DISSERTATION
ON

"EXPERIMENTAL STUDY OF FLYASH BASED CONCRETE FOR ITS VARIOUS CHARACTERISTIC PROPERTIES"

Submitted by

AJAY SINGH
M.Tech(Structural Engineering)
Roll No. 2K12/STR/01

Under the guidance of
Mr. ALOK VERMA
(Associate Professor, Deptt. Of Civil Engg. Delhi Technological University)

Department of Civil Engineering
Delhi Technological University(D.T.U)
(DELHI-110042)
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CERTIFICATE

This is to certify that Project Report entitled "***Experimental Study of Flyash based Concrete for its various characteristic properties***" which is submitted by me in partial fulfillment of the requirement for the award of Degree of Master of Technology in Structural Engineering to Delhi Technological University, Delhi comprises only my original work and due acknowledgement has been made in the text to all other material used.

The matter embodied in the project has not been submitted for the award of any other degree.

AJAY SINGH
M.Tech(Structural Engineeering)
Roll No. 2K12/STR/01

This is to certify that above declaration made by the Candidate is true to the best of my knowledge and belief.

ALOK VERMA
Associate Professor, Deptt. of Civil Engg. DTU
Supervisor

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Last but not least, I specially thank all the people who are active in this field. Reference material (pictures, tables and forms) from various national and international reports and journals are included in this report for academic purpose with due acknowledgement.

Ajay Singh

M.tech(Structures)

Roll No. 2K12/STR/01

OBJECTIVE OF STUDY

The Major Project is aimed to investigate experimentally the properties of Flyash based concrete by adding different percentage of flyash replacement by weight of cement(viz. 10, 20, 30, 40%) in Plain concrete of grade M30 and to compare the results so obtained with that of normal cement based concrete at 28 days and 90 days. Different properties of concrete which the report discusses include-

1. Compressive Strength
2. Workability
3. Water Absorption characteristics.
4. Durability against Sulphate attack (durability test).
5. Impact Resistance

The report also discusses the sulphate attack resistance of flyash based concrete to judge the feasibility of this type of concrete in different exposure condition. For this the mortar cube specimen based on flyash is immersed in sulphate solution and tap water for 28 days so as to observe the effect on compressive strength in both the cases.

ABSTRACT

The application of flyash in concrete as partial replacement of cement is getting a lot of acceptance today, mainly on account of the improvement in the long-term durability of concrete combined with ecological benefits.

This Project report gives us a comparative study on effects of concrete properties when OPC based concrete was partially replaced by fly ash. The main variable investigated in this study is variation of fly ash dosage of 10%, 20%, 30% and 40%. The compressive strength, durability, workability ,water absorption characteristics and Impact Resistance of concrete were mainly studied. Test results shows that, inclusion of fly ash generally improves the concrete properties upto a certain percent of replacement in all grades of OPC.

The sulphate resistance of flyash based concrete is experimentally investigated on using sodium sulphate solution(Na_2 SO_4) . Mortar cubes based on cement and blended cement were immersed in sulphate solution for 28 days in order to investigate its effect on the compressive strength of cubes. The chemical reaction in sulphate solution resulted in the formation of sulphate compound known as Ettringite which decreased the compressive strength of normal cement based mortar cubes but the inclusion of flyash in cement imparted certain resistance to the attack of sulphate solution as depicted in the results section.

In this study it has been focused to use Class F fly ash in concrete, as a part of blended cement or used directly into concrete mixer. There were many articles that highlight the good properties of the use of fly ash, but few with the connection between fly ash blended cement and fly ash blended concrete and field construction. The study takes up both the advances and the drawbacks with use of fly ash cement.

From the experimental investigation the results so obtained are compared with normal grade concrete so that the points of difference can be stated between the two and the utilization of flyash in modern age as a replacement of cement can be justified.

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SCOPE OF WORK

The experimental work involved in the project includes various laboratory tests conducted on mortar cubes, cylindrical cubes as well as on concrete cubes.

Preliminary tests were conducted to show the effect of flyash on the cementitious properties of cement.

Tests performed on cement and flyash based cement.

1. Normal consistency of cement(OPC 43 Grade) using Le Chatelier Apparatus.
2. Initial setting time of cement.
3. Final setting time of cement.
4. Specific gravity test using gravity bottle.

The addition of flyash in cement influences its cementitious properties to a great extent such as its consistency, setting time, rate of hydration, compressive strength etc....as depicted by the results so obtained.

Tests performed on Concrete of grade M30.

1. Slump test to know the workability of the standard mix.
2. Compressive Strength test at different duration viz. 7, 28,56 and 90 days.
3. Water Absorption test at different duration viz 56days and 90 days.
4. Sulphate attack test to check the durability of plain concrete first so as to compare it with flyash based concrete at 28 days.
5. Impact Resistance of concrete cylinders with and without addition of flyash.

The above mentioned tests were planned to be conducted on different grades of flyash blended M30 concrete. These mixes were to be made by replacing cement by flyash in the proportion of 10%, 20%, 30% and 40%.

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CHAPTER I

1. INTRODUCTION

1.1 BACKGROUND INFORMATION

Concrete is the most abundantly and widely used construction material in the world. Concrete has excellent mechanical and durability characteristics depending how it is designed and made. Concrete requires extensive amounts of natural resources for its production such as course aggregates, the fine aggregates which mainly comes from rivers, and the raw material for cement, limestone, is also mined from the earth .The utilization of these resources places large burden on the non renewable resources.Secondly the utilization of cement in the production of concrete creates the problen of CO2 emission which is the main green house gas responsible for ozone gas depletion. Lot of research is undergoing over the last few years to uncover several waste and by-product material. The most common waste/by-product material that have found acceptance in concrete is fly ash which is produced as a residue from coal-burning power plants. The use of such materials in concrete has significant environmental and economic benefits compared to using Ordinary Portland Cement(OPC).Fly ash reacts with the calcium hydroxide produced from cement hydration to form secondary hydration products that result in better material properties. In this project, the aim is to use fly ash at different percentage replacement with cement, to produce a material that has binding properties.

1.2 FLYASH BASED CONCRETES: DEFINITION

Flyash concrete involves the addition of flyash in cement known as blended cement in order to improve the properties of normal concrete. In some cases, fly ash has been replaced by more than 50% of the Portland cement in concrete mixtures . This concrete has very low water content and different %age of Portland cement by mass is replaced with fly ash. Flyash based concrete has excellent workability, low heat of hydration, adequate early-age strength and very high later-age strength, low drying shrinkage, and excellent durability. It can be mixed, transported, placed, and finished by conventional means . However, in order to achieve the full benefits of this concrete particular attention has to be paid to certain design and placement issues when using high levels of fly ash. The two most important factors that have to be addressed in order to ensure flyash concrete be durable is a low water to binder ratio and an extended period of moist curing.This project is aimed in experimenting these properties of flyash based concrete and comparing the results with plain cement concrete.

1.3 SIGNIFICANCE OF PROBLEM

The study of flyash based concrete is important these days and there are many factors that have created the need for its use in construction industry. The report emphasize those factors and hence have great significance.

1. Conventional concrete requires extensive amounts of natural resources for its production which depletes the natural resources. Furthermore, the production of each ton of Portland cement produces an equal amount of carbon dioxide into the atmosphere .
2. Over the last several years, research has uncovered several waste and by-product material from other industries as potential partial cement replacement materials in concrete. The most common waste/by-product material that have found acceptance in concrete is fly ash which is a residue from coal-burning power plants. The use of these materials(flyash typically) in concrete has significant environmental and economic benefits compared to using OPC.
3. The use of flyash has a great significance on durability related properties of concrete in different exposure conditions. The increase in sulphate resistance of flyash based concrete is may be due to the contained reaction of fly ash with hydroxides in concrete to form additional calcium silicate hydrate (C-S-H), which fills in capillary pores in the cement paste, reducing permeability and the ingress of sulphate solution.
4. The ingress of flyash in concrete results in decreased permeability of concrete due to very fine size of flyash particles which gets entrapped in between the cement particles and hence restricts the free passage of water particles through the pores.

CHAPTER II

2. LITERATURE REVIEW

2.1 FLY ASH REPLACEMENT LEVELS

The level of flyash replacement in concrete mainly dependant on the extent of properties that are obtained whether they are acceptable within the permissible limits. This study focusses on the use of Class F fly ash in concrete, as a part of blended cement varying from 10% to 40%.
In recent years economic and environmental considerations have increased the incentive to use fly ash at higher replacement levels than those traditionally used. In some cases, fly ash has replaced more than 50% of the Portland cement in concrete mixtures. In the present study flyash has been replaced upto 40% by weight of cement in the concrete mix.
Fly ash concrete offers greater resistance to alkali aggregate reaction . Several successful field constructions with high volume Class F fly ash concrete are mentioned. Even if the use of fly ash has a lot of advantages there always will be events of less favourable experience, because of different cement types, fly ashes, admixtures, aggregates, environment and temperature. However, there are few examples of poor field constructions with fly ash concrete. Perhaps this is because of its good properties of the fly ash concrete used in the constructions, or the reason is no one wants to report failed projects.

2.2 EFFECT OF FLYASH ON CONCRETE PROPERTIES

A good understanding of the mechanisms by which fly ash improves the rheological properties of fresh concrete and ultimate strength as well as durability of hardened concrete is helpful to ensure that potential benefits expected from flyash concrete mixtures are fully realized. These mechanisms are discussed next.

2.2.1 Effect of fly ash on cementitious properties

The main physical properties of fly ash that influence the activity of fly ash with which it gains strength is its fineness. Fly ash reacts with $Ca(OH)_2$ released from the hydration of cement in the concrete and produces cementing materials. Fly ash is required to be equal or finer than cement for its good cementing efficiency. The fineness of 43 grade cement in this investigation is found to be 8 % residue on 90 micron sieve. Fineness of fly ash obtained from Panipat Thermal Power Plants (India) is found to be 6%. Fly ash is of finer size as comparable to cement particles and hence can be expected to have appreciable influence on the strength development on concrete.[refer **6]. Halstead, Woodrow J. [1986]**14 also explains the uses of Fly Ash in Concrete with special reference to time of setting, bleeding, heat of hydration and pumpability.

2.2.2 Water absorption characteristics

When excess water in concrete evaporates, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. By proper selection of ingredients and mix proportioning and following the good construction practices almost impervious concrete can be obtained. The flow of water through concrete is similar to flow through any porous body. The pores in cement paste consist of gel pores and capillary pores. The pores in concrete as a result of incomplete compaction are voids of larger size which give a honeycomb structure leading to concrete of low strength.

2.2.3 Workability

Water demand and workability are influenced greatly by particle size distribution, particle packing effect, and voids present in the solid system. Typical concrete mixtures do not have an optimum particle size distribution, and this accounts for the undesirably high water requirement to achieve certain workability.

Workability of concrete increased with the inclusion of fly ash in comparison to that of concrete with pure cement. The reason may be due to the increase of the paste volume that leads to the increase of plasticity and cohesion. Fly ash particles tend to coat and lubricate the aggregate particles. The spherical shape of the fly ash particles contributes to the workability of concrete by reducing the friction at the aggregate paste interface, producing a ball bearingeffect at the point of aggregate contact.This behavior may be because the higher the grade ofcement the more fine it is. Finer cement requires more water to wet the surface particles. To plasticize a cement paste for achieving a satisfactory consistency, much larger amounts of water than necessary for the hydration of cement have to be used because portland cement particles, due to the presence of electric charge on the surface, tend to form flocs that trap volumes of the mixing water. . The fact that use of high volume of fly ash in concrete along with superplasticizer in concrete exibits good workability and high early strength is emphasized by Raju[1991]**15.

2.2.4 Compressive strength

This is one of the main characteristic property of concrete which is to be tested under the influence of flyash at a given age and also the rate of strength gain of fly ash concrete which is affected by the characteristics of the fly ash (properties, chemical composition, particle size, reactivity), the cement with which it is used, the proportions of each used in the concrete, the temperature and other curing conditions.

With respect to flyash concrete, there is concern within the industry that the low early strength is a potential problem. Reports have shown that replacement of cement with 20%, 30%, and 40% fly ash content reduces the compressive strength of concrete at 28 days, but there is a continuous and significant improvement of strength beyond 28 days when compared to conventional Portland cement concrete. The maximum strength reported with fly ash and superplasticizer is about 60 Mpa, Swamy [1985]**16. He reported that high volume fly ash concrete has decreased compressive strength at 28 days, better strength at later ages i.e. 56 and 120 days, increased brittleness index and better resistance to chloride ions penetration.

Rafat Siddique[2004]**17 also carried out experimental investigations on class F fly ash concrete with three percentages of replacement i.e. 40%, 45% and 50%. He concluded that partial replacement of cement by fly ash in concrete results in decrease in compressive strength, Split tensile strength, modulus of elasticity and abrasion resistance at 28 days of age. However, all these properties of hardened concrete show significant improvement at 90days .

2.2.5 Sulphate Resistance of flyash based concrete- A Brief Description

Sulphates in soluble state which exists in soils, ground waters and sewage waste corrode and eventually destroy Portland cement concrete unless it is designed with fly ash to maximise sulphate resistance.

Sulphate attack is a two-phased process:

1.0 Sulphates chemically combines with soluble calcium hydroxide, produced from the hydration of Portland cement, to form calcium sulphate or gypsum. The volume of the resulting gypsum is greater than the sum of its components, causing internal pressures which fracture the concrete.

2.0 Aluminate compounds from Portland cement are attacked by sulphates forming a compound called ettringite. Ettringite formation ruptures the concrete in the same way gypsum formation does.

Fly ash has been found to be most effective in reducing this deterioration in two important ways:

1.0 The pozzolanic activity of the fly ash binds it to free lime (calcium hydroxide) released in the hydration of Portland cement. The fly ash and calcium hydroxide combine in cementitious compounds trapping the calcium hydroxide so that it is no longer available for reaction with sulphates. This prevents the formation of gypsum.

2.0 The cementitious compounds formed when fly ash and calcium hydroxide bond block bleed channels and capillary pores in the concrete making it impervious to aggressive dissolved sulphates. Since the sulphates cannot combine with cement aluminates, ettringite cannot occur.

Flyash acts as a strong water reducer and helps in reducing water/ cementitious ratio. The lowering of water/cementitious ratio can significantly results into a more sulphate resisting concrete. To ensure the most durable concrete possible, fly ash is an essential ingredient when the project will be vulnerable to attack by sulphates or other aggressive compounds.[ref **21]
The durability of concrete is determined by its ability to adopt the environmental exposure conditions without affecting its structural as well as physical state. Now concrete mixed with flyash can cater to the durability conditions in environmental and its allied applications.

The study has revealed the effect on compressive strength of concrete in sulphate solution with and without the inclusion of flyash and the results have revealed the resistance of flyash to be more in comparison to normal concrete placed in the same exposure conditions.

Different test methods have been developed to study the sulfate resistance of cementitious materials, from which ASTM C 1012 is considered the most common approach and much data is available in the literature based on the results of this test method. This test method was followed and also modified with the following objectives:

1) To study the resistance of Class C and Class F fly ashes to sulfate attack.

2) To study the effect of different level of Class C and Class F replacement (10%-40%)

3) To study the effect of Class C and Class F ashes on the compressive strength of the

mortar cylinders subjected to sulfate attack.

4) To study the behavior and differences of mortar and paste specimens

5) To study the microstructure of specimens subjected to sulfate attack

6) To study the effect of specimen size (ASTM C1012 standard size sample A

(1”x1”x11”) and modified size sample B (0.4”x0.4”x4”)

7) To calibrate a model for prediction of expansion of specimens exposed to sulphate attack.

Several recommendations can be made to improve the quality of concrete exposed to sulphate attack.Concrete application in the field of construction has been in practice since greek period and roman civilization. But due to numerous reasons, the concrete construction industry is not sustainable and effectively durable. It consumes a lot of raw materials which are not so much durable so as to resist any kind of environmental. Therefore, this industry has encountered various types of concrete in search of a solution to sustainable development and more durable. Infrastructural growth has witnessed many forms of concrete like High Strength Concrete,
High Performance Concrete, Self Compacting Concrete and the latest in the series is High Volume Fly Ash Concrete (HVFC). The trend has shifted from one property to other of concrete with advancement in technology. The construction techniques have been modernized with focus on high strength, dense and uniform surface texture, more reliable quality, improved durability and faster construction. This report discusses the development of resistance to the attack of sulphate on using flyash in concrete in comparison to normal cement based concrete. The literature available on use of fly ash in concrete has been extensively searched for getting a platform for the start of research on use of high volumes of fly ash in various applications and under various exposure conditions.

Ettringite Formation

Various research which has been carried out in the past demonstrates that, for each percentage of blended cement the strength of ordinary cube and that replaced by fly ash immersed in sulphate solution have less compressive strength than the corresponding referral cubes immersed in tap-water. The strength is found less as fly ash contents is increased in both the cases. This loss of strength for ordinary cube may be due to the presence of sulphate salts in OPC which leads to the formation of complex expansive salts i.e. ettringite.Addition of fly ash to cement converts the leachable calcium hydroxide into insoluble non-leachable cementitious products. The increase in sulphate resistance may be due to the contained reaction of flyash with hydroxides in concrete to form additional calcium silicate hydrate (C-S-H), which fills in capillary pores in the cement paste, reducing permeability and the ingress of sulphate solution.
A comparative study on the sulphate resistance of concrete made with an normal OPC based cement and with cements incorporating fly ash was commenced in this project. Concrete specimens of similar w/cm after 28 days moist curing were immersed in 3 % Na_2SO_4 (sodium sulphate). The fly ash based concrete visually looked better than normal concrete.

Secondly the ettringite formation is considered to be the main cause of most of the expansion and disruption of concrete structures involved in the sulfate attack. However, sulfate attack is not necessarily caused by ettringite formation. When ettringite occurs homogeneously and immediately (within hours), it does not cause any significant disruptive action (Early Ettringite Formation, EEF).
Another example of harmless and useful EEF occurs when, under proper restraint, a calcium aluminate sulfate (C_4A_3S) hydrates within few days producing ettringite uniformly distributed and then homogeneous expansion throughout the hardened concrete.
There are two different types of DEF((Delayed Ettringite Formation) related damage depending on the sulphate source- external or internal sulfate attack. External sulfate attack (ESA) occurs when environmental sulfate (from water or soil) penetrates concrete structure. Internal sulphate attack (ISA) occurs in a sulfate-free environment where the sulfate source is inside the concrete and comes from either cement with high sulfate content or gypsum contaminated aggregate.

Internal Sulfate Attack (ISA):

Modern cements, manufactured in kilns that burn sulfur-rich fuels or organic residues - such as rubber tires - can incorporate large amounts of sulfate (up to about 2.5%) in the clinker phase, which is available for DEF formation. ISA occurs in a sulfatefree environment when the sulfate source is inside the concrete and comes from either cement with high sulfate content or gypsum-contaminated aggregate. The major factors affecting ISA are:

1. Sulfate Content in cement: It is noticed that concrete manufactured at room temperatures (20°C) do not show any form of ettringite-related expansion independently of the SO3 content of the cement (2-4%). On the other hand, concrete steam-cured at 90°C show a significant expansion related to ettringite provided that the SO3 content of the cement is relatively high (>4%).

2. Curing Temperature: When concrete is cured at elevated temperatures (>70°C) the early-formed non-destructive ettringite thermally decomposes to producing more available SO3 because of which the ISA can aggravate.

3. Micro Cracks: plastic shrinkage, high stress in pre-stressed concrete, curing at high temperatures, & Freezing/Thawing cycles causes micro cracking in concrete, which promotes the ettringite deposition, and help them expand with the supply of water.

External Sulfate Attack (ESA):

Also called the traditional sulphate attack is the chemical interaction of a sulfate-rich soil or water with the cement paste. Soils containing sodium, potassium, magnesium, and calcium sulfates are the main sources of sulfate ions in groundwater. For ESA to occur, the following three conditions must be fulfilled:
1. High permeability of concrete;
2. Sulfate-rich environment;
3. Presence of water. A diagrammatic representation of the holistic approach;

Factors Affecting Sulfate Attack

1.0 Cement Type:

The most important mineralogical phases of Portland cements that affect the intensity of sulfate attack are C_3A, C_3S/C_2S ratio and C_4AF. Among the hydration products, calcium hydroxide and alumina-bearing phases are more vulnerable to attack by sulfate ions. On hydration, Portland cements with more than 5% tricalcium aluminate (C_3A) will contain most of the alumina in the form of monosulfate hydrate ($C_3A.CS .H_{12}$). If the C_3A content of cement is more than 8% the hydration products will also contain the hydrogarnate ($C_3A.CH.H_{12}$). In the presence of calcium hydroxide, when the cement paste comes in contact with sulfate ions, both the alumina-containing hydrates are converted to ettringite ($C_3A.\ 3CS\ .\ H_{32}$) causing expansion and spalling. For example in a study of two type I cements with 11.9% and 9.3% of C_3A with a C_3S/C_2S ratio of 7.88 and 2.57 respectively were investigated for sulfate deterioration it was observed that the cement with higher C_3A content had a deterioration level 2.5 times higher than the lower C_3A content.

2) Cation Type:

Sulfate attack is usually attributed to sodium, potassium, magnesium and calcium sulfate salts. Due to the limited solubility of calcium sulfate in water at normal temperatures (i.e., approximately 1400mg/l), It is noticed that sodium and potassium sulfates have a very similar sulfate attack and hence it has been studied as one by many authors hence sulfate attack can be divided in to sodium (NSA) and magnesium sulfate (MSA) attack. It has been reported that that the strength reduction in all blended cements exhibited superior performance in the sodium sulphate environment (NSA) as compared with plain cements. However, the strength reduction was very high in all the cements exposed to magnesium sulfate solution (MSA). Further, the reduction in strength in the blended cements was more than thatin the plain cements. This is primarily due to the reduced calcium hydroxide (CH) content in the blended cements.

3) C_3S/C_2S Ratio

Cements with low C_3A generally have a higher C_3S/C_2S ratio. An increase in C_3S content of the cement generates a significantly higher quantity of calcium hydroxide. The produced calcium hydroxide may directly combine with sulfate ions to produce gypsum. The gypsum reduces the stiffness and cohesiveness of the hardened cement and later gypsum also has the tendency to react with C_3A to form ettringite.

4) Effect of Temperature and Concentration

An increase in temperature of the solution at the early ettringite formation (EEF) stage leads to a decrease in expansion for specimens stored in the sodium sulfate solution. However, during at the delayed ettringite formation (DEF) stage the rate of expansion was similar at all temperatures. In the case of specimens exposed to magnesium sulfate solution, an increase in temperatures led to an increase of the rate of expansion. As the concentration of the solution increases the rate of expansion increases for the specimens stored in sulfate solution at the DEF stage. However it makes no difference at the EEF stage. In the case of specimens exposed to magnesium sulphate solution the increase in concentration led to higher expansion both at EEF and DEF stage.

Fly ash reduces sulphate deterioration in three important ways:

- Fly ash chemically binds the CH in calcium silicate hydrate (CSH) rendering it unavailable for sulphate reaction to gypsum (calcium sulphate) and ettringite (calcium sulfoaluminate).

- Fly ash reduced the concrete permeability, keeping sulphate from penetrating concrete.

- By replacing a part of the cement content with fly ash, the amount of reactive aluminates is reduced, and the reaction with sulphate to ettringite is reduced.

For improving the durability related properties of concrete, greater amounts of fly ash i.e. of the order of 25% to 60% should be used in plain cement concrete. Such type of concrete with high volumes of fly ash in it is referred as High volume Fly Ash Concrete. From theoretical consideration and practical experience it is determined that 50% or more cement replacement by fly ash, it is possible to produce sustainable, high performance concrete mixtures that show higher workability, higher ultimate strength and high durability, Malhotra [1999]**18.

However, the use of chemical admixtures such as superplasticizers is worth mentioning here for achieving the above discussed properties. With superplasticizers, concrete with as low as 0.2

W/C ratio is possible with good workability and a strength as high as 83 Mpa is possible at test age of 28 days [ACI-211-1993]**19. The application of high volumes of fly ash in concrete to obtain high strength and durability at both early and later ages has been reported by Malhotra [1986]17. Bhanumathidas and Kalidas [2002]**20 focused on inclusion of complementary cementitious materials such as fly ash, slag, silica fume and rice husk on durability aspect of concrete in the light of revised IS-456-2000. Malhotra and Ramezanianpur [1994]**21 made a comparison in properties of concrete such as durability with varying percentages of fly ash in concrete and found that the inclusion of flyash in concrete resulted in resisting the effect of sulphate to a greater extent in comparison to normal concrete.

Naik H.K.[2007] reviewed some of the experimental studies in the laboratory to analyze the suitability of utilization of a particular type of fly ash sample with the aim to reduce environmental degradation being caused by disposal of high volumes of fly ash in landfills. Sukhvarsh Jerath, p.E. et al [2007] reported that increase of fly ash content from 30% to 45% increased the durability of concrete without loss of compressive and flexural strength .Mehta [2004] has reviewed the theory and construction practice of concrete mixture with more than 50% fly ash. He has discussed the mechanisms of incorporating high volumes of fly ash in concrete for reducing water demand, improving workability, minimizing thermal and drying shrinkage and enhancing durability. The present study for which this literature has been collected is aimed at analyzing the use of fly ash in high performance concrete for various applications in different condtions.

2.2.6 Impact resistance

Many concrete structures are often subjected to short duration dynamic loads. These loads originate from sources such as impact from missiles and projectiles, wind gusts, earthquakes and machine vibrations. The need to accurately predict the structural response and reserve capacity under such loading had led researches to investigate the mechanical properties of the component materials at such high rates of strain. The present experimental investigation is to study the impact strength of concrete with partial replacement of cement with Fly ash with different percentages. The fly ash concrete composites specimens are tested for Impact strength in drop weight test method. The results are to be compared to the control specimens that contains without fly ash

2.2.7 Drying shrinkage

Perhaps the greatest disadvantage associated with the use of neat portland-cement concrete is cracking due to drying shrinkage. The drying shrinkage of concrete is directly influenced by the amount and the quality of the cement paste present. It increases with an increase in the cement paste-to-aggregate ratio in the concrete mixture, and also increases with the water content of the paste.Clearly, the water-reducing property of fly ash can be advantageously used for achieving a considerable reduction in the drying shrinkage of concrete mixtures.
In general, the shrinkage decreases in flyash concrete due to the reduction in water demand

and production of finer paste structure, which restrict the loss of pore water within the paste, which helps in the reduction of shrinkage. However, it has been observed in this study that the shrinkage of specimens with 40% fly ash content measured at the age of 90 days found to be same for pure and fly ash concrete at each proportion with a minimal change in length. Hence, it may be concluded that influence of fly ash on shrinkage is negligible.

CHAPTER III
3.0 EXPERIMENTAL PROGRAM

3.1 INTRODUCTION

Experimental investigations have been carried out on mortar cubes, concrete cubes and cylinder specimens. The mix was designed for target cube strength of 38 MPa at 28 days with water-cement ratio of 0.4. Cement of grade 43 was partially replaced with fly ash by weight (10%, 20%, 30% and40%). A simple method of mix proportioning using fly ash (i.e. fly ash as part replacement of cement by weight) has been adopted . In this project report the effect of flyash on cemetitious properties of cement (such as consistency, setting time), workability,compressive strength, water absorption characteristic and sulphate attack of concrete is studied.

3.2 MATERIALS USED

3.2.1 Cement

The ordinary Portland cement of grade 43 used met the requirements of Indian standard 8112. Its chemical and physical properties are given in Table 3.1.

Table 3.1 Chemical Analysis & Physical Properties of Portland Cement

Chemical analysis(%)	OPC(43)
Silicon dioxide (SiO_2)	21
Aluminum oxide (Al_2O_3)	4.34
Ferric oxide (Fe_2O_3)	3.05
Calcium oxide (CaO)	63
Sulphur trioxide (SO_3)	3.35
Fineness • specific surface, Blaine, m^2/kg	363

3.2.2 FlyAsh

Fly ash which is a fine, light-brown powdery waste product obtained from the dust control equipment of coal-fired power plants. A large volume of this waste product is produced every year. Though some secondary uses for it are found, much of it finds its way to land fills.

Class F flyash from Panipat Thermal Power Station, Panipat conforming to BIS 3812-2000 has been used in the present study shown in figure 3.2(a). Its physical properties and chemical composition is depicted in Table –3.2.Elemental Dispersive Spectroscope (EDS) of the flyash is shown in the figure-3.2(b). The X Ray Diffraction pattern of Flyash is also shown in figure 3.2(c) and scanning electron microscope(SEM) showing the particle size distribution of flyash sample is shown in figure 3.2(d). These tests are used to know the microstructural properties of any material

PRELIMINARY TEST RESULTS OF FLYASH

As per IS 3812-2003

Table. 3(1) Physical properties of flyash

Descriptions	**Test value**	**IS 3812**
Specific gravity	2.09	2.0-2.2
Initial setting time (min)	121 min	--
Final setting time (min)	290 min	-
Retained on 45 micron (%)	2.6	Max. 34
Soundness (Lechatelier)	0.2	-

Fig 3.2(a) Flyash sample.[Ref **13]

3.2.2(a)ELEMENTAL DISPERSIVE SPECTROSCOPE(EDS) TEST ON FLYASH SAMPLE

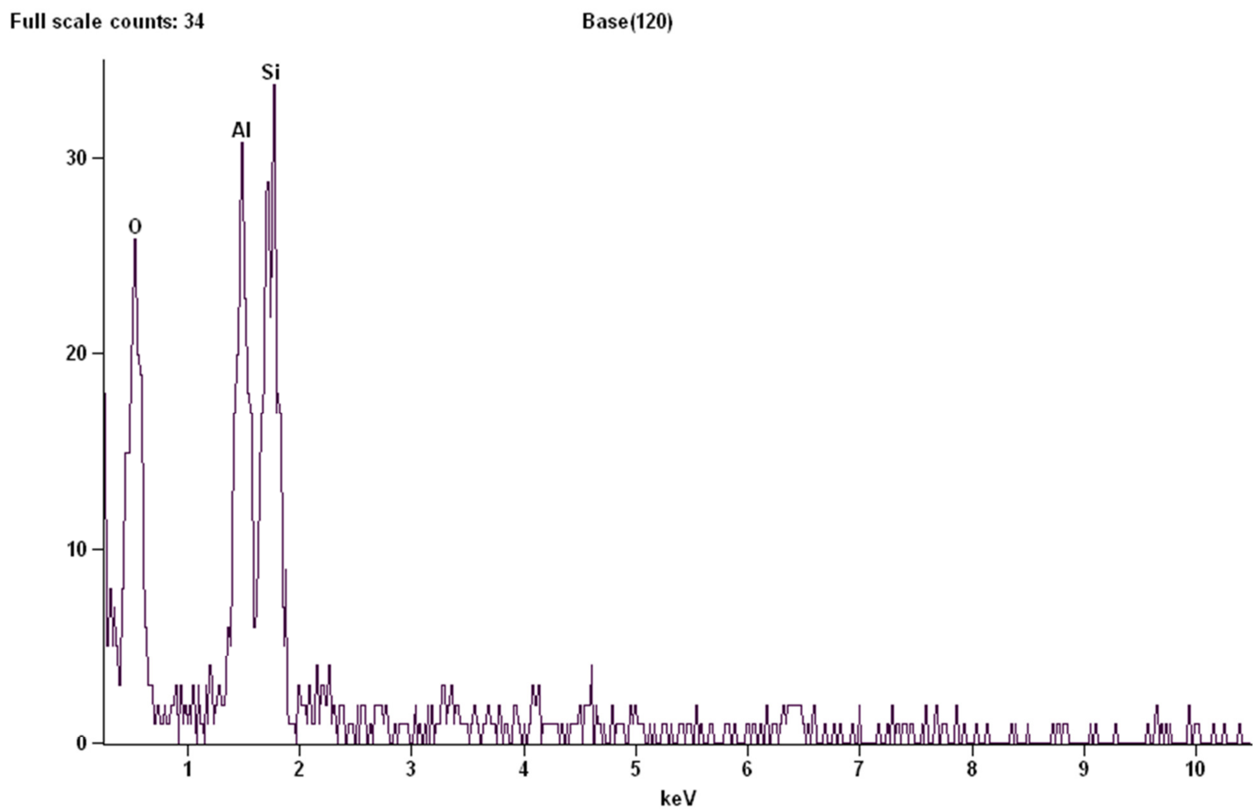

Fig3.2(b) Elemental Dispersive Spectroscope(EDS) of flyash sample depicting the various constituent particles

Acc.Voltage: 15.0 kV Take Off Angle: 78.6 deg.

Table 3.2(a) Quantitative Results for EDS: Base(120)

Element Line	*Net Counts*	*Int. Cps/nA*	*Weight %*	*Weight % Error*	*Atom %*	*Atom % Error*	*Formula*	*Standard Name*
O K	499	0.000	54.77	+/- 3.95	67.67	+/- 4.88	O	
Al K	312	0.000	17.03	+/- 3.06	12.48	+/- 2.24	Al	
Si K	447	0.000	28.20	+/- 3.60	19.85	+/- 2.53	Si	
Si L	0	0.000	---	---	---	---		
Total			100.00		100.00			

3.2.2(b) X-RAY DIFFRACTION PATTERN OF FLYASH SAMPLE

The X-Ray Diffraction pattern is an electronic test that is performed in order to investigate the various physical and chemical properties of any material.Fig 3.2(c) shows the diffraction pattern of flyash with various peaks on y-axis depicting the intensity plotted against angle along with the data plotted.

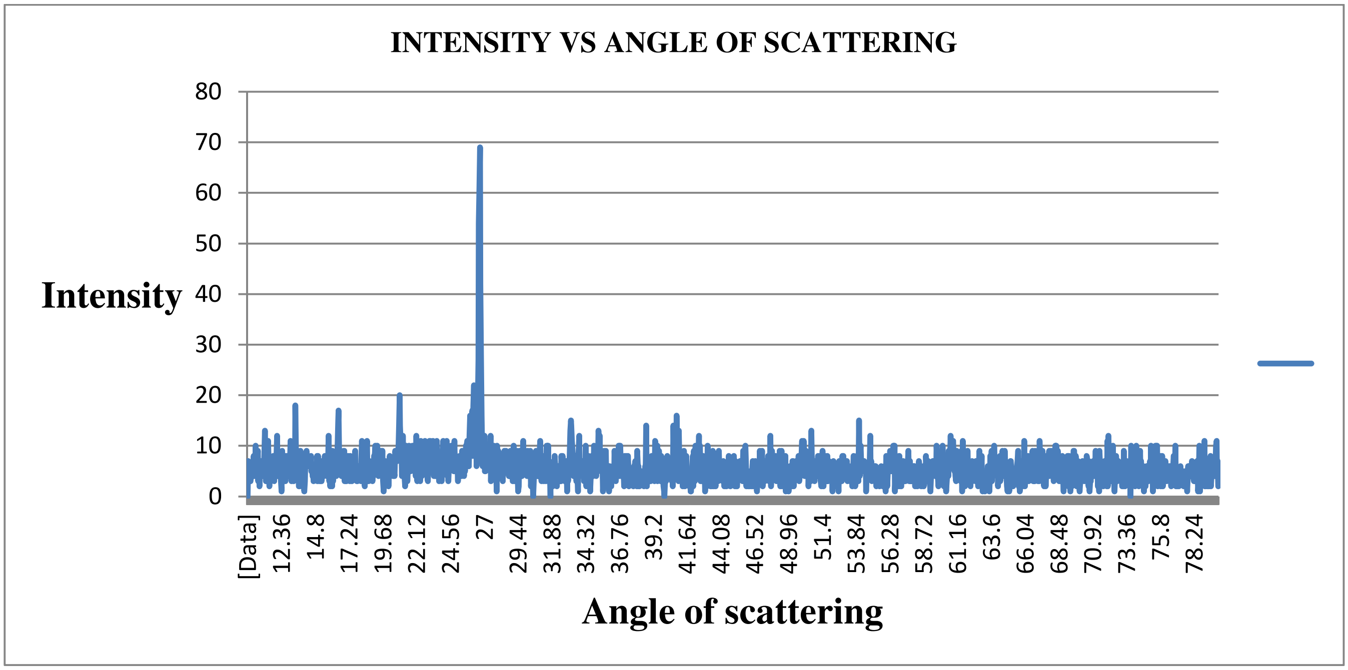

Fig.3.2(c) X-Ray Diffraction pattern of flyash sample

Table 3.2(b) Data sheet of XRD of flyash sample (Dated on: 2nd February 2014)

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
10	7	10.88	5	11.88	3	12.88	4	13.88	6	14.88	4	15.88	4
10.04	4	10.92	5	11.92	7	12.92	4	13.92	4	14.92	4	15.92	2
10.08	5	10.96	6	11.96	6	12.96	5	13.96	2	14.96	8	15.96	6
10.12	3	11	7	12	6	13	6	14	3	15	3	16	7
10.16	3	11.04	7	12.04	8	13.04	11	14.04	1	15.04	8	16.04	2
10.2	4	11.08	4	12.08	12	13.08	7	14.08	3	15.08	4	16.08	9
10.24	6	11.12	6	12.12	4	13.12	3	14.12	6	15.12	4	16.12	3
10.28	4	11.16	8	12.16	6	13.16	4	14.16	8	15.16	3	16.16	8
10.32	6	11.2	13	12.2	4	13.2	7	14.2	9	15.2	7	16.2	8
10.36	5	11.24	6	12.24	6	13.24	5	14.24	7	15.24	4	16.24	4
10.4	8	11.28	3	12.28	8	13.28	3	14.28	6	15.28	3	16.28	5
10.44	4	11.32	6	12.32	6	13.32	4	14.32	7	15.32	6	16.32	8
10.48	5	11.36	9	12.36	3	13.36	5	14.36	6	15.36	7	16.36	4
10.52	10	11.4	9	12.4	1	13.4	18	14.4	6	15.4	5	16.4	7

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
16.88	9	17.88	3	18.88	5	19.88	7	20.88	14	21.88	7	22.88	5
16.92	9	17.92	5	18.92	6	19.92	6	20.92	20	21.92	6	22.92	4
16.96	3	17.96	6	18.96	3	19.96	5	20.96	14	21.96	5	22.96	3
17	7	18	5	19	7	20	5	21	11	22	10	23	6
17.04	6	18.04	5	19.04	4	20.04	5	21.04	12	22.04	9	23.04	8
17.08	3	18.08	4	19.08	8	20.08	7	21.08	4	22.08	4	23.08	11
17.12	6	18.12	3	19.12	8	20.12	2	21.12	4	22.12	12	23.12	11
17.16	6	18.16	7	19.16	10	20.16	5	21.16	12	22.16	9	23.16	7
17.2	8	18.2	11	19.2	5	20.2	8	21.2	5	22.2	3	23.2	9
17.24	4	18.24	8	19.24	9	20.24	6	21.24	5	22.24	9	23.24	7
17.28	4	18.28	4	19.28	5	20.28	7	21.28	4	22.28	6	23.28	8
17.32	3	18.32	9	19.32	10	20.32	6	21.32	2	22.32	7	23.32	11
17.36	8	18.36	4	19.36	5	20.36	6	21.36	9	22.36	5	23.36	7
17.4	5	18.4	2	19.4	4	20.4	7	21.4	10	22.4	3	23.4	4
17.44	7	18.44	5	19.44	5	20.44	4	21.44	8	22.44	11	23.44	4

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
23.88	5	24.88	11	25.88	6	26.88	8	27.88	6	28.88	4	29.88	5
23.92	5	24.92	5	25.92	6	26.92	6	27.92	1	28.92	9	29.92	5
23.96	3	24.96	8	25.96	12	26.96	7	27.96	10	28.96	4	29.96	7
24	6	25	5	26	16	27	7	28	7	29	8	30	5
24.04	10	25.04	5	26.04	13	27.04	12	28.04	9	29.04	6	30.04	6
24.08	11	25.08	7	26.08	12	27.08	5	28.08	6	29.08	3	30.08	7
24.12	8	25.12	3	26.12	15	27.12	5	28.12	8	29.12	3	30.12	4
24.16	5	25.16	6	26.16	17	27.16	7	28.16	4	29.16	10	30.16	9
24.2	10	25.2	5	26.2	8	27.2	10	28.2	4	29.2	8	30.2	6
24.24	10	25.24	8	26.24	18	27.24	6	28.24	6	29.24	4	30.24	5
24.28	5	25.28	5	26.28	22	27.28	7	28.28	5	29.28	3	30.28	7
24.32	11	25.32	4	26.32	16	27.32	6	28.32	7	29.32	3	30.32	5
24.36	4	25.36	4	26.36	18	27.36	9	28.36	3	29.36	7	30.36	9
24.4	9	25.4	4	26.4	15	27.4	8	28.4	7	29.4	9	30.4	2
24.44	3	25.44	9	26.44	19	27.44	8	28.44	8	29.44	5	30.44	5

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
30.88	4	31.88	3	32.88	3	33.88	12	34.88	4	35.88	5	36.88	8
30.92	8	31.92	6	32.92	7	33.92	4	34.92	5	35.92	6	36.92	7
30.96	4	31.96	2	32.96	7	33.96	5	34.96	10	35.96	6	36.96	4
31	6	32	3	33	1	34	7	35	7	36	3	37	7
31.04	10	32.04	5	33.04	5	34.04	7	35.04	6	36.04	1	37.04	7
31.08	11	32.08	5	33.08	3	34.08	5	35.08	7	36.08	6	37.08	6
31.12	4	32.12	8	33.12	7	34.12	7	35.12	4	36.12	4	37.12	2
31.16	3	32.16	6	33.16	6	34.16	7	35.16	9	36.16	3	37.16	8
31.2	5	32.2	6	33.2	8	34.2	4	35.2	10	36.2	2	37.2	4
31.24	4	32.24	5	33.24	13	34.24	3	35.24	9	36.24	5	37.24	5
31.28	4	32.28	2	33.28	15	34.28	3	35.28	13	36.28	4	37.28	8
31.32	3	32.32	6	33.32	14	34.32	7	35.32	10	36.32	6	37.32	4
31.36	6	32.36	4	33.36	11	34.36	10	35.36	12	36.36	4	37.36	4
31.4	8	32.4	5	33.4	9	34.4	2	35.4	7	36.4	4	37.4	8
31.44	4	32.44	6	33.44	7	34.44	6	35.44	5	36.44	9	37.44	5

Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity
37.88	6		38.88	5		39.88	4		40.88	9		41.88	3		42.88	5		43.88	5
37.92	7		38.92	6		39.92	7		40.92	16		41.92	1		42.92	7		43.92	3
37.96	5		38.96	7		39.96	2		40.96	9		41.96	1		42.96	1		43.96	9
38	6		39	5		40	1		41	12		42	3		43	3		44	5
38.04	2		39.04	3		40.04	0		41.04	3		42.04	3		43.04	6		44.04	5
38.08	9		39.08	6		40.08	3		41.08	13		42.08	8		43.08	2		44.08	5
38.12	6		39.12	8		40.12	3		41.12	6		42.12	2		43.12	6		44.12	4
38.16	6		39.16	6		40.16	3		41.16	5		42.16	9		43.16	10		44.16	4
38.2	2		39.2	7		40.2	4		41.2	7		42.2	5		43.2	5		44.2	5
38.24	2		39.24	6		40.24	8		41.24	5		42.24	3		43.24	5		44.24	3
38.28	4		39.28	4		40.28	5		41.28	3		42.28	10		43.28	7		44.28	7
38.32	5		39.32	3		40.32	6		41.32	4		42.32	8		43.32	4		44.32	5
38.36	4		39.36	11		40.36	7		41.36	2		42.36	7		43.36	2		44.36	2
38.4	4		39.4	10		40.4	4		41.4	3		42.4	6		43.4	2		44.4	6
38.44	5		39.44	4		40.44	5		41.44	9		42.44	7		43.44	6		44.44	3
38.48	4		39.48	10		40.48	5		41.48	6		42.48	6		43.48	3		44.48	2
38.52	5		39.52	10		40.52	4		41.52	2		42.52	12		43.52	9		44.52	2
38.56	2		39.56	3		40.56	3		41.56	5		42.56	4		43.56	2		44.56	5
38.6	3		39.6	4		40.6	6		41.6	8		42.6	10		43.6	8		44.6	5
38.64	6		39.64	9		40.64	2		41.64	6		42.64	3		43.64	4		44.64	4
38.68	4		39.68	5		40.68	14		41.68	3		42.68	8		43.68	3		44.68	8
38.72	14		39.72	6		40.72	6		41.72	5		42.72	5		43.72	2		44.72	5

Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity		Angle	Intensity
44.88	5		45.88	10		46.88	3		47.88	5		48.88	4		49.88	4		50.88	3
44.92	3		45.92	6		46.92	9		47.92	4		48.92	4		49.92	8		50.92	7
44.96	7		45.96	2		46.96	4		47.96	4		48.96	5		49.96	11		50.96	4
45	3		46	5		47	5		48	4		49	1		50	5		51	5
45.04	8		46.04	3		47.04	5		48.04	8		49.04	5		50.04	6		51.04	4
45.08	3		46.08	5		47.08	9		48.08	6		49.08	6		50.08	11		51.08	6
45.12	2		46.12	2		47.12	2		48.12	3		49.12	5		50.12	8		51.12	8
45.16	7		46.16	2		47.16	3		48.16	7		49.16	4		50.16	4		51.16	4
45.2	2		46.2	3		47.2	7		48.2	6		49.2	6		50.2	6		51.2	4
45.24	2		46.24	5		47.24	6		48.24	5		49.24	2		50.24	9		51.24	5
45.28	2		46.28	3		47.28	3		48.28	3		49.28	7		50.28	7		51.28	8
45.32	5		46.32	2		47.32	5		48.32	6		49.32	7		50.32	5		51.32	3
45.36	5		46.36	5		47.36	7		48.36	9		49.36	2		50.36	4		51.36	2
45.4	6		46.4	7		47.4	4		48.4	2		49.4	4		50.4	6		51.4	6
45.44	4		46.44	2		47.44	4		48.44	4		49.44	6		50.44	2		51.44	9
45.48	7		46.48	4		47.48	4		48.48	9		49.48	4		50.48	6		51.48	7
45.52	5		46.52	4		47.52	8		48.52	2		49.52	7		50.52	6		51.52	2
45.56	5		46.56	5		47.56	4		48.56	4		49.56	6		50.56	5		51.56	7
45.6	5		46.6	7		47.6	3		48.6	8		49.6	4		50.6	3		51.6	8
45.64	5		46.64	5		47.64	4		48.64	7		49.64	5		50.64	13		51.64	3
45.68	3		46.68	4		47.68	12		48.68	4		49.68	5		50.68	6		51.68	4
45.72	9		46.72	1		47.72	2		48.72	3		49.72	8		50.72	6		51.72	6

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
51.88	6	52.88	8	53.88	3	54.88	12	55.88	3	56.88	2	57.88	3
51.92	7	52.92	4	53.92	8	54.92	6	55.92	6	56.92	2	57.92	3
51.96	4	52.96	8	53.96	6	54.96	7	55.96	4	56.96	8	57.96	6
52	4	53	4	54	6	55	3	56	1	57	8	58	6
52.04	4	53.04	4	54.04	3	55.04	4	56.04	8	57.04	5	58.04	4
52.08	4	53.08	7	54.08	15	55.08	5	56.08	4	57.08	2	58.08	6
52.12	6	53.12	7	54.12	4	55.12	6	56.12	2	57.12	2	58.12	2
52.16	1	53.16	4	54.16	8	55.16	6	56.16	5	57.16	4	58.16	3
52.2	6	53.2	7	54.2	10	55.2	6	56.2	6	57.2	3	58.2	4
52.24	7	53.24	3	54.24	6	55.24	3	56.24	7	57.24	5	58.24	6
52.28	6	53.28	4	54.28	7	55.28	6	56.28	5	57.28	7	58.28	6
52.32	6	53.32	4	54.32	5	55.32	2	56.32	9	57.32	3	58.32	2
52.36	2	53.36	6	54.36	6	55.36	5	56.36	5	57.36	5	58.36	3
52.4	4	53.4	4	54.4	5	55.4	5	56.4	7	57.4	6	58.4	7
52.44	5	53.44	3	54.44	7	55.44	5	56.44	6	57.44	3	58.44	6
52.48	5	53.48	4	54.48	5	55.48	3	56.48	5	57.48	6	58.48	5
52.52	3	53.52	5	54.52	5	55.52	4	56.52	7	57.52	4	58.52	3
52.56	5	53.56	4	54.56	6	55.56	2	56.56	10	57.56	5	58.56	2
52.6	1	53.6	2	54.6	1	55.6	5	56.6	6	57.6	6	58.6	4
52.64	7	53.64	5	54.64	5	55.64	5	56.64	10	57.64	9	58.64	3
52.68	3	53.68	8	54.68	5	55.68	6	56.68	1	57.68	4	58.68	5
52.72	5	53.72	6	54.72	5	55.72	3	56.72	4	57.72	3	58.72	6

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
58.88	3	59.88	8	60.88	11	61.88	3	62.88	4	63.88	6	64.88	2
58.92	8	59.92	6	60.92	6	61.92	9	62.92	8	63.92	5	64.92	1
58.96	5	59.96	8	60.96	5	61.96	3	62.96	4	63.96	5	64.96	2
59	7	60	6	61	7	62	4	63	1	64	7	65	7
59.04	5	60.04	5	61.04	4	62.04	4	63.04	4	64.04	6	65.04	7
59.08	7	60.08	7	61.08	3	62.08	3	63.08	4	64.08	6	65.08	5
59.12	3	60.12	10	61.12	9	62.12	2	63.12	4	64.12	2	65.12	4
59.16	3	60.16	7	61.16	5	62.16	6	63.16	1	64.16	4	65.16	4
59.2	2	60.2	2	61.2	6	62.2	5	63.2	3	64.2	7	65.2	2
59.24	1	60.24	3	61.24	6	62.24	7	63.24	3	64.24	8	65.24	4
59.28	4	60.28	5	61.28	6	62.28	3	63.28	5	64.28	3	65.28	5
59.32	4	60.32	3	61.32	4	62.32	4	63.32	3	64.32	6	65.32	3
59.36	6	60.36	1	61.36	5	62.36	5	63.36	6	64.36	6	65.36	3
59.4	7	60.4	2	61.4	4	62.4	6	63.4	4	64.4	5	65.4	4
59.44	4	60.44	4	61.44	3	62.44	5	63.44	4	64.44	9	65.44	4
59.48	5	60.48	6	61.48	9	62.48	3	63.48	1	64.48	4	65.48	6
59.52	7	60.52	4	61.52	1	62.52	7	63.52	4	64.52	8	65.52	7
59.56	5	60.56	9	61.56	11	62.56	3	63.56	8	64.56	7	65.56	9
59.6	4	60.6	9	61.6	5	62.6	5	63.6	5	64.6	9	65.6	2
59.64	5	60.64	7	61.64	5	62.64	5	63.64	9	64.64	6	65.64	4
59.68	10	60.68	12	61.68	7	62.68	2	63.68	3	64.68	5	65.68	1
59.72	8	60.72	9	61.72	2	62.72	6	63.72	7	64.72	5	65.72	3

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
65.88	2	66.88	6	67.88	6	68.88	6	69.88	7	70.88	4	71.88	3
65.92	4	66.92	5	67.92	9	68.92	4	69.92	3	70.92	6	71.92	3
65.96	4	66.96	7	67.96	9	68.96	3	69.96	4	70.96	7	71.96	2
66	11	67	3	68	6	69	3	70	1	71	5	72	11
66.04	2	67.04	3	68.04	7	69.04	3	70.04	3	71.04	4	72.04	2
66.08	3	67.08	3	68.08	8	69.08	4	70.08	5	71.08	6	72.08	12
66.12	3	67.12	11	68.12	3	69.12	8	70.12	3	71.12	5	72.12	7
66.16	6	67.16	6	68.16	7	69.16	8	70.16	4	71.16	9	72.16	3
66.2	5	67.2	5	68.2	4	69.2	2	70.2	7	71.2	4	72.2	5
66.24	5	67.24	7	68.24	10	69.24	8	70.24	4	71.24	7	72.24	5
66.28	8	67.28	5	68.28	8	69.28	3	70.28	4	71.28	8	72.28	3
66.32	3	67.32	9	68.32	10	69.32	1	70.32	3	71.32	2	72.32	3
66.36	7	67.36	4	68.36	8	69.36	2	70.36	6	71.36	4	72.36	4
66.4	5	67.4	3	68.4	8	69.4	7	70.4	4	71.4	1	72.4	10
66.44	5	67.44	2	68.44	9	69.44	2	70.44	5	71.44	9	72.44	3
66.48	5	67.48	8	68.48	6	69.48	4	70.48	3	71.48	6	72.48	4
66.52	4	67.52	4	68.52	3	69.52	4	70.52	8	71.52	5	72.52	1
66.56	8	67.56	2	68.56	3	69.56	9	70.56	7	71.56	5	72.56	4
66.6	9	67.6	5	68.6	3	69.6	9	70.6	4	71.6	5	72.6	3
66.64	3	67.64	4	68.64	5	69.64	5	70.64	2	71.64	3	72.64	8
66.68	6	67.68	6	68.68	5	69.68	6	70.68	7	71.68	3	72.68	4
66.72	7	67.72	7	68.72	6	69.72	8	70.72	1	71.72	2	72.72	3

Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity	Angle	Intensity
72.88	5	73.88	5	74.88	4	75.88	8	76.88	5	77.88	4	78.88	7
72.92	4	73.92	4	74.92	5	75.92	3	76.92	10	77.92	6	78.92	5
72.96	5	73.96	5	74.96	3	75.96	8	76.96	2	77.96	4	78.96	5
73	3	74	2	75	6	76	2	77	4	78	4	79	11
73.04	3	74.04	7	75.04	6	76.04	5	77.04	2	78.04	5	79.04	2
73.08	2	74.08	10	75.08	7	76.08	3	77.08	4	78.08	6	79.08	2
73.12	5	74.12	5	75.12	5	76.12	6	77.12	4	78.12	7	79.12	4
73.16	2	74.16	8	75.16	10	76.16	4	77.16	2	78.16	5	79.16	6
73.2	9	74.2	7	75.2	4	76.2	7	77.2	4	78.2	4	79.2	3
73.24	5	74.24	3	75.24	7	76.24	4	77.24	5	78.24	3	79.24	2
73.28	2	74.28	2	75.28	1	76.28	3	77.28	6	78.28	4	79.28	5
73.32	5	74.32	5	75.32	5	76.32	5	77.32	3	78.32	6	79.32	2
73.36	4	74.36	9	75.36	8	76.36	5	77.36	5	78.36	3	79.36	5
73.4	7	74.4	5	75.4	3	76.4	5	77.4	3	78.4	4	79.4	3
73.44	5	74.44	7	75.44	5	76.44	6	77.44	5	78.44	3	79.44	8
73.48	3	74.48	4	75.48	10	76.48	5	77.48	5	78.48	7	79.48	2
73.52	6	74.52	6	75.52	4	76.52	3	77.52	2	78.52	4	79.52	4
73.56	5	74.56	4	75.56	5	76.56	6	77.56	2	78.56	1	79.56	5
73.6	6	74.6	6	75.6	10	76.6	2	77.6	5	78.6	3	79.6	6
73.64	7	74.64	1	75.64	2	76.64	4	77.64	4	78.64	10	79.64	5
73.68	0	74.68	4	75.68	4	76.68	4	77.68	2	78.68	1	79.68	6
73.72	10	74.72	2	75.72	5	76.72	4	77.72	4	78.72	4	79.72	4

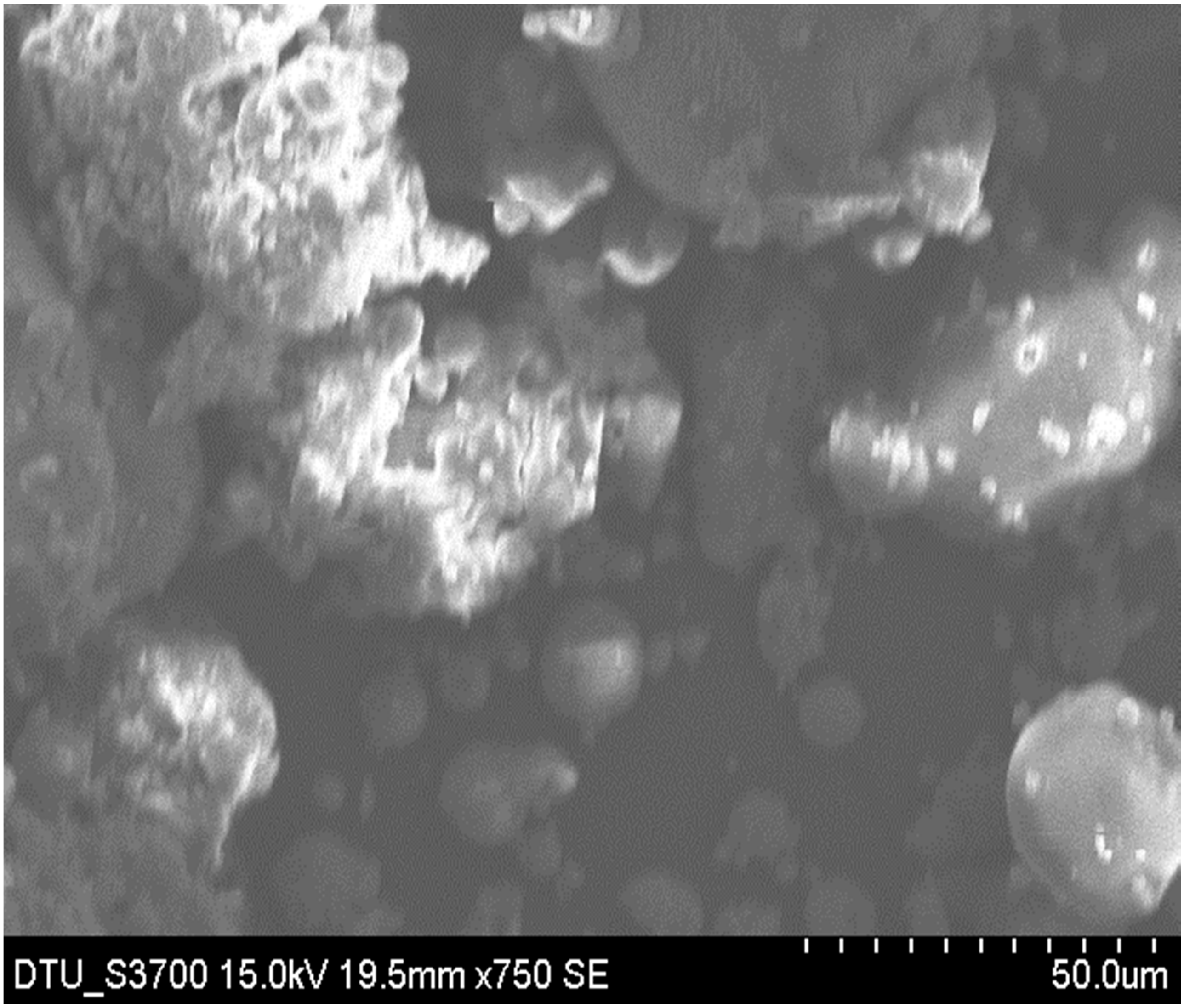

Figure3.2(d) Particle size distribution of flyash by Scanning Electron Microscope(SEM).

3.2.3 Aggregates

The coarse aggregate used was a crushed coarse aggregate from local building supplier with a maximum nominal size of 20 mm. The fine aggregate used Badarpur sand. Both the coarse and fine aggregate was from local sources in the Rohini region. The coarse aggregate had a specific gravity of 2.76 and a water absorption value of 0.81%. The fine aggregate had a specific gravity of 2.65 and a water absorption value of 1.32%. Both aggregates meet the requirements of IS 383.

3.2.4 Mixture Proportions

The proportions of the concrete mixtures are outlined in Table 3.2(b). All aggregates are listed in a saturated surface dry condition (SSD).

CONCRETE MIX DESIGN OF GRADE M30 AS PER 10262-2009 MATERIAL –

- Cement – ACC cement(OPC 43 grade)
- Badarpur sand, 20 mm & 10 mm aggregate

DESIGN STIPULATIONS -

Grade designation : M30

1. Type of cement : OPC 43
2. Minimum cement content : 360 kg
3. Maximum cement content : 450 kg
4. Maximum nominal size of aggregate: 20mm (angular)
5. Water cement ratio : 0.36
6. Design of workability : medium
7. Workability: 100mm (slump)
8. Degree of quality control : good
9. Type of exposure : moderate

Test data for materials-

1. Type of cement – ACC Cement (OPC 43 Grade)
2. Specific gravity of cement - 3.15
3. Specific gravity of coarse aggregate – 2.76
4. Specific gravity of fine aggregate – 2.65
5. Water absorption for
   Coarse aggregate – 0.5%
   Fine aggregate – 1%
6. Free surface moisture
   Coarse aggregate(C.A) – Nil

Fine aggregate(F.A) – Nil

Sieve analysis

S.No.	**Sieve Size**	**C.A.(% passing)**	**F.A.(% passing)**
2	20 mm	100	-
3	10 mm	43.05	-
4	4.75 mm	2.64	100
5	2.36 mm	0.00	99.50
6	1.18 mm	-	97.20
7	600 µ	-	68.20
8	300 µ	-	6.10
9	150 µ	-	0.03

(Coarse aggregate and fine aggregate sieve analysis tests are performed as per IS Code IS-4031-1968 and IS-383-1970 respectively)

The proportion between 20 mm and 10 mm aggregate is 64% : 36%

Target lab strength of 28 days = 30 + 1.65 * 5 = 38.25Mpa

MIX PROPORTION – The designed mix proportions on the basis of properties of the supplied material are as follows:

CEMENT	**:**	**F.A.**	**:**	**C.A.**
400 kg		661.62 kg		1225.44 kg
1.00		1.65		3.06

Water:

1. For w/c ratio of 0.4 quantity = 186 litres
2. Extra quantity of water to be added for absorption in case of C.A. at 0.5% by mass = 0.756 litres
3. Actual quantity of water mass required to be added = 186 + 0.756 =186.76 litres

Detailed design procedure

1. Mean target strength

   Ft = fck + kS

Fck = 30
K =1.65
S = 5 (Table 1 . of IS 10262:2009)

2. Water-cement ratio
   Free water cement ratio = 0.4 (for G 43 and fck = 30 from 10262:1982)
   Maximum free water cement ratio = 0.45(table 5 IS 456:2000)
3. Selection of free water content
   Water content = 186 lt(Table 2 IS 10262:2009 for 25 – 50 mm slump)
   This water content should be increased at the rate of 3% for every additional 25 mm slump.
   Water content = 186 + (6/100) * 186
   = 197 litres
4. Calculation of cement
   w/c = 0.4(adopt)

   c = 197/0.4
   =492.5 kg
   But for M30 minimum cement is 360 kg
   And maximum cement is 450 kg
   So taking cement content = 400 kg
   So, w = 0.4 * 400 = 160 litres

5. % of fine aggregate
   Entrapped air content = 2%
   % of F.A = 36% (Table 4, conforming to IS 383:1973, zone 3)
   The C.A is crushed (angular)
   % of C.A = 64% (Table 3 conforming to IS 10262:2009, ZONE 3)

6. Computation of total absolute volume of aggregate
   Let , Volume of concrete = 1 cu. m
   Volume of cement = (400 / 3.15) * (1/1000)
   = 0.127 cubic m
   Volume of water = 160/1000
   = 0.160 cubic m
   Volume of entrapped air = 0.02 cubic m
   Total volume of aggregate = 1-(0.127 + 0.160 + 0.02)
   = 0.693 cu. M
   Mass of C.A = 0.64 * 0.693 * 2.763 * 1000

= 1225.44 kg

Mass of F.A = 0.36 * 0.693* 2.652 * 1000

= 661.62 kg

RATIO

Cement	:	F.A	:	C.A	:	Water
400		661.62		1225.44		160
1	**:**	**1.65**	**:**	**3.06**	**:**	**0.40**

The mix design for the project is also tabulated as below.

Table 3.2(c) Concrete mix design of grade M30

CONCRETE MIX DESIGN		
As per IS 10262-2009		
A-1	**Stipulations for Proportioning**	
1	**Grade Designation**	**M30**
2	Type of Cement	OPC 43 grade confirming to IS-8112-1987
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content	310 kg/m^3
5	Maximum Water Cement Ratio	0.45
6	Workability	100 (Slump)
7	Exposure Condition	Severe
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate
10	Maximum Cement Content	450 kg/m^3
A-2	**Test Data for Materials**	

1	Cement Used	ACC Cement 43 grade
2	Sp. Gravity of Cement	3.15
3	Sp. Gravity of Water	1.00
4	Sp. Gravity of Aggregates	2.76
5	Sp. Gravity of Sand	2.65
6	Water Absorption of 20 mm Aggregate	0.81%
7	Water Absorption of 10 mm Aggregate	0.4%
8	Water Absorption of Sand	1.23%
9	Free (Surface) Moisture of 20 mm Aggregate	Nil
10	Free (Surface) Moisture of 10 mm Aggregate	Nil
11	Free (Surface) Moisture of Sand	Nil
12	Sieve Analysis of Individual Coarse Aggregates	Separate Analysis Done
13	Sieve Analysis of Combined Coarse Aggregates	Separate Analysis Done
14	Sp.Gravity of Combined Coarse Aggregates	2.76
15	Sieve Analysis of Fine Aggregates	Separate Analysis Done
A-3	**Target Strength for Mix Proportioning**	
1	Target Mean Strength	38.25 N/mm^2

2	Characteristic Strength @ 28 days	30 N/mm^2
A-4	**Selection of Water Cement Ratio**	
1	Maximum Water Cement Ratio	0.45
2	Adopted Water Cement Ratio	0.4
A-5	**Selection of Water Content**	
1	Maximum Water content (10262-table-2)	186 Litres
2	Estimated Water content for 50-75 mm Slump	160 Litres
A-6	**Calculation of Cement Content**	
1	Water Cement Ratio	0.4
2	Cement Content (160/0.4)	400 kg/m^3
		Which is greater then 310 kg/m^3
A-7	**Proportion of Volume of Coarse Aggregate & Fine Aggregate Content**	
1	Vol. of C.A. as per table 3 of IS 10262-2009	62.00%
2	Adopted Volume of Coarse Aggregate	64.00%
	Adopted Volume of Fine Aggregate (1-0.62)	36.00%
A-8	**Mix Calculations**	
1	Volume of Concrete in m^3	1.00
2	Volume of Cement in m^3	0.13
	(Mass of Cement) / (Sp. Gravity of Cement)x1000	
3	Volume of Water in m^3	0.16
	(Mass of Water) / (Sp. Gravity of	

	Water)x1000	
4	Volume of Admixture @ 0.5% in m^3	0.00168
	(Mass of Admixture)/(Sp. Gravity of Admixture)x1000	
5	Volume of All in Aggregate in m^3	0.71
	Sr. no. 1 – (Sr. no. 2+3+4)	
6	Volume of Coarse Aggregate in m^3	0.44
	Sr. no. 5 x 0.62	
7	Volume of Fine Aggregate in m^3	0.27
	Sr. no. 5 x 0.38	
A-9	**Mix Proportions for One Cubic metre of Concrete (SSD Condition)**	
1	Mass of Cement in kg/m^3	400
2	Mass of Water in kg/m^3	160
3	Mass of Fine Aggregate in kg/m^3	661.62
4	Mass of Coarse Aggregate in kg/m^3	1225.44
6	Water Cement Ratio	0.40

Ratio of the design mix= 1 : 1.65 : 3.06(Binder: Fine aggregates: Coarse aggregates)

3.3 PRELIMINARY TESTS CONDUCTED ON INGREDIENTS

SPECIFIC GRAVITY TEST

1.0 For Flyash and Cement

Table.3.3.1 Specific gravity test results

S. No.	**Observation material**	**Flyash (gm)**	**Cement (gm)**
1.	Weight of material	10	10
2.	Weight of density bottle (W_1 g)	36.4	36.4
3.	Weight of density bottle + kerosene (W_2g)	75.7	81.9
4.	Weight of bottle + material + kerosene (W_3 g)	75.7	83.2
5.	Weight of bottle + water (W4 g)	85.7	85.7
6.	Specific gravity G at T_x^0 C	**2.09**	**3.18**

2.0 For aggregates

Table 3.3.1(a) Specific gravity of aggregates

Sr. No.	**Particulars**	**Fine aggregate**	**Coarse aggregate**
1	Mass of Pycnometer(M1) gm	700.5	700.5
2	Mass of pycnometer + material (M2) gm	1175.9	1203.3
3	Mass of pycnometer + material + distilled water (M3) gm	1869.9	1904
4	Mass of Pycnometer + distilled water (M4) gm	1574.5	1574.9
5	Specific Gravity = G = M2-M1 (M2 – M1) - (M3 – M4)	**2.65**	**2.75**

Sieve size distribution of aggregates(Sieve Analysis Test)

(a)Coarse aggregates

Table .3.3.2 sieve size distribution of coarse aggregates

Sieve size	Wt. retained	%wt retained	Cumulative wt retained	%finer
20mm	425 gm	8.5%	8.5%	91.5%
16mm	1463.1 gm	29.26%	37.76%	62.24%
12.5mm	2547.7gm	50.95%	88.71%	11.29%
10mm	496.5gm	9.93%	98.64%	1.36%
4.5mm	56.3gm	1.13%	99.77%	0.23%
Pan	11.4gm	0.23%	100%	0%

The fineness modulus for the coarse aggregates=4.5

(b)Fine Aggregates

Table 3.3.3 sieve size distribution of fine aggregates

Sieve size	Wt retained(gm)	%wt retained	Cumulative weight retained	%finer
4.75mm	21.1	2.11	2.11	97.89
2.36mm	242.4	24.24	26.35	73.65
1.18mm	201.3	20.13	46.48	53.52
600u	143.5	14.35	60.83	39.17
300u	132.1	13.21	74.04	25.96
150u	221.2	22.12	96.16	3.84
Pan	30.4	3.04	99.2	0.8

The fineness modulus for the fine aggregates =2.94

3.4 CASTING, CURING AND TESTING OF SPECIMEN SAMPLES

Twelve cubes of sizes 150x150x150 mm were for strength test. Cube strength was examined at different age's i.e. 7, 28, 56 and 90 days.
Five cylindrical cubes of sizes 100mm diameter and 50mm height were casted for water absorption characteristics of concrete for different % of flyash replacement..
Fifteen mortar cubes of 50x50x50 mm based on ordinary Portland cement and blended cement mixed with flyash for durability test (sulphate resistance). The resistance to sulphate attack were evaluated by immersion of well-cured specimens after 28 days of curing in a standard sodium sulphate solution(Na_2SO_4) having concentration of 16 gm/l [Buenfeldand Newman, 1984]. The specimens were alternately wetted and dried at 7 days intervals and then determining the strength loss as a result of sulphate exposure for 28 days.

Details of fly ash replacement

Fly ash has been added as percentage by weight of total cementitious material replacing cement by various percentages. Table A illustrates the detail of various percentages chosen.

Table(3.4) Denotation of symbols

Symbols	**% of cement**	**% of flyash**
C100	100	0
F10	90	10
F20	80	20
F30	70	30
F40	60	40

Fig3.3(a).Design mix for plain concrete of grade M30

Fig .3.3(b) Design mix for flyash based concrete

Fig 3.3(c)(i) Plain Concrete in moulds

Fig.3.3(c) (ii) Flyash based concrete in moulds

Fig. 3.3(d) Concrete cube of grade M30

Fig 3.3(e) Cylinderical specimen based on plain concrete(M30)

Fig. 3.3(f) Concrete cubes in curing tank

Fig 3.3(g) Cylinder cubes based on plain concrete and flyash based concrete

Fig 3.3(h) Mortar cubes based on cement and flyash based cement

Fig.3.3(i) Concrete cube tested under compression testing machine

Fig 3.3(j) Plain Concrete cube under compression testing machine

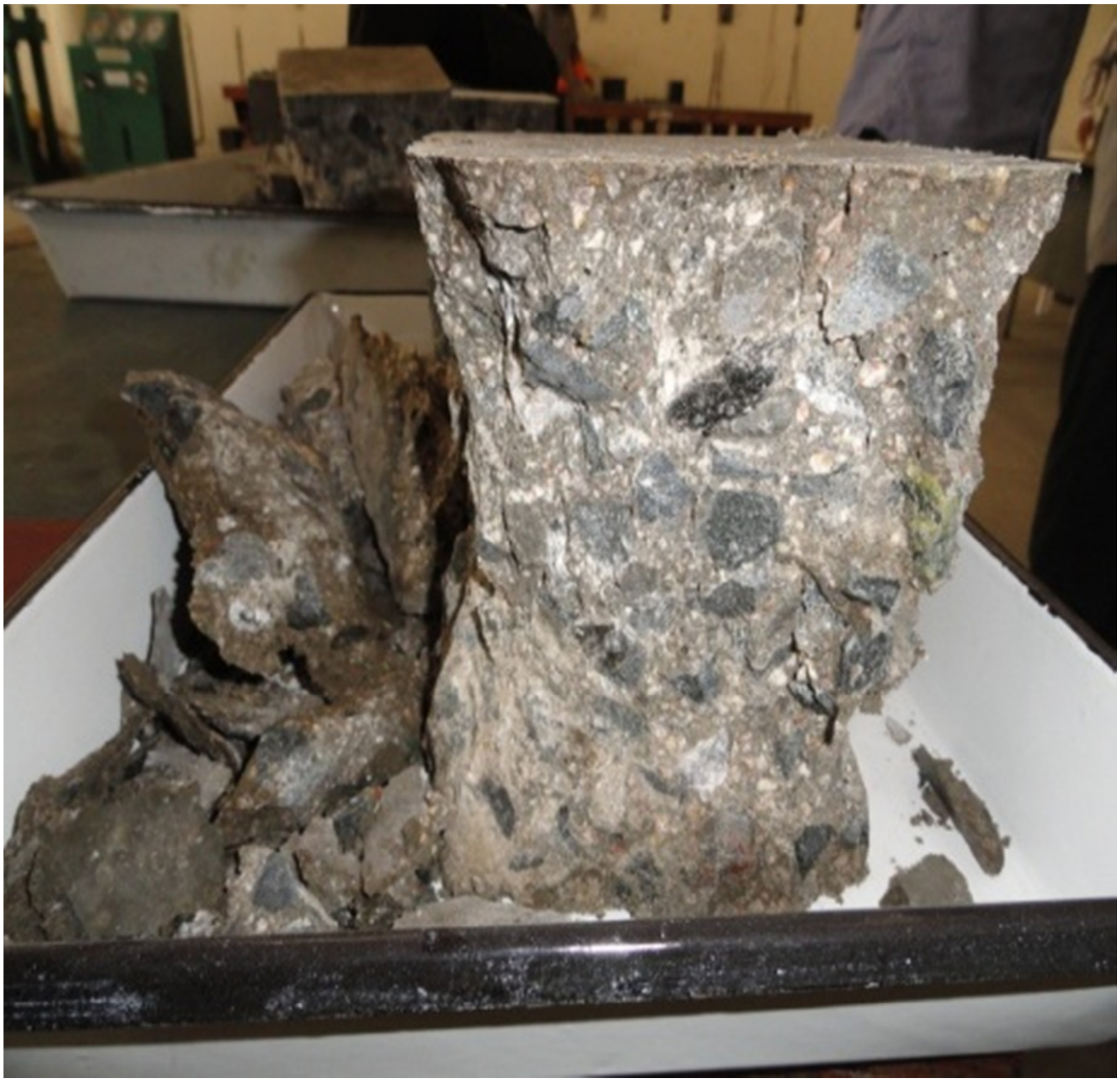

Figure 3.3(k) **Fractured surfaces of flyash based concrete cubes exposed after compression.**

CHAPTER IV

4. RESULTS AND DISCUSSIONS

Various parameters which significantly affect the properties of fresh and hardened concrete with the inclusion of fly ash and also on the cementitious properties of cement are discussed below.

4.1 EFFECT OF FLY ASH ON CEMENTITIOUS PROPERTIES

The variation of normal consistency for different grades of cement using different percentage of fly ash as partial replacement by weight is shown in Fig. 4.1(a).
The variation of initial setting time (IST) and final setting time (FST) for cement with fly ash content are approximately linear(refer Fig. 4.1(b) (c).
This shows that setting time increases with the increase in flyash content. The variation of normal consistency of cement, initial setting time, final setting time etc. using different percentage of fly ash as partial replacement by weight is shownin tabular form below.

Table .4(2) Effect on cementitious properties of cement on adding flyash.

Descriptions	**Normal consistency(P%)**	**Initial Setting Time(min)**	**Final Setting Time(min)**
C100	26	40	150
F10	28	60	200
F20	29	90	280
F30	31	130	320
F40	33	155	330

From the tabular data it is seen that the inclusion of flyash in cement increases the water requirement as indicated by increase of normal consistency, initial setting time,final setting time. This may be due to the slower heat of hydration of flyash particles on addition of wate

The variation of the cementitious properties of flyash can be shown graphically below.

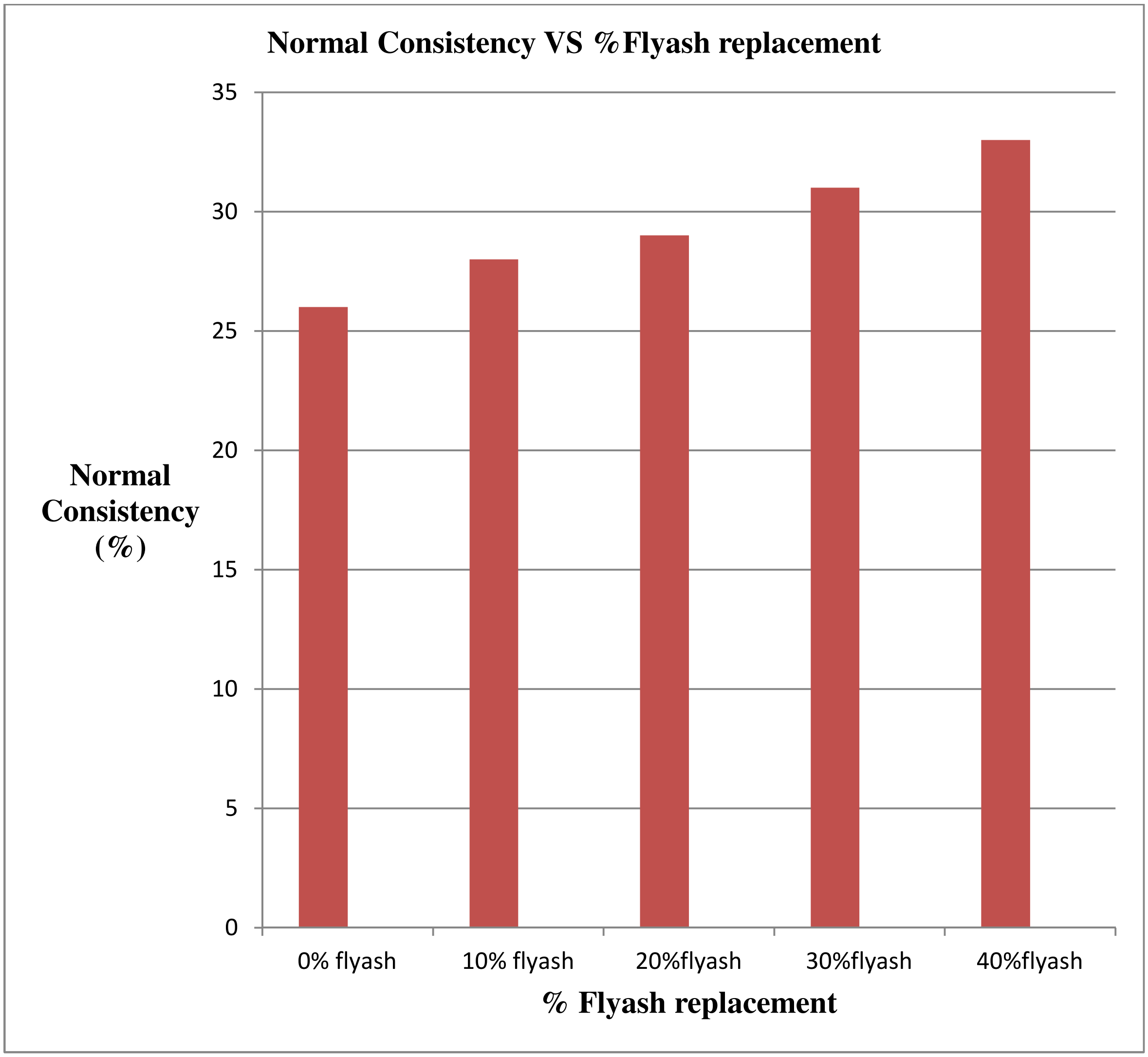

Fig.4.1(a)graph showing consistency of cement paste with percentage increase in flyash

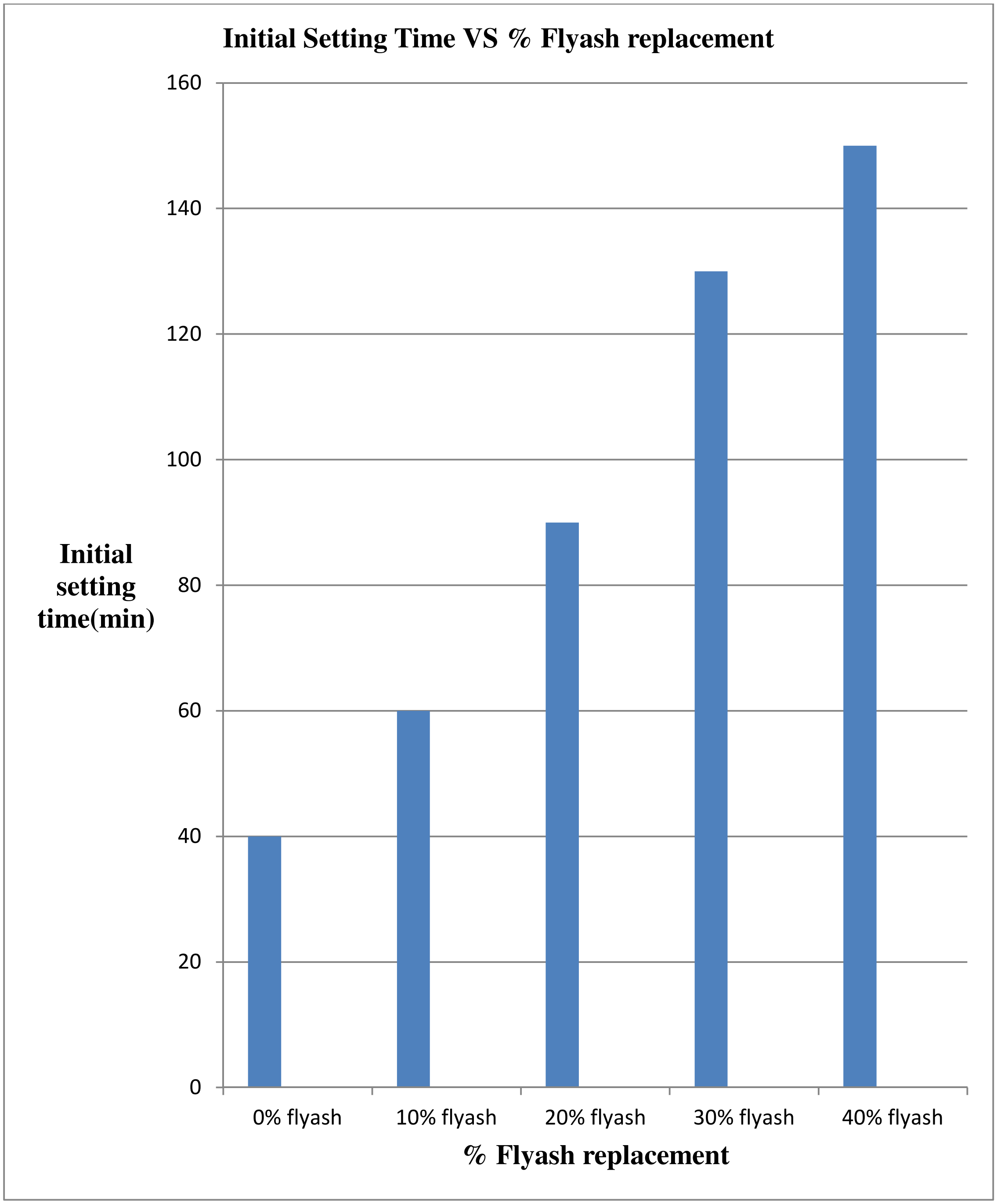

Fig .4.1(b)Initial setting time variation with increase in percentage flyash replacement

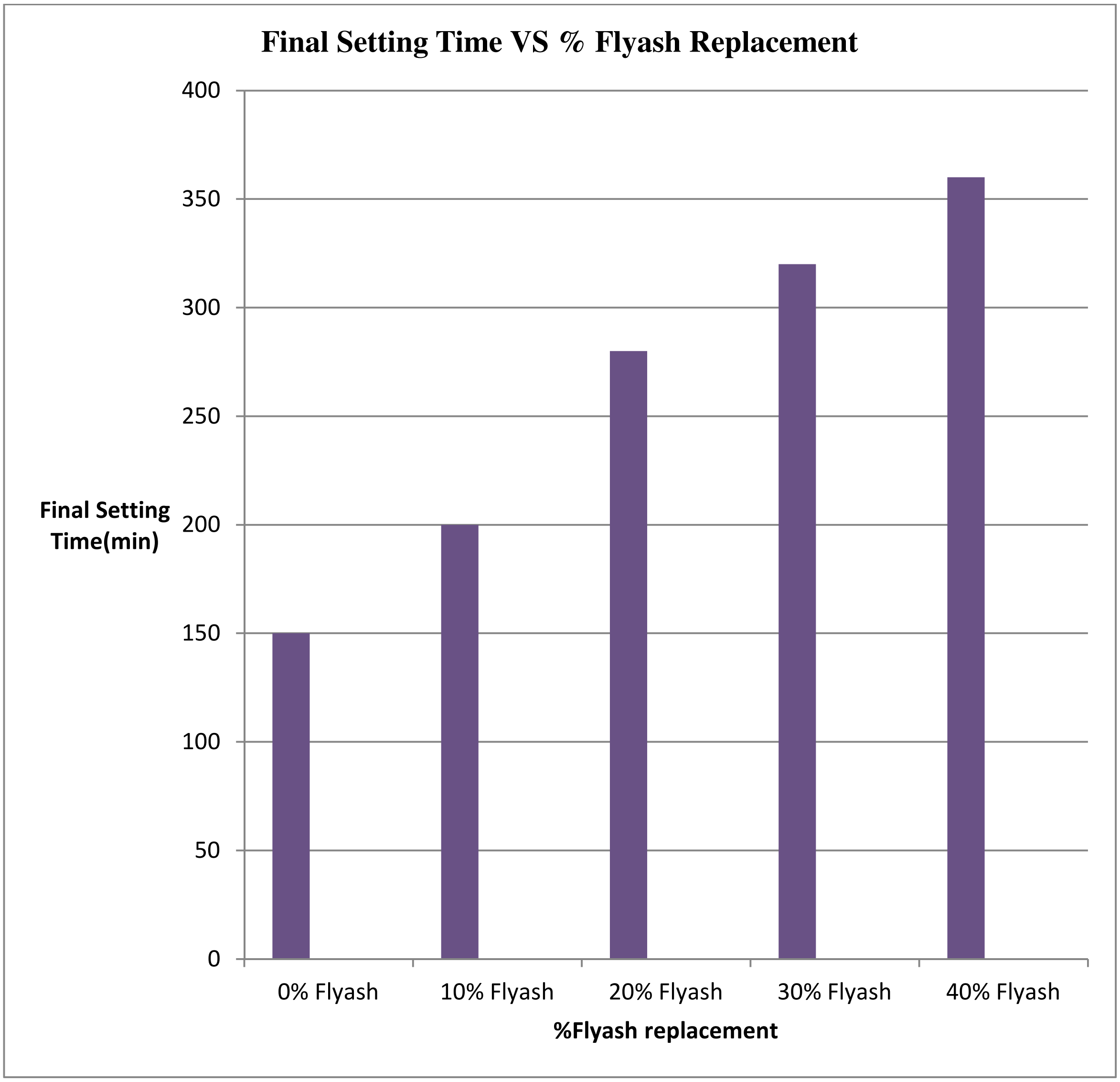

Fig.4.1(c) Final settting time variation with percentage flyash replacement

4.2 EFFECT OF FLY ASH ON CONCRETE PROPERTIES

Fresh concrete

4.2.1. Workability

Workability of concrete increased with the inclusion of fly ash in comparison to that of concrete with pure cement. The reason may be due to the increase of the paste volume that leads to the increase of plasticity and cohesion. To accomplish the workability properties, for each mix slump test was carried out. The test
results of workability properties are presented in Table. The test is carried out keeping wate binder ratio constant of 0.4. Theresults of the quantitative measurements and visual observations showed that increase of flyash had good flowability and produced desired results but upto a certain limit of flyash addition.The test is performed at same water cement ratio of 0.4 on increasing the percentage flyash replacement.

Table 4(3). Slump test results of fresh concrete

S.No	Description	Slump(mm)
1.	C100(plain concrete)	70
2.	F10(10% flyash based concrete)	75
3.	F20(20% flyash based concrete)	82
4.	F30(30% flyash based concrete)	70
5.	F40(40% flyash based concrete)	68

The variation of workability with percentage flyash replacement is shown graphically below.

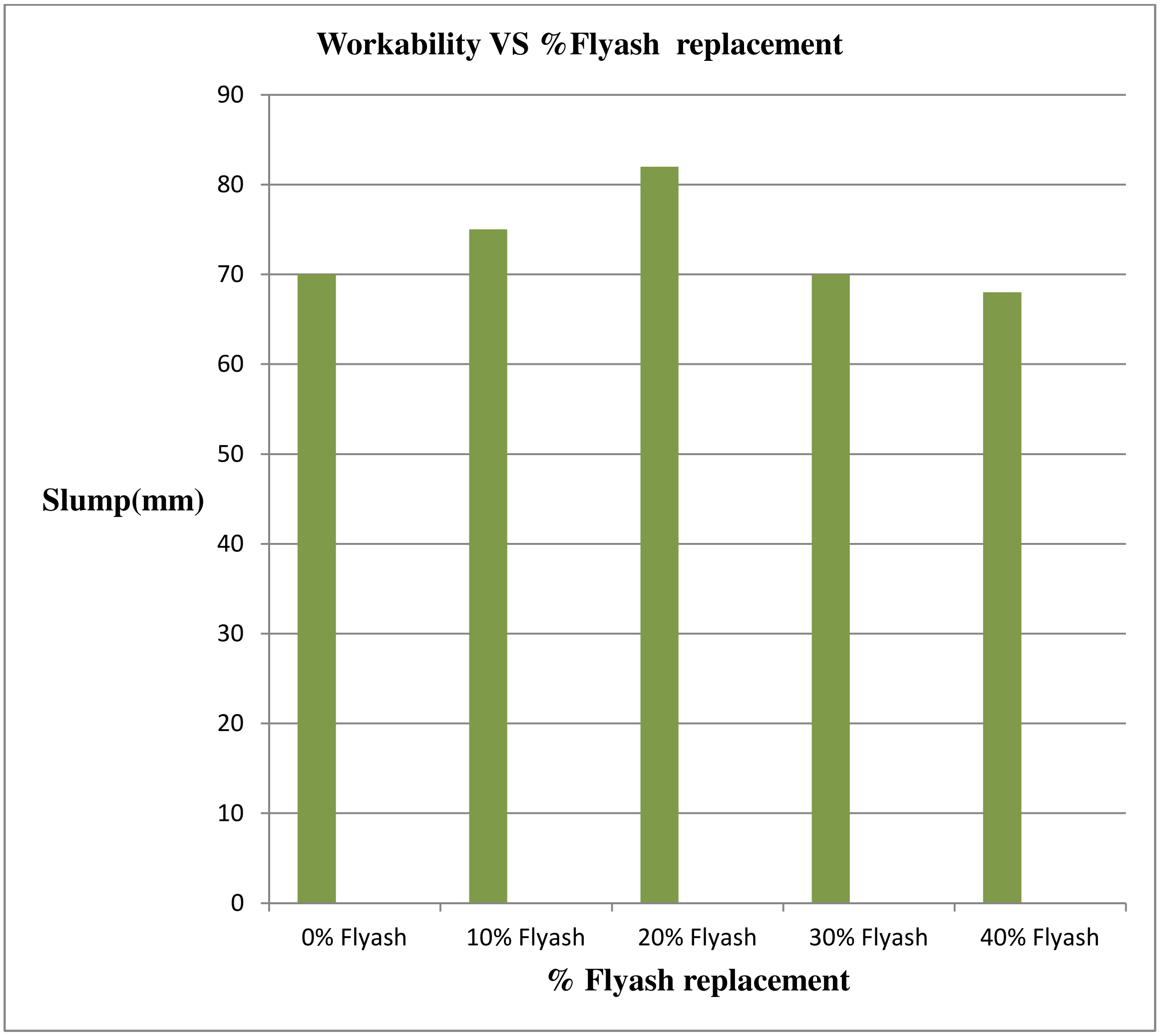

Fig4.2.(a). Graph showing variation of workability vs percentage Flyash replacement

4.3 Hardened concrete

4.3.1.Compressive strength

Variation of cubes strength at different ages of 7, 28, 56 and 90 days with different percentage of fly ash as partial replacement by weight is shown in table 4(5). The plot shows that the strength of concrete decreases with increase of fly ash contents at the early ages.. The 28 days cube strength at different percentage flyash replacement is also considerably reduced as compared to that of concrete with pure cement. Similarly, at 56 days also strength is comparably lesser than plain concrete but increases in comparison to 28days.. At this age, the reduction in strength is lower as compared to that of 7 and 28 days.. Similarly, the 90 days cube strength reduction for sample containing different fly ash is still lower to normal concrete.This shows that strength of fly ash concrete increases with age. Further, it is also observed that at the age of 90 days the rate of strength gain of concrete is increased ..This shows that fly ash have an effect of delayed hardening on strength gain of concrete. For concrete at 90 days the 10, 20, 30 and 40% replacement by fly ash causes a reduction in strength of about 7, 5, 16, 26% at 10,20,30,40%flyash replacement respectively.

Table 4(4).Mix design (M30 Grade)

	C100 (0% flyash)	F10 (10%flyash)	F20 (20%flyash)	F30 (30%flyash)	F40 (40%flyash)
Flyash(in kg/m3)	0	40	80	120	160
Cement (in kg/m3)	400	360	320	280	240
Fine aggregates(in kg/m3)	661.62	661.62	661.62	661.62	661.62
Coarse aggregates(in kg/m3)	1225.44	1225.44	1225.44	1225.44	1225.44
Water(kg/m3)	160	160	160	160	160

Design ratio

Cement : F.A : C.A : Water

400 661.62 1225.44 160

1 : 1.65 : 3.06 : 0.40

where F.A= fine aggregates(sand)
C.A=coarse aggregates

Table4 (5). Compressive strength at different age

S.No	Description	Strength at 7days(MPa)	Strength at 28days(MPa)	Strength at 56days(MPa)	Strength at 90days(MPa)
1.	C100	32	41	45	47
2.	F10	26	36	40	45
3.	F20	24	34	39	44
4.	F30	21	32	38	42
5.	F40	18	28	35	40

The graphical variation of compressive strength with increase in %age flyash replacement is shown below at different age.

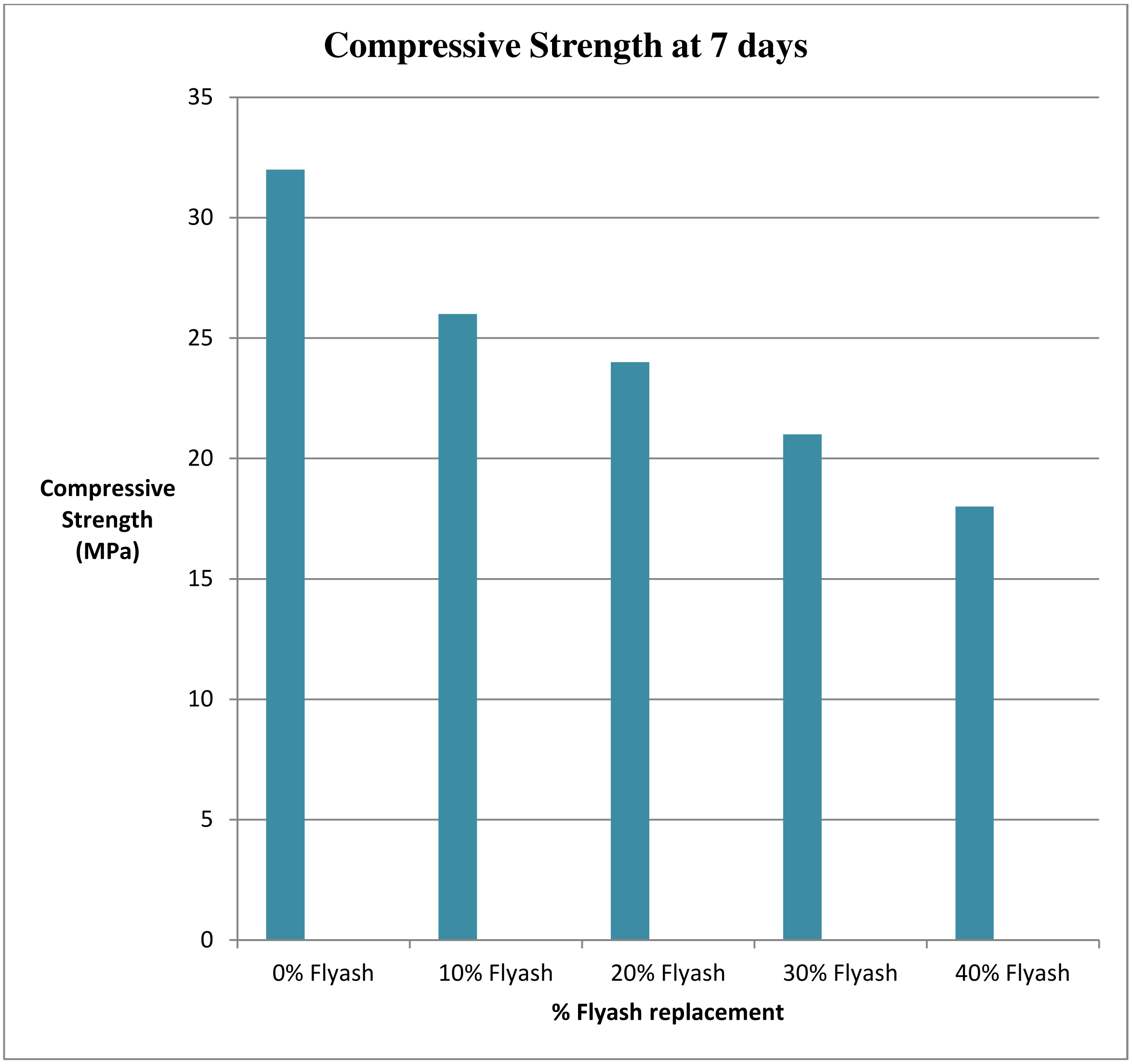

Fig.4.3(a) Graphical variation of compressive strength with %Flyash replacement at 7 days

The graph drawn above shows that with increase in %age flyash , the compressive strength is decreasing due to slow heat of hydration. This effect is observed at 28 days as well which is drawn below.

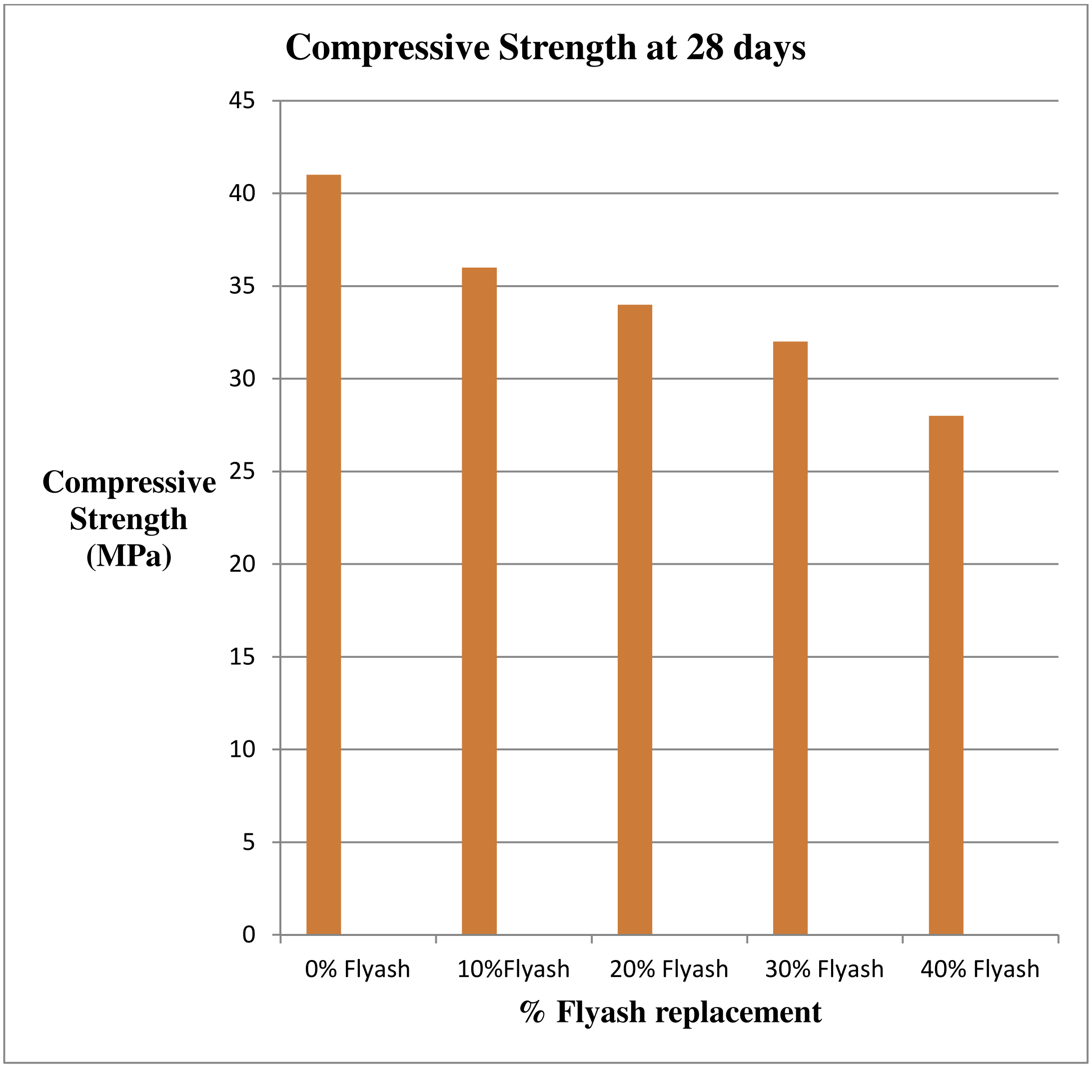

Fig.4.3(b) Graphical variation of compressive strength with %Flyash replacement at 28days.

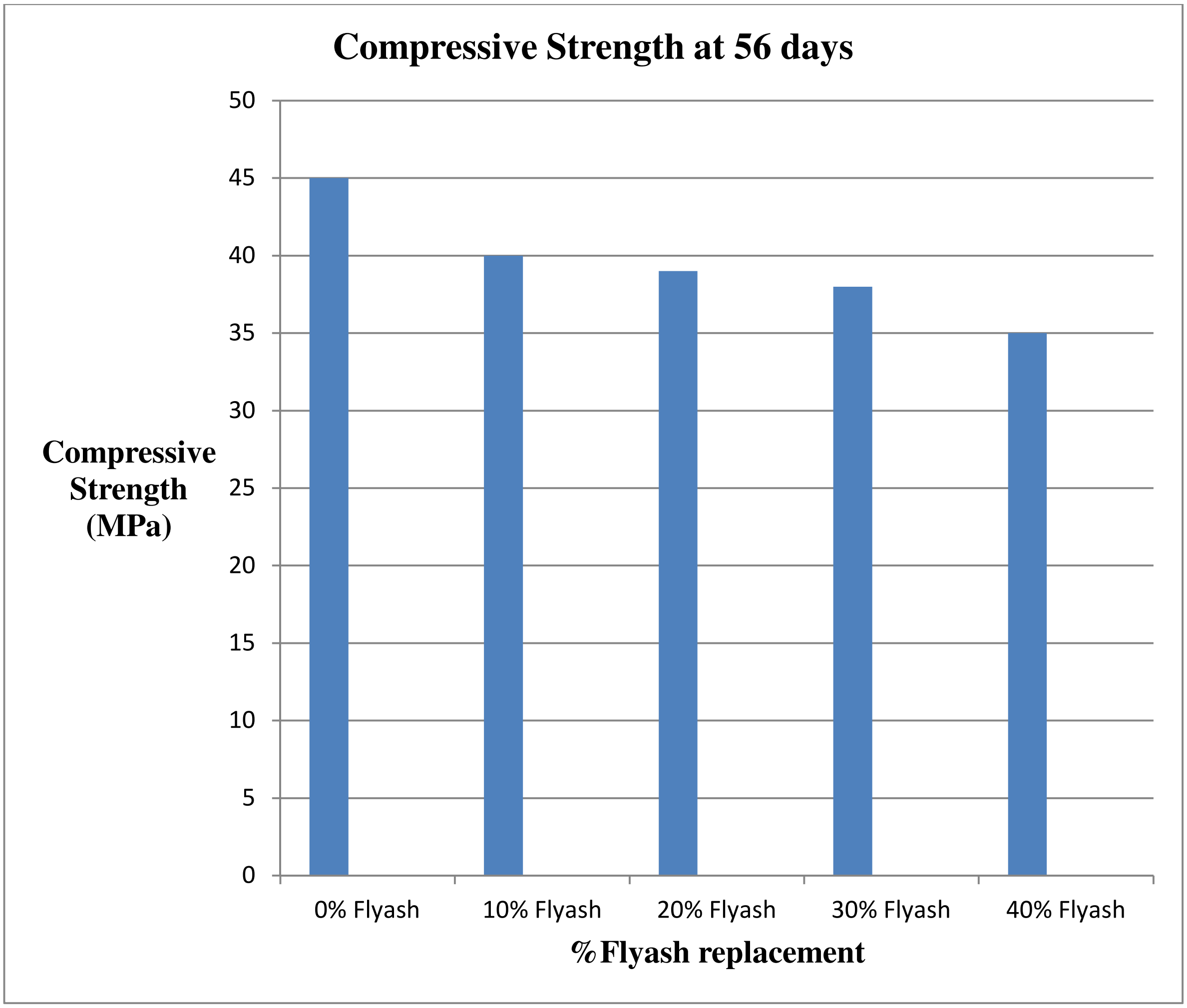

Fig.4.3(c) Variation of compressive strength with increase in %flyash replacement at 56 days.

From the above graph we can see that with increasing time period of curing the decrease in %age decrement in compressive strength on flyash addition is decreasing and it is becoming comparable with that of plain concrete. The strength at 90days is comparable as shown in the figure below.

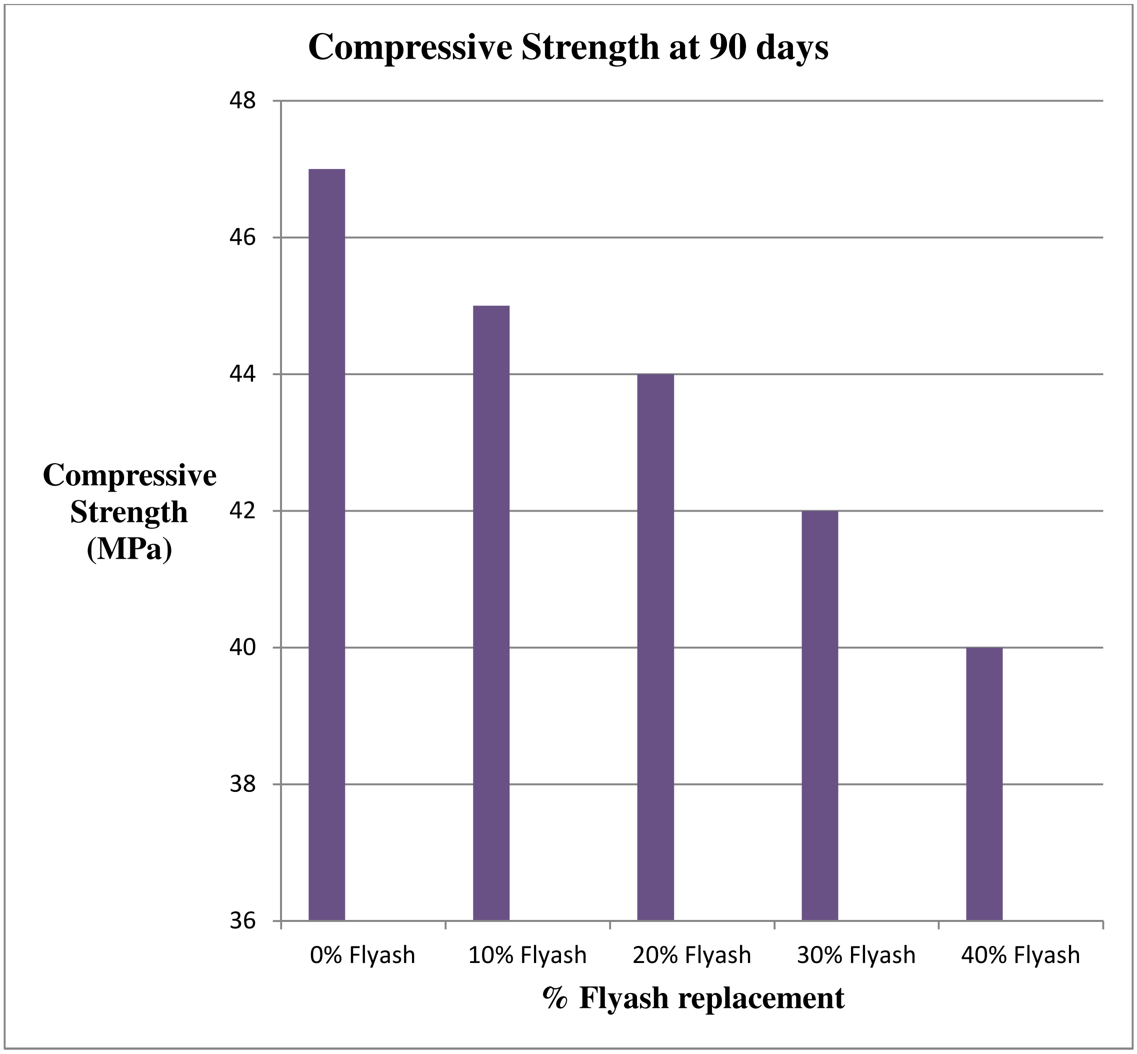

Fig.4.3(d) Variation of compressive strength with increase in %flyash replacement at 90 days.

The increase in compressive strength of concrete with age is increasing at a very fast rate in comparison to normal concrete at 56 and 90 days.

Table 4(6) The percentage variation in strength is plotted below.

Designation	**% increase in strength at 56 days**	**% increase in strength at 90 days**
C100	9.75	14.6
F10	11.11	25
F20	14.7	29.4
F30	18.75	31.25
F40	25	42.28

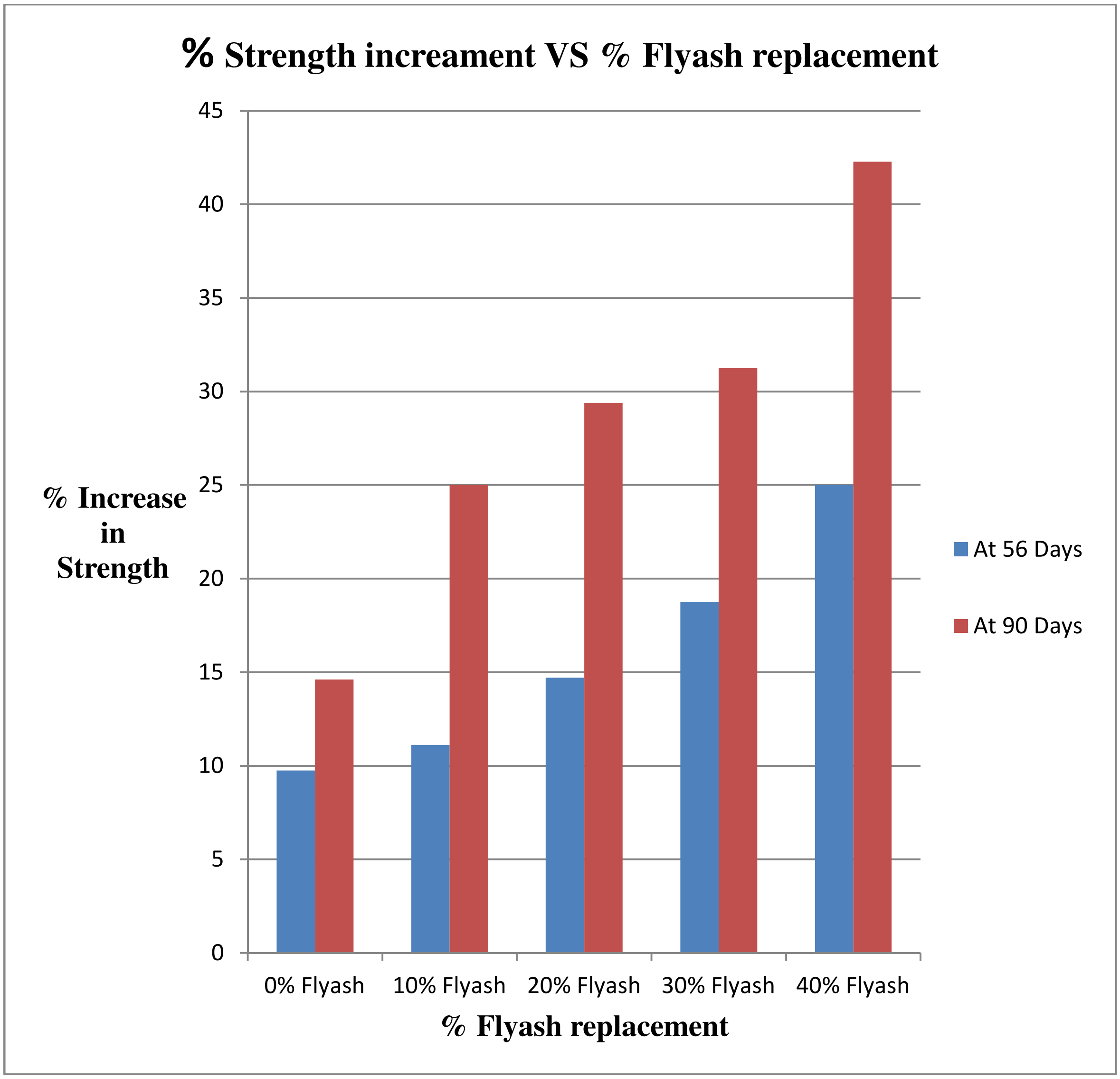

Fig.4.3(e)Percentage increase in strength with increase in percentage flyash at 56 and 90days.

4.3.2 Water Absorption

Cylindrical specimen of dimension 100mm dia x 50 mm height after casting were immersed in water for 90 days curing. Ref [**12] .These specimens were then oven dried for 24 hours at the temperature110°C until the mass became constant and again weighed. This weightwas noted as the dry weight (W1) of the cylinder. After that the specimen was kept in hot water at 85°c for 3.5 hours. Then this weight was noted as the wet weight (W2) of the cylinder. % water absorption = [(W2– W1) / W1] x 100 Where, W1 = Oven dry weight of cylinder in grams W2 = After 3.5 hours wet weight of cylinder in grams.Inclusion of flyash increases the water absorption of concrete as depicted by the experimental results shown in the tabular form below.

Table 4(7) Average % water absorption at 90 days for M30

Description	**dry wt in grams (W1)**	**Wet wt. in grams (W2)**	**% water absorption**
C100	928.52	933.42	0.52
F10	940.81	958.60	1.89
F20	920.36	940.33	2.16
F30	880.44	905.61	2.85
F40	901.50	931.66	3.40

Graphical variation of Water absorption with increase in% Flyash at 90 days is shown below.

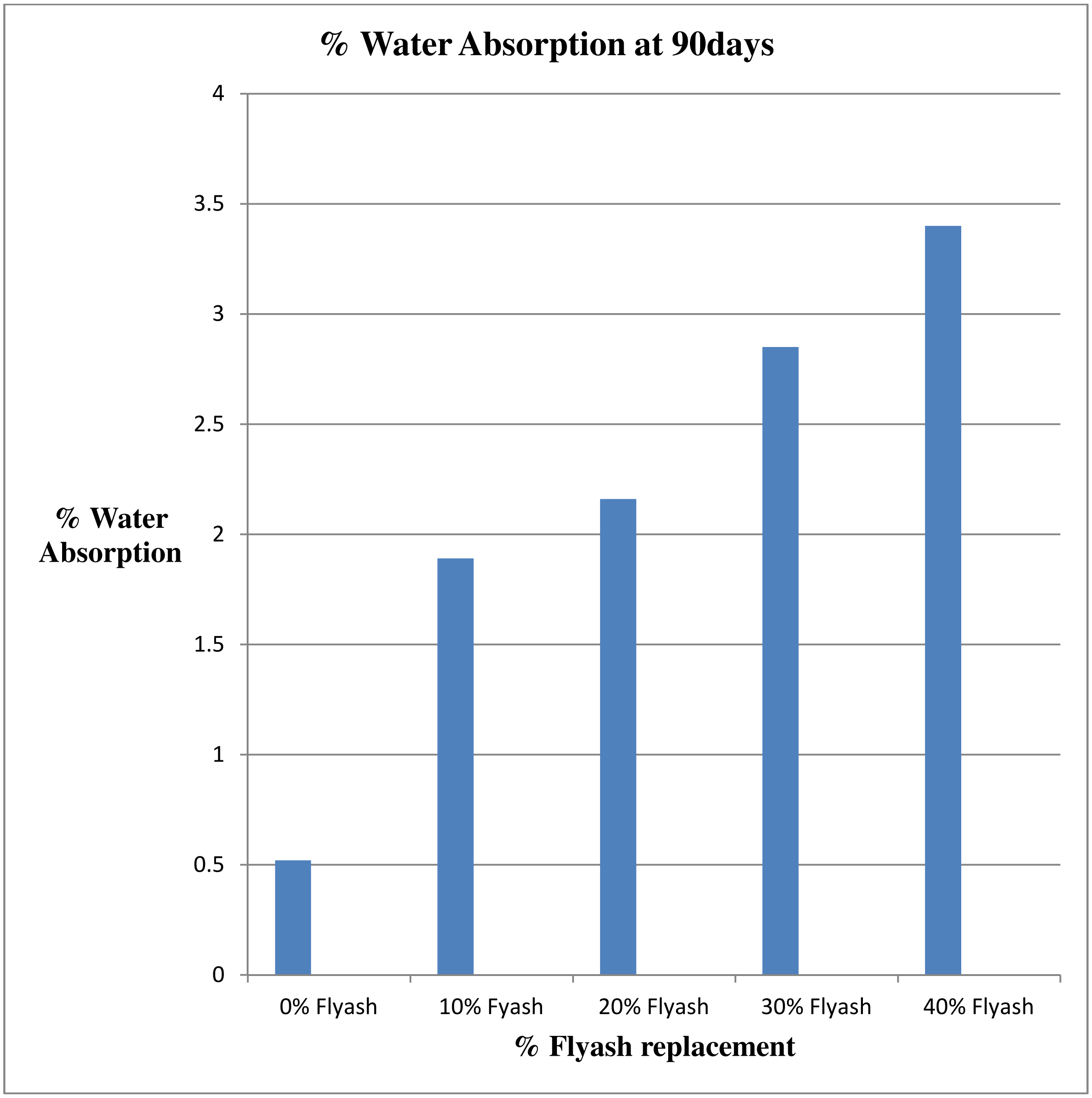

Fig.4.3 (f) Water absorption VS % Flyash replacement at 90 days

4.3.3 Sulphate attack

The project report discusses the effect of flyash addition to concrete in resisting the sulphate attack when concrete is exposed to saline environment. Variation in compressive strength of mortar cubes with fly ash content for 28 days exposed in sulphate solution and tap-water is observed and shown in Table 4(8). The figure demonstrates that, for each grade of mortar cube the strength of ordinary cube and that replaced by fly ash immersed in sulphate solution have less compressive strength than the corresponding referral cubes immersed in tap-water. The strength was found less as fly ash contents is increased in both cases. Though, the strength exposed to sulphate solution decreases at each proportion of replacement as compared to cube strength exposed in tap-water, the decrease in strength is found to be more for ordinary cube than that of cubes containing fly ash. Cement paste containing fly ash favored the formation of expansive salts. Addition of fly ash to cement converts the leachable calcium hydroxide into insoluble non-leachable cementitious products. The increase in sulphate resistance may be due to the contained reaction of flyash with hydroxides in concrete to form additional calcium silicate hydrate (C-S-H), which fills in capillary pores in the cement paste, reducing permeability and the ingress of sulphate solution. Ref[**1].

Table 4(8) showing the compressive strength in tap water and sulphate solution at 28days.

Designation	Strength (MPa) in tap water at 28 days	Strength (MPa) in Sulphate solution at 28 days	% Decrease in Compressive strength
C100	37	34	5.4
F10	35	32	5.7
F20	33	31	6.2
F30	30	28	6.6
F40	26	24	7.6

The reduction in compressive strength when concrete is exposed in sulphate solution is marginally increased in comparison to plain concrete which is shown graphically below.

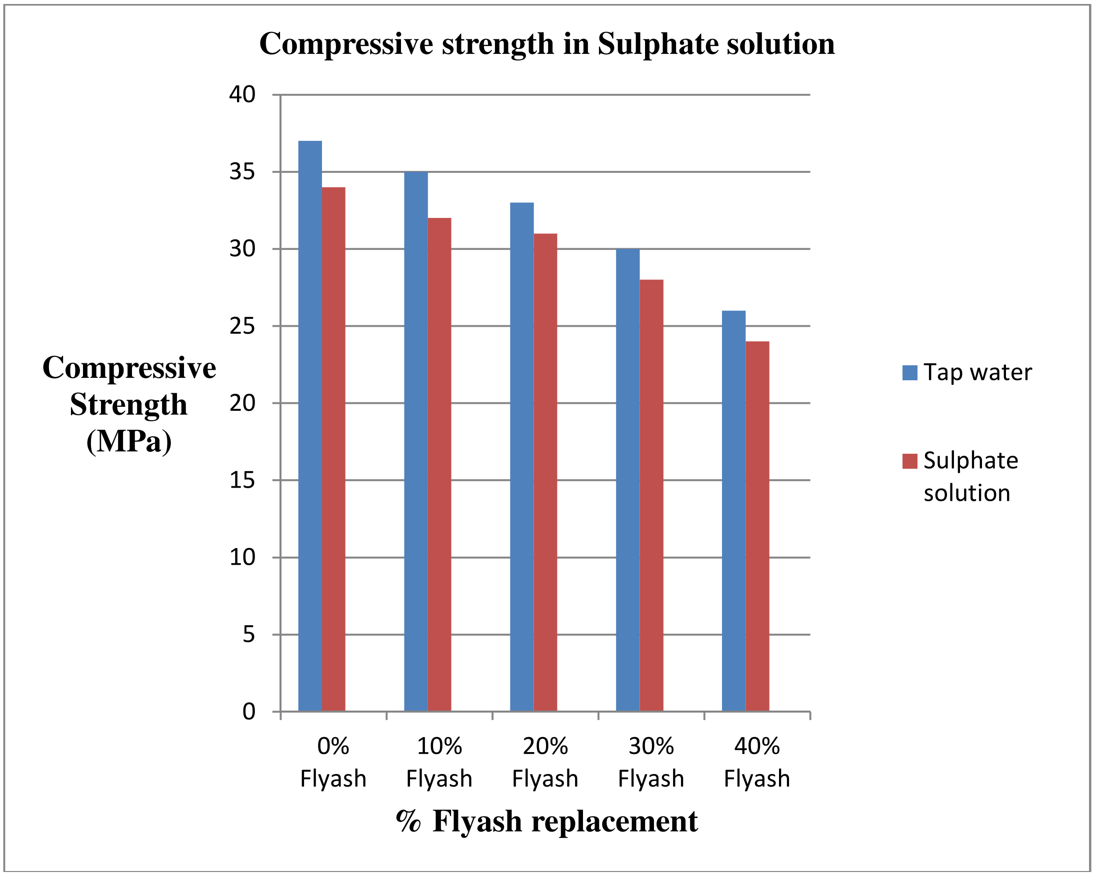

Fig.4.3(g) Compressive strength of mortar cubes exposed to sulphate solution and tap water at 28 days.

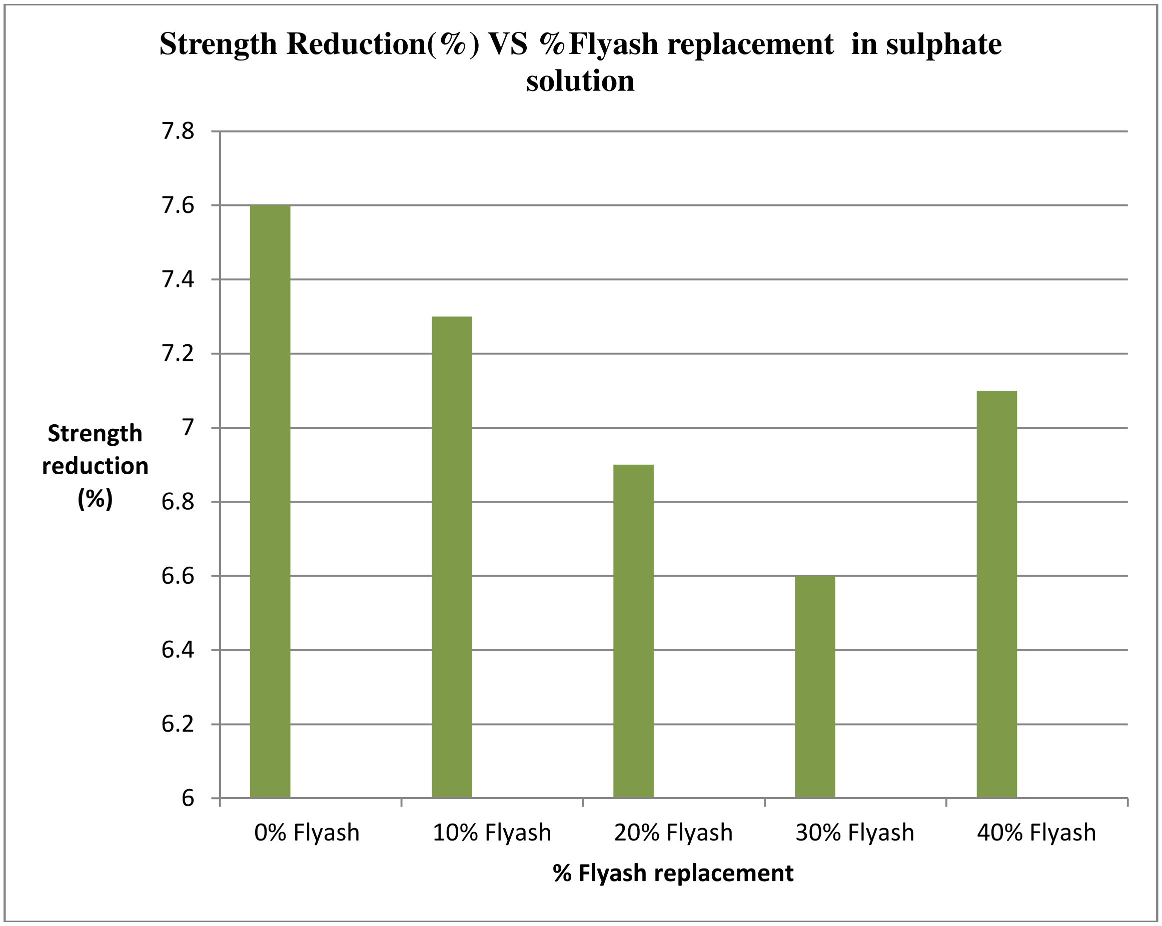

Fig.4.3(h) Plot of strength reduction of mortar cubes exposed to sulphate solution in comparison to tap water.

4.3.4.Impact Resistance Test

The impact resistance of the specimen was determined at 28 days, 90 days. The first visible crack (N1) and then cause ultimate failure (N2) were noted for all the specimens. The results of the Impact strength in number of blows are shown in Table No.4(9). The impact energy delivered to the specimen are calculated by each impact is calculated [8] as follows: EI = Nmgh where EI is impact energy (N m), N is the number of blows, m is mass of the drop hammer (kg), g is gravity acceleration (N/kg), and h is height of drop hammer (m). The impact resistance of the specimen was determined by using drop weight method of Impact test recommended by ACI committee 544 procedure. The size of the specimen recommended by ACI committee is 152 mm diameter and 63.5 mm thickness and the weight of hammer is 4.54 Kg with a drop of 457mm. The specimens placed on the base plate with the finished face up and positioned within four lugs of the impact testing equipment. [Ref **10]

Also Indian Standard 875-Part 5 discusses the impact loading on structures in the form of cyclic loading which gives us the idea of impact resistance.

Fig .4.3(i) Impact resistance machine[ref **9]

Table-4(9)Impact resistance of flyash based concrete(Impact strength in number of blows)

Description	Curing period(days)	Average No. of drops at first crack (N1)	Average No. of drops at failure (N2)	N2-N1	Impact Energy (Nm) at First Crack	Impact Energy (Nm) at Failure
C100	28	41	47	6	834	956
F10	28	36	40	4	732	814
F20	28	29	34	5	590	692
F30	28	24	29	5	488	590
F40	28	20	25	5	407	508
C100	90	42	47	5	855	956
F10	90	56	62	6	1140	1261
F20	90	60	68	8	1221	1384
F30	90	83	88	5	1689	1791
F40	90	53	59	6	1078	1200

Where C100= plain concrete specimen
F10= flyash specimen at 10% flyash content
F20= flyash specimen at 20% flyash content
F30= flyash specimen at 30% flyash content
F40= flyash specimen at 40% flyash content

The failure pattern of cylindrical cubes on impact is shown below and also the variation of impact strength with addition of % flyash can be shown graphically as below.

Fig 4.3(j) Concrete specimen after impact test showing the crack pattern

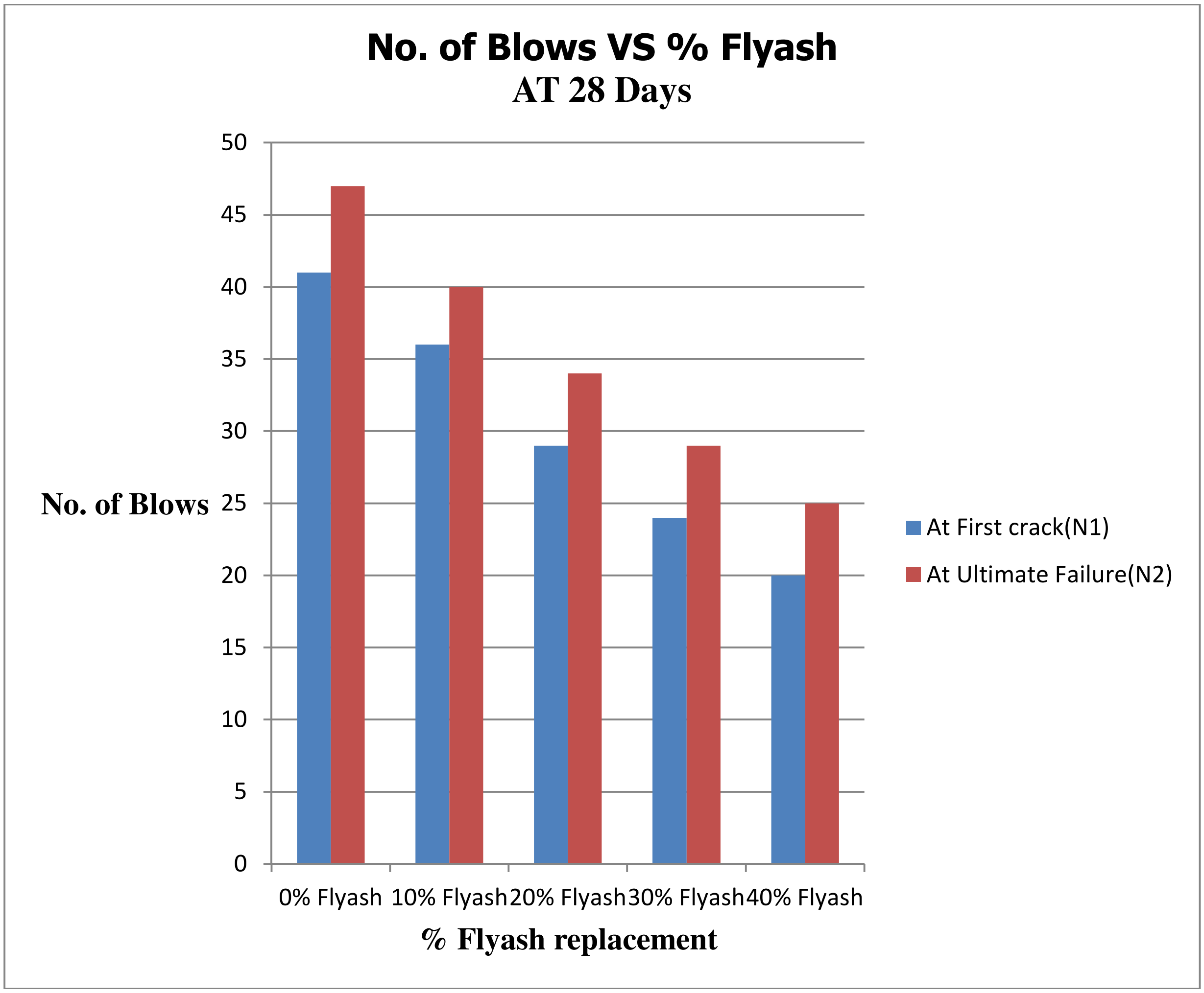

Fig.4.3(k) Variation of Number of blows in Impact Resistance with increase in % Flyash at 28 days.

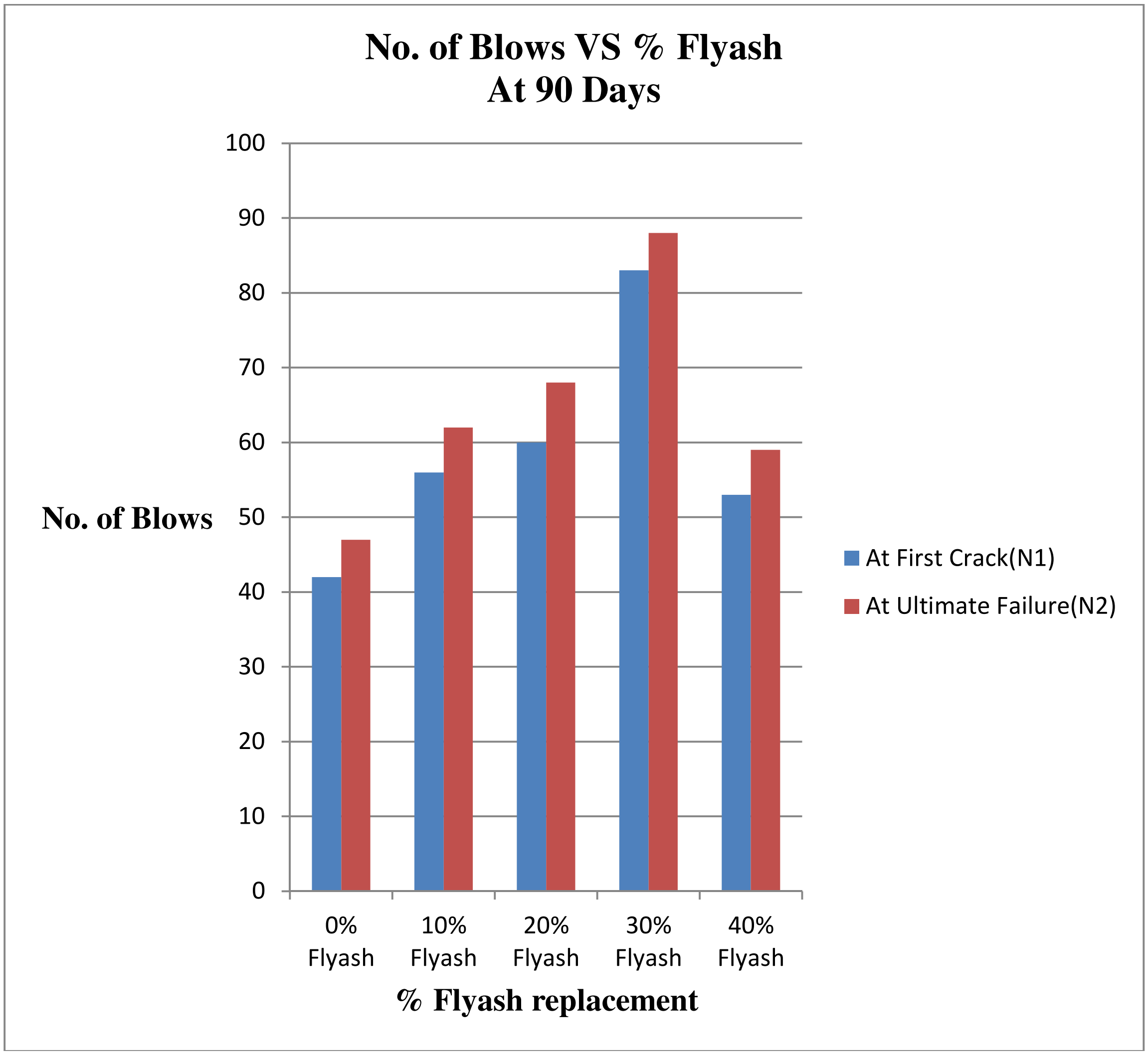

Fig.4.3 (l) Variation of number of blows in Impact Resistance with increase in % Flyash at 90 days.

DISCUSSION

In this study it has been focused on literature of the use of Class F fly ash in concrete as a part of blended cement or used directly into concrete mixer. Reported advantages and disadvantages have been collected. Several search on the Web for literature has been done, and a lot of articles and referrals have been checked, some with field results, but most of them with laboratory results. There were many articles that highlight the good properties of the use of fly ash, but few with the connection between fly ash blended cements and fly ash blended concretes and field constructions.

The advantages of the fly ash concrete can be listed up as following:

1. The experimental investigation has revealed that the workability due to fly ash based concrete has been improved due to the fineness of flyash particles and the spherical particle shape with lubricating effect. The workability is indicated by the slump value of concrete which increases on addition of flyash in the mix but upto a certain extent at same water -cementitious ratio.

2. The compressive strength of concrete based on cement only can be enhanced by the addition of flyash in the mix but only at later stage of reaction. This is due to the slow rate of hydration of flyash mixed in concrete. Strength is improved due to the pozzolanic reaction that produce more CSH gel and hence concrete is more strong in case of flyash mixed in it. Though the percentage increase in the strength of flyash based concrete is less at 28 days but it is improved at 56 days and 90 days.

3. Better crack resistance due to denser paste because of more CSH gel as depicted by the impact test

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4. Higher durability due to denser paste, less CH and consumption of alkali in the CSH.The resistance to sulphate attack on addition of flyash in concrete is improved. This is shown by the compressive strength of mortar cubes placed in tap water and sulphate solution.

5. Lower heat of hydration due to lower amount of hydrating cement and slow pozzolanic reaction.
6. More resistance to impact at later stage in comparison to plain concrete.

7. The main drawback with fly ash is the slower strength development. This makes a problem in concrete construction where rapid stripping and turnaround are essential. The reason is a smaller amount of cement to hydrate. The pozzolanic reaction of the fly ash is slow, but contributes to the later strength. To increase the strength of high volume fly ash more reactive cement or finer flyash may be used. Another possible solution is to change the demand for 28 days strength to 90 days .

CONCLUSION

From the experimental work carried out and the analysis of the results following conclusions seem to be valid with respect to the utilization of fly ash.

1) Normal consistency increases with increase in the grade of cement and fly ash content.

2) Initial setting time of cement increases with increase in content of flyash in cement.

3) Final setting time of cement increases with increase in content of flyash in cement.

4) Use of flyash improves the workability of concrete but upto a certain extent as depicted by the slump test. The slump value is increased on increasing the flyash content in concrete upto a certain limit and then starts decreasing at same water cement ratio.

5) Percentage water absorption at 90 days in case of concrete increases with increase in fly ash replacement. It may be because of decrease in the density of flyash concrete.

6) Compressive strength of concrete increases with grade of cement. As the fly ash contents increases there is reduction in the strength of concrete. This is expected, as the secondary hydration due to pozzolanic action is slower at initial stage for fly ash concrete. The reduction is more at earlier age as compared to later age.

7) Addition of flyash in mortar cubes provides better sulphate resistance. The compressive strength of mortar cubes decrease with increase in flyash content. It is seen that percentage decrease in compressive strength reduces and it is found to be minimum(6.6%) for 30% flyash replacement case.I t may be concluded that 30% of flyash replacement may be taken as the optimum case in connection with sulphate resistance.

8) It may also be concluded that the use of flyash in concrete gives a satisfactory performance in connection with impact resistance.

FUTURE SCOPE OF WORK

1.0 Flyash concrete poses a great problem of later strength development which is not a desirable property of concrete if early removal of formwork is desirable. Hence research must be undertaken in order to increase the strength enhancement of flyash at early stage of its preparation.

2.0 Strength enhancement of flyash can be done by various activation techniques of flyash such as mechanical activation in which the flyash particles are made more fine by grinding in suitable equipments so that the fineness of flyash samples can be enhanced and it may give more heat of hydration and hence strength development.

3.0 Secondly chemical activation of flyash can also be done by adding certain chemicals to flyash such as Sodium salts of sulphates, chlorides etc. in order to activate the particles of flyash and hence they become electrically more charged and reacts more rapidly.

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