text{Mass of water}}{\text{Specific gravity of water} \times 1000}$
3. Volume of waters =0.1628 m^3 eq. (3)

4. Volume of chemical admixture $= \frac{\text{Mass of chemical}}{\text{Specific gravity of admixture} \times 1000}$ eq. (4)

(@0.7% by mass of cementations Material) $= \frac{2.653}{1.2 \times 1000}$

$= 0.0022\ m^3$

5. Volume of all in aggregate =[1-(2)+(3)+(4)]

= 1-(0.113+0.163+0.003)

=0.7147 m^3

The fine and coarse aggregate contents per cubic meter of concrete are calculated from codal provision and the results are as follows:-

- Fine Aggregate Content in Total Volume of Concrete FA = 687.85 kg/m^3
- Coarse Aggregate Content in Total Volume of Concrete CA = 1200.68 kg/m^3

CA 10mm = 480.27 kg/m^3

CA 20mm = 720.41 kg/m^3

Correction of moisture and water absorption

Corrections for moisture and water absorption were applied and corrected water content is reported in Table 3.11 as follows:

Table 3.6 Corrected water content after corrections.

Material	Initial Quantity (kg)	Free Surface Moisture(%)	Absorption (%)	Revised Quantity (kg)	Extra Water (L)
CA 10	480.27	-	1%	475.47	4.80
CA 20	720.41	-	1%	713.21	7.20
FA	687.85	2%	0.52%	698.09	-10.24
				Total	1.76
				Revised Water Content	193.34

The revised quantities of materials after making corrections in aggregates and water content are given below

Table 3.7 The estimated actual mix proportion for one cubic meter of concrete

Water (L)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	
			10 mm	**20 mm**
193.34	379	698.09	475.47	713.21
0.51	1	1.84	3.136	

.0

3.4.1.9 Mix Design Report

Taking mix design concrete into consideration by way of IS approach, three trial mixes have been organized along water cement ratio of 0.forty three, casting 6 cubes for every blend and were examined at seven days and twenty eight days. Compressive strength, barely extra than goal mean strength (38.25 N/mm2) became finished for trial blend no. three of table 3.thirteen and particular mix was taken into the consideration for this study. There are various constituent mixes that are summarized in table 3.13.

Table 3.8 Trial Mix for M30 Grade

Trial Mix.	W/C Ratio	Water (L)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
Mix 1	0.41	167	408	627	1273
Mix 2	0.45	176	391	754	1133
Mix 3	0.43	165	385	719	1149

From the test results of trial mix 1, 2 and 3 as shown in table 3.14, suitable target mean strength of 38.48MPa is arrived with trial mix 3 at w/c ratio of 0.43. So trial mix 3 with cement content 385 Kg/m^3 was adopted for study. As a consequence the proportions of diverse components (by weight) of reference mix (M0) are mentioned below:

Table 3.9 Test Results of Compressive Strength at 28 days

Sr No.	Grade of Concrete	Trial Mix	Load at Failure (ton)	Cube Compressive Strength(f_{ck}) (N/mm^2)	Average Compressive Strength(N/mm^2)
1	M30	Mix 1	93.73	41.66	40.23
			92.54	41.13	
			85.27	37.9	
2	M30	Mix 2	68.85	30.60	32.36
			73.03	32.46	
			87.8	34.02	
3	M30	Mix 3	76.54	38.52	38.48
			87.77	39.01	
			85.29	37.91	

Table 3.10 Proportioning of reference mix adopted (M0) for 1m^3 of mix

Water (liters)	Cement (kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)
165	385	719	1149
0.43	1.00	1.87	2.98

The quantity of cement 385 kg/m^3 also satisfies the IS code 456-2000 requirements of minimum cement content.

3.5 Proportioning of ternary mixes

Flyash, Metakaolin composites contain cement, fine aggregate, coarse aggregate, water, fly ash and Metakaolin. In the mix, the major variables that control strength and workability are cement content, maximum aggregates size, gradation (size distribution), the presence of entrained air, fly ash. Generally, mix designs focuses on target mean strengths, ignoring durability considerations. However, IS: 456-2000 has given emphasis on durability consideration. Fly ash supplements the quantitative requirements of cementations input in a mix design, controlling simultaneously the heat of hydration and surplus free lime. Chemical admixture may bring down the W/C or increase the slump, but certainly cannot participate in hydration chemistry. Whereas, fly ash has direct role in the chemistry for mineralogy improvement. Being comparatively cheaper than cement, concrete mixes have been used as the partial different material. Various investigations showed that for the optimum use of fly ash, it need to be proportioned in concrete on the basis of economic system and equal energy requirements.

Thomas has stated that it is possible to proportion fly ash mixes for strength equivalent to that of 28 days strength of control mixes by using fly ash quantity in excess of quantity of cement replaced. As per Smith and Raba, it is possible to design fly ash concrete mixes of equal strength in controlled concrete without fly ash and covering a strength range of up to 50 N/mm^2 at 28 days. Smith formulated method of design of orthodox concrete on the basis of extensive experimental investigations on concrete with fly ash from over twenty-five generating stations. This method can be applied equally well to those concrete in which fly ash replaced the cement.

3.6 Detail of mixes

In the present study, cement was replaced by fly ash on equal weight basis. The sand was kept the same as that in the original plain concrete mix. The limited replacement of cement by fly ash was done in different % that is 15%, 20% and 25% on equivalent weight basis. The Metakaolin added to fly ash mixes in various % by doing weight of cement to replace fly ash that is 5%, 10% and 15% to get ternary mix containing fly ash and Metakaolin. The details of all the mixes are described below:

M0 - Reference mix

M1-25% replacement of cement by fly ash and 5% by incorporating Metakaolin

M2 -20% replacement of cement by fly ash and 10% by incorporating Metakaolin

M3 - 15% replacement of cement by fly ash and 15% by incorporating Metakaolin

Table 3.11 Mix proportions for different specimens per cubic meter ternary mix containing fly ash and Metakaolin.

Sr. No.	Mix designation	Cement (C) in kg	Water (W) in L	Fine aggregates (FA) in kg	Coarse aggregates (CA) in kg	Fly ash (FA) in kg	Metakaolin in kg
1	M0	385.00	165	719	1149.0	0	0
2	M1	269.5	165	719	1149.0	96.25	19.25
3	M2	269.5	165	719	919.2	77	38.5
4	M3	269.5	165	719	689.4	57.75	57.75

3.7 Moulds for specimens

Standard beam moulds of size 100mm X100mm X500mm build up of cast iron is helpful and used in preparation of specimens to determine flexural power of that concrete.

3.7.1 Mixing

The material was weighted in batches in required proportions given as per Table 3.16 and was put into the mixer. Some quantity of water is added slowly to get a uniform mix. All the moulds were cleared and applied with oil on the inner faces well before concreting operation for casting of specimen so that oil may not affect concrete ingredients. Those had been tightened carefully to accurate dimensions before casting. Special care was taken that cement slurry should not leak.

3.7.2 Batching, Casting and Curing of Specimens for Compressive Strength

As per IS: 516-1959 (reaffirmed 1999), the complete procedures were adopted in the making and casting operations. The cement and coarse aggregates (20 mm size), fine aggregate, fly ash, Metakaolin and amount of water put for every batch is for distinctive percent of fly ash replaced with varying percentage of Metakaolin was weighed accurately. The aggregates were put into the mixer and over that cement, fly ash and Metakaolin were added, mixer started to rotate to mix the dry ingredients. Then water was added carefully and mixer was started to rotate again, till the time the concrete appeared in homogenous and of the needed consistency as shown in Plate No. 3.2. The prepared concrete was then out from rotating drum into M.S. Plate. Then concrete fill inside the previously prepared in three layers. Electric vibrator was used for compaction of concrete. Vibrations had been interrupted as quickly as the emergence of cement slurry pinnacle surface of mold. The floor of the concrete become completed stage with the top of the mold the use of a trowel and marked properly to indicate the mix proportions date of casting etc. as shown in Plate No. 3.3. The leftover specimen were left to harden more. The specimens is removed from the moulds after casting for 24 hours. Then they had been placed inside the water tank packed along the potable tap water inside lab for curing till the time testing is done completely. For plain cement concrete specimens, no fly ash and Metakaolin was added to the mix and all the specimens for a particular testing age were cast in one batch. The specimens for fly ash concrete replacing by fly ash and incorporating Metakaolin with varying percentages of fly ash and Metakaolin were cast in separate batches. The procedure was adopted to ensure uniform properties of the specimens in each batch. 6 Specimens of each mix were prepared out of which three were tested after seven days and three were tested after period of twenty eight days for each mix.

Fig .3.2: Mixing of materials in the mixer

Figure 3.3: Preparing of specimen For Flexural Strength

3.8 Testing of specimens

Flexural strength test have been carried out on the beam specimen:

Fig. 3.4 Testing of specimen

Fig.3.5 Specimen after curing

3.8.1 Flexural Strength

The flexural strength was tested in the laboratory, the changes in the length of 100 mm x 100 mm x 500 mm concrete specimens in Plate No. 3.4. The surfaces helps in support and loading of rollers helps in changing clean and any losses and different cloth eliminated from the surfaces of the specimen where the contact was made with the rollers. The specimen changes the positioned in the system in different manner which load and become carried out to the top most surface as forged within mold , at middle of the specimen . The axis of the specimen changed into cautiously aligned with the axis of the loading device . the weight became implemented without surprise and growing constantly at a fee such that the intense fibber strain will increase at approximately 7 kg/sq.cm/min , this is , at a charge of loading of 180kg/min for the ten. Zero cm specimens. The load become accelerated until the specimen fails and maximum load carried out to the specimen all through the take a look at was recorded .The specimens are tested for flexural electricity after 7 and 28 days of curing.

Fig. 3.6: Beam Specimens for Measurement of Flexural Strength

Fig. 3.7: Beam after testing

Chapter 4

Results and Discussion

4.1 General

A systematic study showed to achieve objective of present investigation. The results obtained on concrete containing cement, flyash, Metakaolin and ACBFS are presented and discussed in this chapter**.** Total number 24 beams were cast for flexural strength, us of fly ash and Metakaolin uses in various proportions. The specimens are tested at different ages of 7 and 28 days. Following forms in concrete was checked:

- The result of percentage of fly ash and Metakaolin as a partial replacement of cement on flexural strength of concrete.

4.2 Test results

4.2.1 Flexural strength

The flexural energy of all of the mixes has been decided at the a long time of seven and 28 days for the numerous alternative tiers of fly ash, Metakaolin and ACBFS with cement , fly ash and coarse aggregate respectively. Flexural strength of various mixes at various days i.e.-7 and 28 days is presented in tables 4.1 to 4.5. Figure 4.1 shows the change of flexural strength along with different % of fly ash and Metakaolin for various mixes.

Table 4.1: flexural strength (M0-Reference mix)

Sr. No	Mix Designation	Moist Curing (Days)	Flexural strength (N/mm^2)	Average flexural Strength (N/mm^2)
1	M0	7	4.2	4.05
			4	
			3.95	
2	M0	28	5.75	5.90
			6.05	
			5.90	

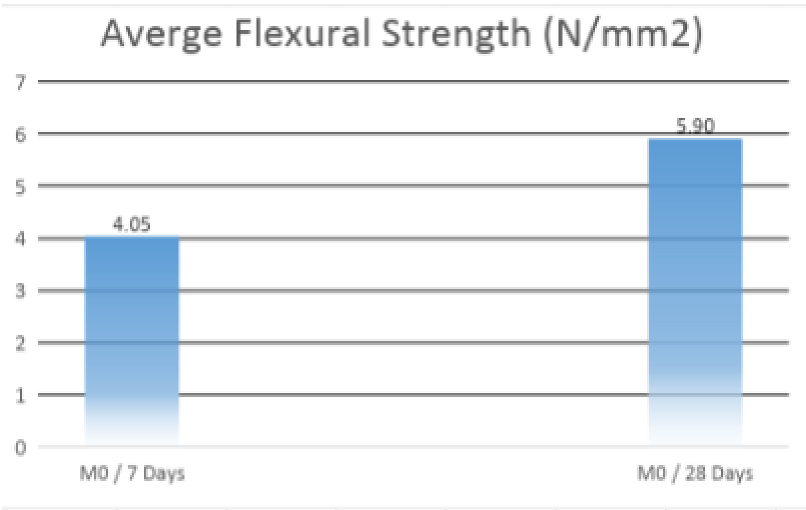

Fig. 4.1 : Average Flexural strength for M0 mix

Table 4.2: flexural strength (M1-Cement replaced by 25% fly ash and 5% Metakaolin)

Sr. No	Mix Designation	Moist Curing (Days)	Flexural strength (N/mm^2)	Average flexural Strength (N/mm^2)
1	M1	7	3.38	3.36
			3.12	
			3.6	
2	M1	28	5.15	4.98
			5.04	
			4.75	

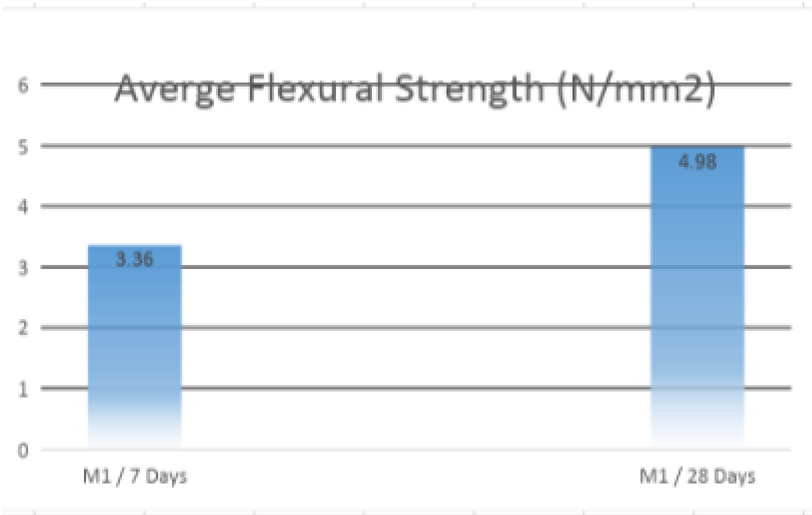

Fig. 4.2 : Average Flexural strength for M1 mix

Table 4.3: flexural strength (M2-Cement replaced by 20% fly ash and 10% Metakaolin)

Sr. No	Mix Designation	Moist Curing (Days)	Flexural strength (N/mm^2)	Average flexural Strength (N/mm^2)
1	M2	7	3.44	3.62
			3.58	
			3.84	
2	M2	28	5.31	5.25
			5.16	
			5.28	

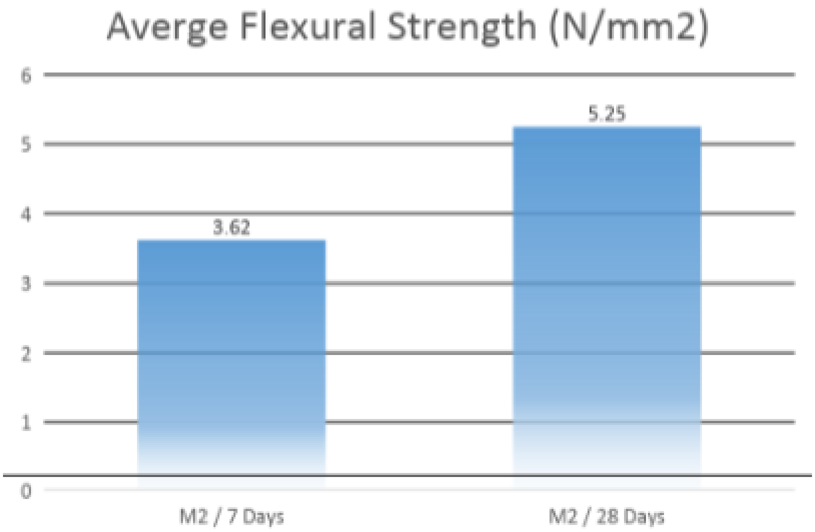

Fig. 4.3 : Average Flexural strength for M0 mix

Table 4.4: flexural strength (M3-Cement replaced by 15% fly ash and 15% Metakaolin)

Sr. No	Mix Designation	Moist Curing (Days)	Flexural strength (N/mm^2)	Average flexural Strength (N/mm^2)
1	M3	7	4.02	3.94
			3.89	
			3.91	
2	M3	28	5.62	5.56
			5.54	
			5.52	

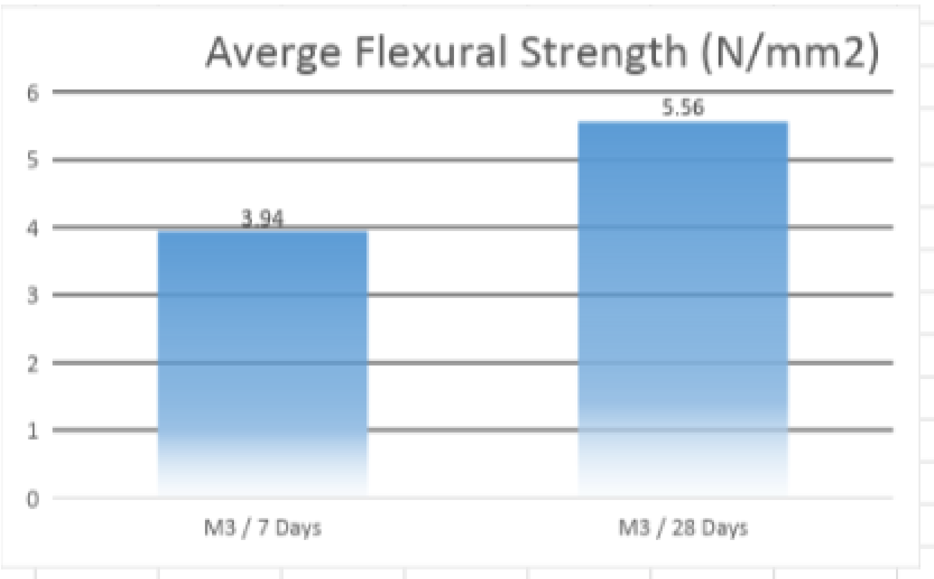

Fig. 4.4 : Average Flexural strength for M3 mix

Table 4.5: Flexural strength for different replacement levels of cement by fly ash and Metakaolin

Mix Designation	Percentage Replacement by fly ash	Percentage Replacement by Metakaolin	Flexural Strength (N/mm^2)	
			Duration of moist Curing (days)	
			7	28
M0	0%	0%	4.05	5.90
M1	25%	5%	3.36	4.98
M2	20%	10%	3.62	5.25
M3	15%	15%	3.94	5.56

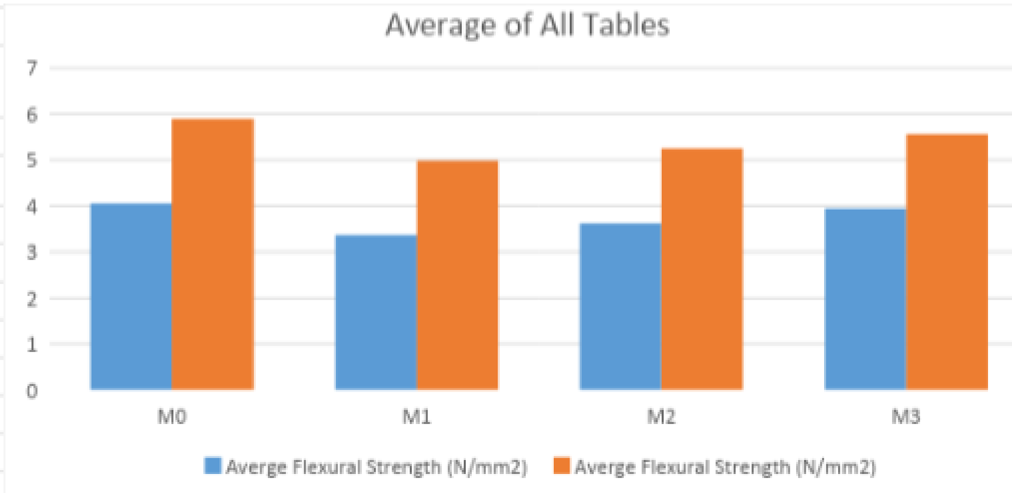

Fig 4.5: Average of all flexural strength

It is clear from tables above tables and figure that the flexural strength of mixes M1, M2 and M3 is less than the reference mix M0, however flexural strength enhanced with increase in percentages of Fly Ash along with Metakaolin.

4.3 Cost Analysis

The cost of concrete decreases with growth in percent of cement substitute, by fly ash whereas the great strength of concrete decreases with addition of fly ash. However, it is observed that for M3 Flexural strength at 28 days is comparable that of reference mix (M0), therefore the cost comparison of mixes M0 and M3 is carried out, table 4.6 shows the comparison of mix M0, M4.

Table 4.6: Cost analysis of concrete mix without fly ash and concrete mix containing both fly ash and Metakaolin for similar flexural strength

MIX DESIGNATION	**Rate (Rs/kg)**	**M0 (reference mix)**		**M4 (15% Fly ash , and 15% Metakaolin)**	
Material		**Quantity kg/m^3**	**Amount Rs**	**Quantity kg/m^3**	**Amount Rs**
Cement	7	385	2695	269.5	1886.5
Fly ash	1.2	0	0	57.75	69.3
Sand	0.53	719	381.07	719	381.07
Aggregates	0.6	1149	689.4	689.4	413.64
Metakaolin	12	0	0	57.75	693
Water	-	165	-	165	-
TOTAL			3868		3443.51
% SAVING					10.97% for 1 m^3

It can be seen from above table that there is saving of quantity of cement and aggregates in M3 mix as compared to M0 that is plain cement concrete. Therefore, cement is replaced by by fly ash and addition of Metakaolin for partial replacement cement is a viable proposition.

Chapter 5
Conclusion

5.1General

The effects of replacement of cement by flyash and Metakaolin, coarse aggregates by ACBFS on compression and great strength of concrete have been searched in the present study, the conclusion drawn on the basis of present study have been reported in this chapter. Results of investigation indicate that compressive strength and flexural strength of concrete show similar trend that is growth in strength in addition of Metakaolin and ACBFS, while decrease in strength with addition of fly ash in general .

5.2Conclusion

The following conclusion are drawn suggested by the results during investigation-

i. The limited amount of cement which was replaced by fly ash showed in decrease in compressive and flexural strength of concrete at 7 and 28 days. With replacement of 25% of cement by flyash the compressive strength decreased by 25% and flexural strength decreased by 17% as compared to reference mix at the age of 28 days

ii. The addition of Air cooled blast furnace slag resulted in increase in compressive strength and flexural strength of concrete at 7 and 28 days . Further with increase in percentages of Aircooledblast furnace slag the compression strength increased. A maximum increase of 25% in compressive strength and 8% in flexural strength was obtained for mix containing 25% flyash and 60% Air cooled blast furnace slag (M4)in comparison to reference mix (M0)

iii. The partial replacement of flyash by Metakaolin resulted in increase in compressive and flexural strengths of concrete. Further with increase in percentages of Metakaolin the strength of mixes increased.

iv. The maximum compressive strength and flexural strength was obtained for mix containing 10% flyash, 15% Metakaolin and 60 % Air cooled blast furnace slag (M16) .

v. The cost comparison of the comparable mixes that is reference mix (M0) and the mix containing 15% flyash 10% Metakaolin 60% Air cooled blast furnace slag (M12) shows that the replacement of cement by flyash and Metakaolin along with replacement of coarse aggregate by Air cooled blast furnace slag is a viable proposition.

5.3 Future Scope of Study

Within the limited scope of present study, the conclusions have been drawn and reported. However, further studies can be planned in following directions:

i) The effect of fly ash for cement replacement and Metakaolin for fly ash replacement along with effect of ACBFS for coarse aggregate replacement prepared with various sizes of aggregates on compressive strength and flexural strength of concrete i.e. 40mm

ii) The effect of Metakaolin and ACBFS along with other supplementary materials like alccofine, rise husk, glass waste powder etc and their role in more performance concrete.

iii) The effect of fly ash, ACBFS and Metakaolin on other parameters like durability, split tensile strength, drying shrinkage etc.

iv) Effect of fly ash, ACBFS and Metakaolin on compressive strength and shrinkage of concrete beyond 28 days.

v) The effect of higher percentages of ACBFS on compressive , flexural and split tensile strength can be investigated

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