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EFFECT OF CURING DAYS ON CONCRETE MADE BY PARTIALLY REPLACED CEMENT BY FLY ASH

A THESIS

BY

GROUP-02(B1)

Submitted to the Department of Civil Engineering, Sonargaon University(SU), Dhaka in partial fulfillment of the requirements for the degree

of

B.Sc. IN CIVIL ENGINEERING



Sonargaon University (SU)

Department of Civil Engineering

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LETTER OF TRANSMITTAL

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Subject: Submission of Project Report.

Sir,

This is our great pleasure that we are submitting here with the project report on ***"Effect Of Curing Days On Concrete Made By Partially Replaced Cement By Fly Ash"*** It is an important topic. The project report has been done according to the requirement and guidelines of the Sonargaon University (SU).

We hope that this report will certainly help you in evaluating our project report on ***"Effect Of Curing Days On Concrete Made By Partially Replaced Cement By Fly Ash".*** We would be very glad to provide any assistance in interpreting any part of the paper, whenever necessary.

Thanking You
Sincerely your

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DECLARATION

This is to declare that the work and material presented in the report has been carried out by us and has not previously been submitted to any University/College/Organization for any Academic qualification

We herby ensure that the work that has been presented does not breach existing copyright.

We undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligation.

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This is to certify that the project paper on ***"Effect Of Curing Days On Concrete Made By Partially Replaced Cement By Fly Ash"*** is the bona fide record of project work done others for partial fulfillment of the requirement of the degree of B.Sc. in Civil Engineering from the Sonargaon University(SU).

This project work has been carried out under my guidance and is a record of the successful work.

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Authors

ABSTRACT

Concrete is a construction material that is mostly used across the world. It is a composite material made out of water, cement, fine aggregate (sand) and coarse aggregate (stones). However, the manufacturing process of raw materials used in concrete such as cement and aggregate causes environmental influences (emission of greenhouse gases and dust) and significantly consumes energy and natural resources.

Aggregate normally accounts 70 to 80 % of the entire volume of concrete, while water and cement account 20 to 30 %. These percentages affect the mechanical properties of concrete. Replacing any of these materials by industrial waste material can have a positive impact on the environment. Hence, this project has focused on evaluating the opportunity of using one of these waste materials which is the fly ash as a partial replacement material for cement.

Fly ash is generally considered as a waste material that is produced as a by-product of coal combustion process. The physical and chemical properties of fly ash are similar to cement, which allows it to be used in concrete. The primary aim of this research is to determine the feasibility of using fly ash as a replacement of cement in concrete and their effects on the mechanical properties of concrete.

This Paper presents the results of an experimental investigation carried out to evaluate the mechanical properties (workability and compressive strength) of concrete mixtures in which cement was partially replaced with Fly Ash. Cement was replaced with two percentages (5%, 10%) of fly ash by weight. Tests were conducted for properties of fresh concrete (workability), and compressive strength was determined at 7, 14 and 28 days. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement of cement and can be effectively used in concrete structures.

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ABBREVIATION LIST

1. American Society for Testing and Materials (ASTM)
2. Aluminium oxide (Al_2O_3)
3. Calcium carbonate ($CaCO_3$)
4. Carbon dioxide (CO_2)
5. Calcium oxide (CaO)
6. Calcium hydroxide (CH)
7. Calcium silicate hydrate (CSH)
8. Dicalcium Silicate C2S ($2CaO.SiO_2$)
9. Fly Ash (FA)
10. High calcium Fly Ash (Class C)
11. Iron oxide (Fe_2O_3)
12. Low calcium Fly Ash (Class F)
13. Magnesium oxide (MgO)
14. Potassium oxide (K_2O)
15. Silicon dioxide (SiO_2)
16. Sodium oxide (Na_2O)
17. Sulfur Trioxide (SO_3)
18. Tetracalcium alumina-ferrite C4AF ($4CaO.Al_2O_3.Fe_2O_3$)
19. Tricalcium Aluminate C3A ($3CaO.Al_2O_3$)
20. Tricalcium Silicate C3S ($3CaO.SiO_2$)

CHAPTER-1
INTRODUCTION

1.1. BACKGROUND

Concrete plays a significant role in the construction of structures around the world. According to Construction Materials (2007) Concrete is a composite material obtained by mixing cement, sand, gravel and water. A concrete mix can be considered to consist of two main parts, aggregates (sand and gravel) and cement paste (water and cement).

The global demand of concrete is significantly increasing due to infrastructure growth worldwide. Therefore using alternative sources as replacement for cement and aggregates appears to be a challenging task. Industrial waste materials (recycled materials) can be used as alternative sources in concrete as they can assist in solving some environmental concerns , as they diminish the problem of waste disposal and reduce the intensive use of energy and natural resources (aggregate mining). In addition; the amount of emission of gases gets reduced.

There are many potential industrial waste products that have the potential to replace aggregates in concrete such as: plastic, fly ash, rubber, steel slugs and leather wastes. However, fly ash is the industrial waste material that is discussed in depth in this particular research.

1.2. OBJECTIVES

In order to achieve the scope of this research, the following objectives have to be met:

- Research background information on the basic materials of fly ash, cement and aggregate.
- Research the compressive strength of concrete replacing cement by fly ash.

1.3. SCOPE

The purpose of this research is to determine the feasibility of using fly ash as a replacement of cement in concrete. Using a product such as fly ash in concrete can influence the mechanical properties of concrete. The original scope of this study is to investigate the fresh and hardened properties of concrete with fly ash as a replacement of cement.

1.4. OUTLINE OF THE THESIS

The report is divided into five-chapter; Introduction (chapter 1) Literature review (Chapter 2), Methodology (Chapter 3), Laboratory Investigation (Chapter 4), Results and Discussion (Chapter 5) and Conclusion (Chapter 6).

In chapter-1, Is an introduction which addresses the topic, the reason for choosing this particular topic and the scope of this research.

In Chapter 2, Gives background information about fly ash, cement and aggregate. It provides information about their chemical and physical properties. It also includes the advantages and disadvantages of fly ash in concrete.

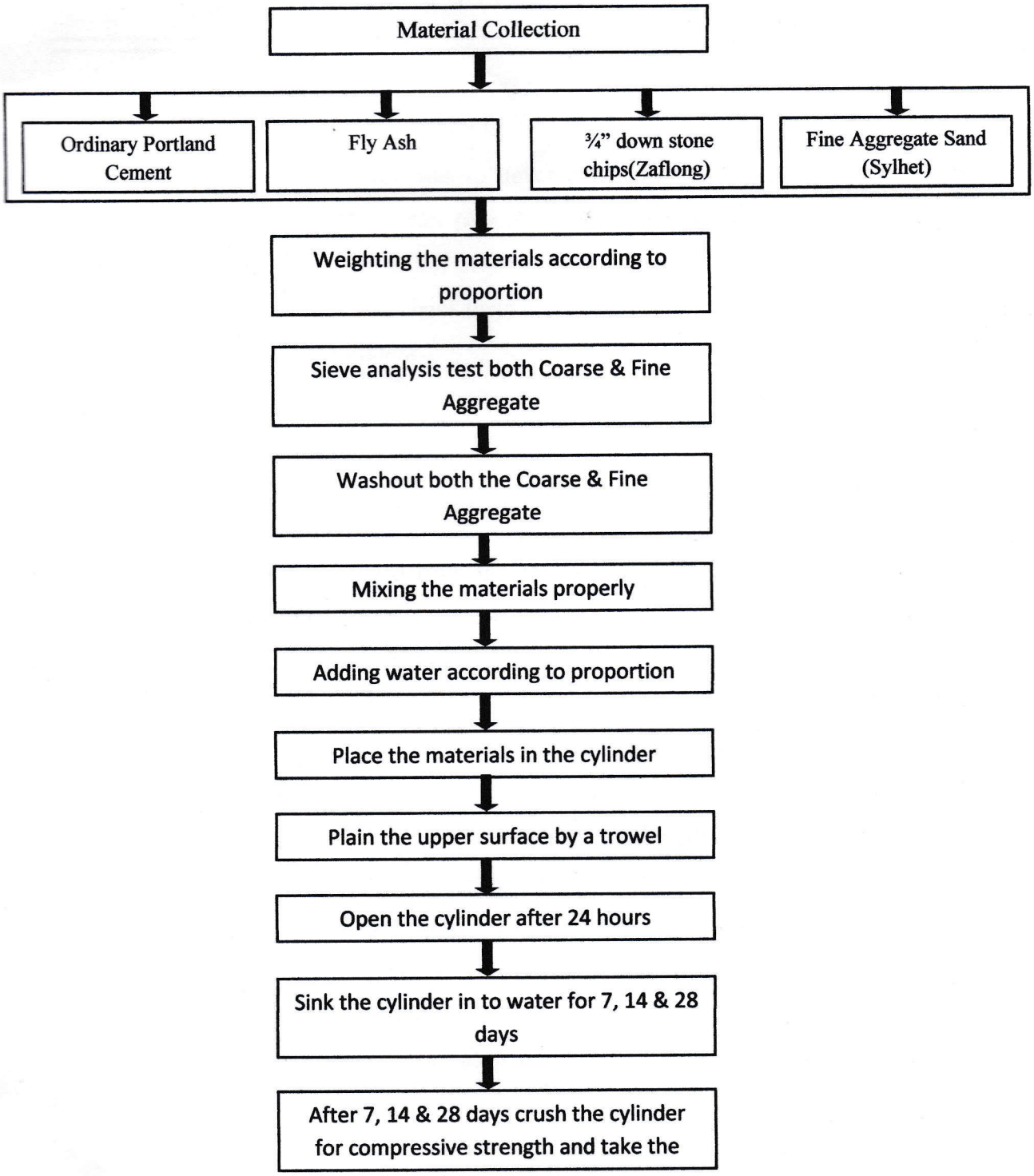
In Chapter 3, Presents the experimental design and materials, it also explain the procedures of the experiment in details. This chapter also provides the overview of the materials that were used for this particular research.

In Chapter 4, presents the experimental design and materials, it also explain the procedures of the experiment in details. This chapter also provides the overview of the materials that were used for this particular research.

In Chapter 5, Discusses and analyses the obtained results during the preparation and testing stage. It provides the results such as values of compressive strength in tabulated and graphical format in order to make the comparison of the results easier to be understood.

And finally in chapter 6, Summaries and the conclusions from the studies, limitation of the thesis and given some suggestions for further studies.

1.5 FLOW CHAT


Material Collection
Ordinary Portland Cement
Fly Ash
¾" down stone chips(Zaflong)
Fine Aggregate Sand (Sylhet)
Weighting the materials according to proportion
Sieve analysis test both Coarse & Fine Aggregate
Washout both the Coarse & Fine Aggregate
Mixing the materials properly
Adding water according to proportion
Place the materials in the cylinder
Plain the upper surface by a trowel
Open the cylinder after 24 hours
Sink the cylinder in to water for 7, 14 & 28 days
After 7, 14 & 28 days crush the cylinder for compressive strength and take the

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CHAPTER-2
LITERATURE REVIEW

2.1. INTRODUCTION

The main objective of this study was to develop better understanding of the "***Effect Of Curing Days On Concrete Properties (Fly Ash)***". This chapter includes introduction to fly ash, cement and fine aggregate, also it describes their process of manufacturing. In addition the chapter provides information about their chemical composites, their physical properties and their effects on the environment.

2.2. FLY ASH

2.2.1. Nature of Fly Ash and its Production

Fly ash is a by-product produced from the combustion of coal in an electrical generation station. According to Design and Control of Concrete Mixtures (2010). Fly ash is a natural pozzolan, which means that it is a "siliceous or siliceous-and-aluminous material" which chemically reacts with calcium hydroxide (CH) to form composites having cementitous properties. According to Bremseth (2010) the procedure of production of fly ash is as follow; Firstly, coal is crushed into fine powder in grinding mills. The fine powder is then transferred into a boiler. In the boiler the coal combusts producing heat with a temperature up to 1500 degrees. At this temperature, non-combustible minerals melt in the furnace and fuse together. These minerals are taken away from the burning region by exhaust or flue gases. After a while these minerals are cooled and form spherical glassy particles which are known as 'fly ash'. The fly ash particles are then collected by mechanical and electrostatic precipitators from the exhaust gases. The picture below explains the process of producing fly ash at a power station.

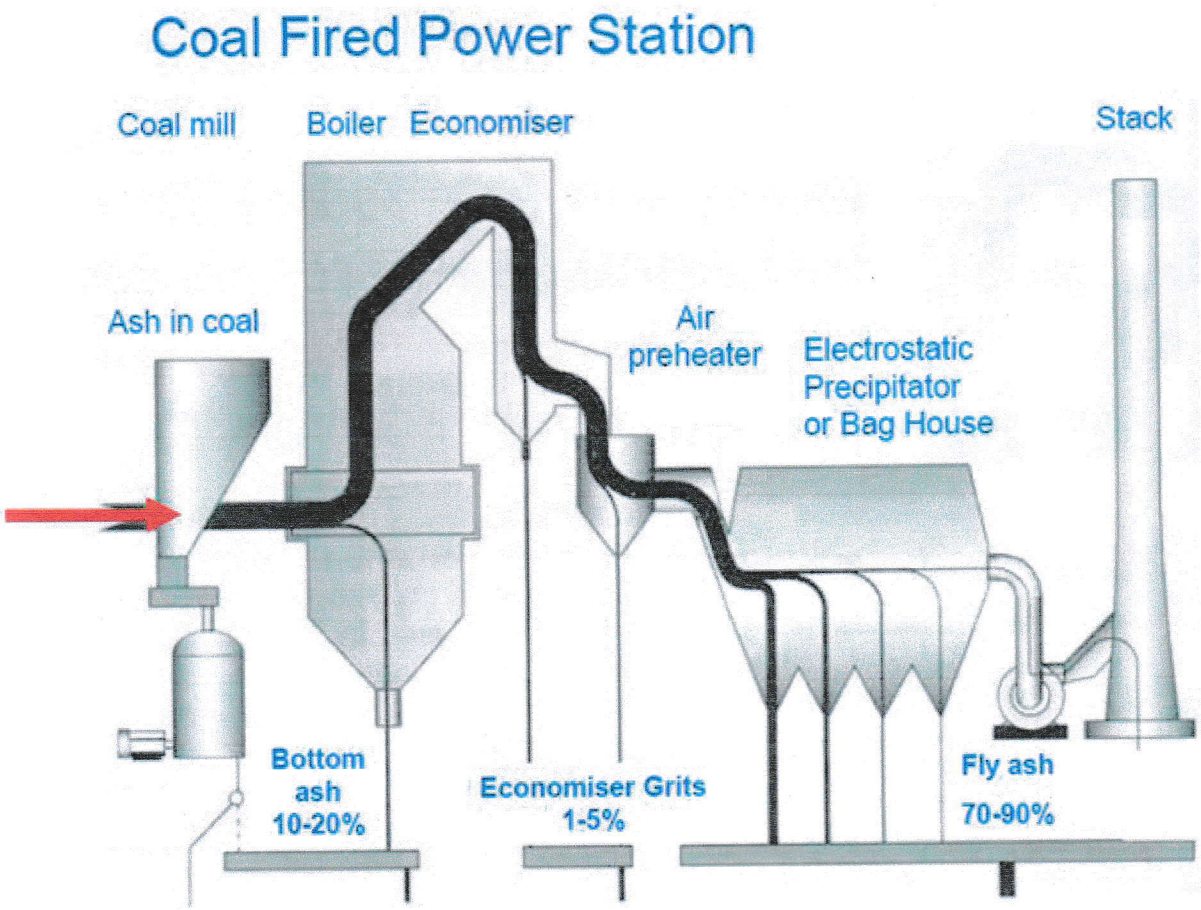


Figure 2.1: Coal Fired Power Station

2.2.2. Physical and Chemical Properties of fly ash

The chemical compositions and the physical properties of fly ash are mainly controlled by the nature of coal and the processing conditions of the furnace.

The chemical composition of fly ash varies significantly between plants. However, Silicon dioxide (SiO2) occupies most of the volume of fly ash. According to (Bremseth, 2010) the chemical composition of the coal controls the chemical contents of fly ash, American Society for Testing and Materials (ASTM) C618-03 defines two classes of fly ash, class F and class C. These two classes differ from each other in the volume of calcium. The percentage of calcium in class F is low whereas in class C is high. According to (de Brito & Saikia, 2013) larger number of unwanted chemical components such as free lime and sulphite are present in high calcium fly ash, which minimize the use of this kind of fly ash. The table below shows the chemical properties of fly ash (Gamage et al, 2011).

Table 2.1 Chemical Properties of fly Ash

Chemical Compound	Low calcium fly ash Class F	High calcium fly ash Class C
Silicon dioxide (SiO2)	54.90	39.90
Aluminium oxide (Al2O3)	25.80	16.70
Iron oxide (Fe2O3)	6.90	5.80
Calcium Oxide (CaO)	8.70	24.30
Magnesium oxide (MgO)	1.80	4.60
Sulfur Trioxide (SO3)	0.60	3.30
Sodium oxide (Na2O) and Potassium oxide(K2O)	0.60	1.30

Fly ash particles are irregular to spherical in shape, their diameters range between 0.5 m to 150 m. According to (Ramezanianpour, 2014) the sizes of fly ash particles are determined by the type of equipment that are used to remove the fly ash and it also depends on the sources. The physical properties of fly ash are tabulated in table below.

Table 2.2 Physical Properties of fly ash. (Gamage 2011)

Properties	--------
Specific gravity	2.3
Moisture content	19.75%
Fineness	0.001-0.6 mm
Maximum Dry density	1.53 g/cm3
Permeability	4.87×10-7 cm/s
Angle of internal friction	23°-41°
Cohesion	3-34 Kpa
Compression of index	0.15
Coefficient of consolidation	0.1-0.5 m2 per year

2.2.3 Effects of fly ash on the environment

In general fly ash is considered a waste material. It is a by- product that is produced due to the combustion of coal. According to (Morrison, 2005) combustion of coal in Australia produces around 12 million tonnes of fly ash per year. Approximately 60 % of fly ash is being dumped. However, doing so many causes several environmental problems such as: contamination of ground water and ground pollution. Waste materials generally and fly ash specifically can be used in concrete as replacement of cement. This kind of use has positive impacts on the environment as it diminishes the problem of waste disposal and reduces the intensive use of energy and natural resources (aggregate mining). In addition, it reduces the amount of CO2 emissions and it saves energy when fly ash replaces some of the energy (intensive produced cement).

2.2.4 How fly ash works with cement in concrete

Ordinary Portland cement is a product of four mineralogical phases, which are Tricalcium Silicate C3S (3CaO.SiO2), Dicalcium Silicate C2S (2CaO.SiO2), Tricalcium Aluminate C3A (3CaO.Al2O3) and Tetracalcium alumina-ferrite C4AF (4CaO.Al2O3.Fe2O3). These compounds react with water to produce a hydrated calcium silicate (CSH) and lime. However, if fly ash was added to the mix, it would react with the lime to form CSH which is the same as the cementing product produced by hydration of cement paste (National Precast Concrete Association 2010).

2.2.5 Effects of fly Ash on the properties of fresh concrete

2.2.5.1 Water demand and Workability

Replacing the cement by fly ash will reduce water demand and improve the workability of concrete. According to Al-Omri (2007) workability is the ease of handling, placing, transporting, compacting and finishing of fresh concrete. Workability of concrete is improved due to small, smooth and spherical fly ash particles, their small size and their smoothness, which act as ball bearing in concrete mixes (Thomas 2014). Generally, for the same slump fly ash concrete is more workable than conventional (plain cement) concrete. Which means that to achieve the same slump, fly ash concrete requires less water than plain cement concrete. When vibrating concrete, fly ash concrete flows and consolidates more efficiently than a

plain cement concrete. In addition, using fly ash in concrete improves the cohesiveness and reduces segregation of concrete (Headwaters Resources 2014).

2.2.5.2 Bleeding and Segregation

According to Concrete plants (2012) raising the water to the surface of freshly placed concrete is known as bleeding. This generally happens due to settlement of the heavy particles of cement and aggregates in the mix, allowing water to go to the top surface as they cannot hold the water. Having fly ash in concrete reduces bleeding (Thomas 2014). When fly ash is added, the concrete mixture becomes more cohesive. This because the fly ash particles are very fine, therefore increasing in total volume and surface area of the cementitous and solid materials. An increase in surface area means more areas for particles to bond, thus increasing the cohesiveness of the concrete. The cohesive effect of fly ash also makes the concrete mix homogenous. Therefore, concretes with fly ash are less prone to bleeding and segregation due to the cohesive effect of the fly ash.

2.2.5.3 Setting Time

Setting is the process of concrete to obtain its rigidity. It can be achieved when the wet cement becomes solidified. However, solidification of the plastic cement paste takes a considerable amount of time. Concrete sets due to the hydration process of the cement compounds.(Mehta & Monteiro 2014).

Setting time of concrete is controlled by the chemical reaction that takes place between cement compounds which are alite (C3S), belite (C2S), aluminate (C3A), aluminoferrite (C4AF) and water. The quicker this reaction occurs, the quicker the concrete sets and vice-versa.

From the graph below it can be seen that C3S sets firstly between the other cement's compounds. According to Ramezanianpour (2014), having fly ash in concrete retards the chemical reaction between C3S and water; therefore retarding the whole hydration process of the cement. The type of fly ash that is used in concrete controls the hydration of cement and therefore the setting time. For instance, Class C fly ash (high calcium) retards setting to a lesser degree than Class F fly ash (low calcium). Moreover, besides the influence of fly ash

The hydration process of cement is influenced by several factors. Firstly, the temperature, according to (Neville & Brooks, 1987) a rise in concrete temperature results in a more rapid hydration process, which accelerates the setting time of concrete. The chemical reaction is also influenced by the cement content; high cement content accelerates the process of the cement hydration. Moreover, high fineness of cement particles increases the speed of the chemical reaction.

According to (Thomas, 2014) using fly ash in concrete structures influences heat of hydration and hence the internal temperature of concrete. Whether Fly ash is used as replacement of cement or as a mineral additive, it slows the chemical reaction between cement and water, limits the amount of heat generation and reduces the internal temperature rise, resulting in less thermal cracking and higher strength and more durable concrete structures.

Calcium Hydroxide (lime) is produced due to the chemical reaction between Portland cement and water. According to (NTPC limited, 2007) when fly ash is present in the concrete mixture, it behaves as secondary cement by reacting with lime. Both classes of fly ash (C and F) retard the hydration process. However, Class C fly ash reacts faster with water than Class F fly ash due to the high content of calcium.

2.2.5.5 Curing

According to (Portland Cement Association, 2014), curing can be defined as providing the required amount of moisture, temperature and time in order to allow the concrete to gain its strength quicker. Curing improves concrete short term strength, eliminates surface drying shrinkage cracks and reduces long term drying shrinkage cracking. The pozzolanic reaction of fly ash in concrete is slower than the hydration process of cement, and therefore the setting time becomes longer, and the early age strength gets reduced. Due to these reasons, fly ash concrete requires to be properly cured if the early age compressive strength is desired to be achieved.

According to (Kholia, 2013), curing techniques and duration significantly affect curing efficiency. Several curing techniques are used such as; membrane curing, self-curing, dry-air curing, and water curing.

2.2.6 Effects of fly Ash on the Properties of Hardened Concrete

2.2.6.1 Compressive Strength Development

According to (Thomas, 2014) using fly ash in concrete as a replacement of cement reduces the early-age strength. However, fly ash concrete keeps gaining strength with time as the chemical reaction keeps reacting for up to six months or longer. Therefore, fly ash concrete achieves higher ultimate strength than can be achieved with conventional concrete.

There are several factors that influence the strength of fly ash concrete such as types, chemical composition, fineness and usage ratio of the fly ash and the Portland cement. According to (Yazici & Arel, 2012) class C (high calcium) fly ash produces higher early strength than Class F (low calcium) fly ash because it can generate the chemical reaction by its own lime content. In addition to that, using high fineness of fly ash increases the density and the pozzolanic activity of concrete resulting in increasing the strength of the concrete.

The percentage of fly ash that replaces the cement plays a major role in developing the strength of concrete, according to (Chindaprasirt, 2005) using fly ash in concrete increases the ultimate compressive strength of concrete. However, when high volume of fly ash replacement is used (10%), the compressive strength of concrete will decrease. Fly ash affects the strength of concrete due to a process known as the packing of fly ash particles. Physical features of fly ash such as sphericity, uniformity, and fineness of fly ash particles influence the effects of packing on concrete. Due to these physical properties, most of the voids or airspaces get filled with fly ash particles which increase the density of concrete. In addition to that, the pozzolanic reaction improves which results in increasing the compressive strength. (Chindaprasirt 2005).

2.2.6.2 Other Mechanical Properties

Partially replacement of cement by fly ash does not have significant effects on the tensile strength, flexural strength and elastic modulus of concrete. According to Ramezanianpour (2014) due to the presence of fly ash in concrete the elastic modulus of concrete is increased slightly. In some cases, when a high percentage of cement is replaced by fly ash, not all the fly ash particles undergo the hydration process and they behave as fine aggregate due to their low porosity, resulting in increasing the elastic modulus of concrete. Similar to compressive strength, the elastic modulus is lower at early ages and higher at later ages.

Using high volume of fly ash in concrete increases the long-term flexural and tensile strength of concrete as the hydration process continues for a longer time than if fly ash was not present in the mixture, resulting in strengthening the bond between the cement paste and the aggregate. (Thomas 2014)

2.2.6.3 Creep

Using fly ash in concrete influences the potential of concrete to creep. However, Fly ash concretes do not always show better creep properties than conventional concrete as fly ash concrete gains its strength with the time. For instance, when a fly ash concrete structure is loaded at an early age, it will creep more than if the structure was made without fly ash, because fly ash retards the hydration process of cement, thus the concrete structure has not yet gained its strength. Whereas, if a fly ash concrete structure is loaded at a later age, it will creep less than concrete made of pure cement paste because of its continued strength gain. (Wallah 2010).

High volume fly ash concrete undergoes lower creep behaviour when compared to conventional concrete for the same strength, due to the reduced water content caused by fly ash and the presence of unreacted fly ash particles. (Thomas 2014).

2.2.7 Effects of fly Ash on the Durability of Concrete

According to Nath & Sarke (2011), the application of fly ash in concrete as partial replacement of cement improves the durability properties of concrete. Durability of concrete can be measured using several properties such as permeability, drying shrinkage, carbonation of concrete and freeze-thaw resistance.

2.2.7.1 Permeability

According to Neville & Brooks, (1987) permeability can be defined as the ease with which water is transmitted through concrete. Permeability and durability are inversely proportional, for instance when the permeability of concrete goes down its durability increases. According to Bremseth (2010) permeability of concrete is influenced by many factors like water content, aggregate grading and amount of cement materials.

During the hydration process of cement, calcium hydroxide is produced which is a water soluble product. However, when fly ash is present in concrete as either a replacement of cement or as mineral additive, it reacts chemically with calcium hydroxide producing a hydrated calcium silicate, therefore reducing the potential of leaching calcium hydroxide and consequently reducing concrete permeability.

Generally, in concrete some spaces and voids get occupied by water as they did not get filled up by the hydration products of cement. However, when fly ash is present in the mix and due to its pozzolanic activity, these spaces get filled up by fly ash hydration products, resulting in decreasing concrete permeability.

2.2.7.2 Drying Shrinkage

According to Homwuttiwongb, et al (2004), one of the main properties that affect the performance of a concrete structure is the drying shrinkage. Drying shrinkage can be defined as the reduction of the volume of concrete due to the loss of water (Neville & Brooks 1987). Drying Shrinkage can increase the tensile strength which has the potential to create cracks on concrete structures.

There are several factors that influence the drying shrinkage behaviour of concrete such as the amount of water present in the mix, as well as the volume and quality of cement paste. Fly ash concrete usually has better drying shrinkage behaviour than conventional concrete because of the presence of fly ash in the concrete mixture, which reduces the water demand and therefore reduces the amount of water in the mix (Bremseth 2010).

2.2.7.3 Freeze thaw Resistance

Deterioration of concrete due to freeze-thaw actions occurs when most of the voids in concrete gets filled up by water. When the water is in the freezing phase (water is converting to ice) its volume increases by 9%. This expansion in volume causes an additional pressure in the concrete. This distressing of the concrete may result in serious problems such as damaging the concrete surface. (Bremseth 2010).

Entrained air voids play a significant role in protecting concrete from freeze-thaw damage. In addition to that, the presence of fly ash in concrete mixtures improves the ability of concrete to resist freeze-thaw cycles. As was discussed in 3.2.1, fly ash reduces the required amount of

water for a concrete mix, which leads to reduction in bleed channels and entrance of water. Due to the physical properties of fly ash particles, most of small voids get filled by fly ash resulting in making the concrete less absorptive.

2.3. CEMENT

2.3.1 Nature of Cement and its Production

Cement is a material that has the ability to hold concrete together. It binds coarse aggregate with fine aggregate. Over one billion tonnes of cement are produced per year. It is expected that the demand for cement will increase significantly. To this point, there is no alternative material for cement. However, in this research a study will be conducted to see if the fly ash could be used as partial replacement of cement.

Cement is a fine powder essentially controlling concrete properties of strength and hardness. There are several types of cement; however Portland cement is the most cement type that is used across the world. According to (Nawy, 2009) Ordinary Portland cements are made out of a mixture of limestone and clay rock as these rocks contain the raw materials of cement production as calcium carbonate(CaCO3) Iron oxide (Fe2O3) Aluminium oxide (Al2O3) and Silicon dioxide (SiO2). These rocks get crushed and blended then heated to a clinker in a kiln. Clinker is cooled and then ground into a fine powder. A small proportion of gypsum is added at the final grinding stage to produce a dry powder (Ordinary Portland cement).

2.3.2 Setting and Hardening of Cement

Cement when mixed with proper proportion of water starts setting hard due to series of complex reactions and so far the reactions are partly understood. The constituents present in cement causes slow interactions and interlinking yielding crystalinity and intern strength. During initial reactions carbon dioxide is slowly released and converted to Portlandite (Ca(OH)2) into insoluble calcium carbonate, after the initial setting, the material is subjected to curing in warm or normal water where the reactions speeds up intern accelerating hardening. Gypsum is mixed in clinker to inhibit rate of reaction.

In conventional practice cement is extensively used to prepare concrete which in turn used in construction. For production of concrete which consists of gravel, water, sand and cement. The material to be constructed can be casted to any desired shape and upon hardening becomes a structural product, which withstands loads. Taylor made structures are also produced in the cement plant based on the requirement by the customer.

When water is mixed with Portland cement, the mass sets in few hours and hardens over a period of about few weeks. This processesvaries widely with the parameters like curing temperature, humidity but in general concrete sets within 6 hours and builds a compressive strength of about 9-15 Mpa in a day, then develops to 20-24 Mpa in 3 days, then develops to 30-35 Mpa in 7 days and then develops to 40-60 Mpa in 28 days.

The Pozzolona Cement (PPC) is a kind of cement, produced when fly ash is blended with Ordinary Portland Cement (OPC), to a maximum percentage of 35. The process of blending is done in a ball mill with Ordinary Portland Cement, gypsum and fly ash, in order to produce homogenous quality of cement.

Pozzolona occurs naturally as well as from thermal power plants, where huge volumes of coal is combusted to produce heat, in turn steam to run the turbine and in turn coupled to alternator to produce electricity. Pozollona processes siliceous and aluminous material, which is very reactive with Ordinary Portland Cement, to produce cementious compounds. Finer the silica in Pozzolona leads higher cementious properties of producing calcium silicates. Pozollanic materials available in nature are volcanic ash, calcined clay, fly ash and silica fumes.

2.3.3 Types of Cement

The demand to produce different types of cement based on the utility had been increasing over decades, and scientists are successful in producing different types of cement as demand arises. Following are the types of cements:

1. Ordinary Portland Cement (OPC)
    a. 33 grade cement
    b. 43 grade cement
    c. 53 grade cement
2. Portland Pozzolona Cement (PPC)
3. Portland Blast Furnace Slag Cement
4. Oil Well Cement
5. Rapid Hardening Portland Cement
6. Sulphate Resisting Portland Cement
7. White Cement

2.3.4 Constituents of Ordinary Portland Cement

Tricalcium silicate $(CaO)_3.SiO_2$	C_3S	45-75%
Dicalcium silicate $(CaO)_2.SiO_2$	C_2S	7-32%
Tricalcium aluminate $(CaO)_3.Al2O_3$	C_3A	0-13%
Tetracalcium alumino ferrite $(CaO)_4.Al_2O_3.Fe_2O_3$	C_4AF	0-18%
Gupsum $CaSO_4.2H_2O$		2-10%

Where, C_3S, C_2S, C_3A, C_4AF are the notations of cement chemists

2.3.5 Environmental Impact of Ordinary Portland Cement

There are lots of environmental impacts of Cement on our ecology. One of the major problems is emission of CO_2 from the Cement industry. It is found that world yearly 1.6 billion tons production of cement covers 7% of carbon dioxide's yearly production. As CO_2 is harmful for human health and also for the wild life. It causes many respiratory problems like asthma, bronchitis, and nasal infections.

The cement manufacturing industry is labor intensive and uses large scale and potentially hazardous manufacturing processes. The industry experiences accident rates that are high compared with some other manufacturing industries. There are a number of hazards inherent to the cement production process. Some examples for health hazards are:

1. Exposure to dust and high temperatures;
2. Contact with allergic substances; and
3. Noise exposure

And some examples for safety hazards:

1. Falling / impact with objects
2. Hot surface burns

It is responsibility of the government to implement the laws as described in EPA (Environmental Protection Agency) rule to protect both the environmental and human health.

2.4. COMPARISON BETWEEN FLY ASH AND CEMENT

It can be seen from the table below that both fly ash and cement have similar chemical contents. The same chemical compounds are present in cement and fly ash. However, their percentages differ. Portland cement is rich in Calcium oxide (CaO) but low in Silicon dioxide (SiO2). On the other hand, fly ash is rich in SiO2 but low in CaO. Therefore, it is recommended to use both fly ash and Ordinary Portland cement in a concrete mixture (Headwaters Resources 2014).

Table 2.3 Chemical Properties of fly ash and Ordinary Portland Cement

Chemical Compound	Low calcium fly ash Class F	Cement
Silicon dioxide (SiO2)	54.90	22.60
Aluminium oxide (Al2O3)	25.80	4.30
Iron oxide (Fe2O3)	6.90	2.40
Calcium Oxide (CaO)	8.70	64.40
Magnesium oxide (MgO)	1.80	2.10
Sulfur Trioxide (SO3)	0.60	2.30
Sodium oxide (Na2O) and Potassium oxide(K2O)	0.60	0.60

2.5. AGGREGATE

In a concrete mix, aggregates occupy between 60% to 80%. This high content of aggregates influences the properties of concrete both the fresh and hardened. Therefore, they must be well selected. Aggregate is classified as two different types, coarse and fine. Coarse aggregate is usually greater than 4.75 mm while fine aggregate is less than 4.75 mm.

The intense usage of both Coarse and Fine aggregate in civil engineering constructions raises concerns about the preservation of natural aggregates sources. (Amarnath & Ramachandrudu, 2012). In addition, the process of extracting and processing the natural aggregate are the primary reasons of environmental concerns. In order to avoid these concerns and to protect the natural resources alternatives materials can be used as partially or fully replacement of aggregates in concrete production.

2.5.1 Fine Aggregate

The term "Sand" is defined as the aggregate with the restriction that it refers to the material resulting from natural disintegration and abrasion of rock or of completely friable sandstones (ASTM Designation C 125). Sand is the most common fine aggregate. Sand should be free foreign materials like organic matter, clay etc. The sand grains may be of sharp angular or round. Sand showing proper gradation in size from fairly coarse to fairly fine be preferable to either uniformly coarse or uniformly fine sand. The quality of sand is determined by sieve analysis. The coarseness or fineness of sand can be identified by fineness modulus the sum (the cumulative percentage retained in each sieve prescribed by ASTM divided by 100).

2.5.1.1 Properties of Fine Aggregate and its Function in Concrete

Sand is the most commonly material used as fine aggregate in concrete; it consists of small angular and rounded grains of silica.

Functions of sand:

1. Sand or fine Aggregate fills the empty existing voids in the Coarse Aggregate.
2. It helps in the reducing the potential of the concrete to shrink or crack.
3. It helps in hardening of cement as it allows the water to go through its voids.

Requirements of Sand:

1. Fine aggregate should consist of coarse angular sharp and hard grains.
2. It must be free from coatings of clay and silt.
3. It should not contain any organic matter.
4. It should be free from hygroscopic salt.
5. It should be strong and durable and chemical inert.

Fly ash has common physical properties that are similar to sand, which increases the potential to use fly ash as sand replacement (Table 2.5).

Table 2.4 Physical properties of fine aggregate (Sand) and fly ash

Properties	Fine Aggregate (Sand)	Fly Ash
Specific gravity	2.70	1.28
Bulk Density (kg/m3)	1808	838
Size (mm)	Below 4.75	Below 4.75
Fineness modulus	2.68	2.70

2.5.1.2 Environmental Implication of Fine Aggregate

According to (Gonçalves, 2007). In the past, river sand was considered as the only choice for the fine aggregate ingredient in concrete. However, excessive extraction of river sand causes the degradation of rivers. In stream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system. Excessive in stream sand mining is a threat to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Due to these issues, several environmental restrictions were put in place. This increases the shortage of natural fine aggregates and leads to search for alternate sources for its replacement. (Gonçalves, 2007).

2.5.2 Coarse Aggregate

The strength of concrete is dependent on size, shape, grading, surface texture mineralogy of the aggregate, strength, stiffness [5]. Mehta and Monteiro (1993) suggested that the effect of aggregate strength on the compressive strength of concrete is not considered in the case of normal-strength concrete, as it is much stronger than the transition zone and cement paste matrix. Mehta and Monteiro (1993) also explained that the transition zone and the cement paste matrix would fail before the aggregate and thus nullify the effect of the strength of aggregate. Kosmatka et al. (2002) also suggested that the aggregate strength is usually not a

factor in normal strength concrete as the failure is generally determined by the cement paste-aggregate bond. Much research has linked the bonding of the aggregate to the strength of concrete. Neville and Brooks (1987) explained that greater aggregate surface areas result in better bonding between the aggregate and the cement paste. They also observed that rough aggregates tend to exhibit better bonding than smooth aggregates. Jones and Kaplan (1957) made similar observations as Neville and Brooks (1987) but linked the surface properties to the cracking stress suggesting rough aggregates would crack at a higher stress compared to smooth aggregates. It can be seen that compressive strength decreases with an increase in maximum coarse aggregate size especially for concretes with low water-cement ratios. It should be noted that the compressive strength is more sensitive to the water-cement ratio than the maximum aggregate size.

2.5.2.1 Physical Properties

Coarse aggregates shall meet the following physical property requirements, except as noted here in:

Los Angeles Abrasion (FM 1-T 096) ..... maximum loss 45%
Soundness (Sodium Sulfate) AASHTO T104 ..... maximum loss 12%
Flat or elongated pieces ..... maximum 10%

2.5.2.2 Environmental Implication of Coarse Aggregate

Aggregates form the major part of concrete and are derived from many types of rock. Granite and limestone are extracted from quarries, crushed and graded. In many parts of the UK, land-based or marine sand and gravel are available: these require some processing, such as washing and grading, before use in concrete. Washing removes deleterious contaminants such as chlorides from marine-derived materials or excessive amounts of clay and silt from land-based sources. In some cases, silt particles can be recovered by flocculation so that they can be used as part of the fine aggregate. To minimize transport costs, aggregates are processed at their source or the landing point of marine materials.

2.6. FLY ASH IN CONCRETE

2.6.1 Advantages

This section identifies only the advantages of using fly ash in concrete. However, the effects of fly ash on the mechanical properties of both fresh and hardened concrete are presented in detail in the following chapter.

One of the major effects that the fly ash has on concrete is improving its workability, as the percentage of fine particles in fly ash is greater than in cement. Using fly ash in concrete reduces the water demand. Fly ash increases the cohesiveness of concrete as a result both bleeding and segregation get reduced (Marthong & Agrawal 2012).

Concrete hardens through a chemical reaction that takes place between cement and water, this chemical reaction is known as Hydration. Fly ash plays an important role in this chemical reaction as it slows the processing of this reaction and reduces the heat of hydration, which lead to greater strength and minimise thermal cracks in concrete (Maharashtra Fly Ash Information Centre 2007).

The small particles of fly ash fill all the small and empty voids which make the concrete denser. Fly ash reduces the permeability of concrete. Also, it increases its durability.
In summary, using fly ash in concrete has several advantages as it increases the durability, and strength of concrete. On the other hand, it reduces the water demand and permeability. Fly ash concretes have high workability and are durable.

2.6.2 Disadvantages

Different kinds of fly ash have different properties. The quality of fly ash and its properties control the disadvantages of concrete. Fly ash with high amount of carbon encounters a difficulty in controlling the air content.

Fly ash concrete requires longer setting time than conventional concrete. It also slows the hydration process in concrete which leads to low early strength, which can be considered a problem in concrete construction where high early strength is required (Bremseth 2010).

2.6.3 Economic and Environmental impacts of using fly ash in Concrete

Using fly ash in concrete produces economical and environmental benefits. Concrete mixtures with fly ash as a partially replacement of cement are considered to be cheaper than the conventional concrete.

According to (Hendrik & Amy, 2003) Portland cement manufacturer emits a high percentage of carbon dioxide CO2. Every ton of cement produces one ton of CO2. Replacing cement with fly ash results in reduction of the emissions of carbon dioxide CO2, which leads to a reduction in greenhouse gases and their negative effects; also limiting the effects of global warming.

Moreover, using fly ash in concrete impacts significantly on the environment as it helps in solving the problem of waste disposal. It also reduces the exhaustive use of energy and natural resources.

On the other hand, millions of fly ash are made annually; however, 40 % of fly ash are used in concrete and the rest is normally dumped, because their contents differ than the contents of cement and therefore cannot be used in concrete (Gamage 2011). Dumping fly ash may pollute the ground and contaminate the water.

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CHAPTER-3
METHODOLOGY

3.1. INTRODECTION

The main purpose of this research was to investigate the potential of replacing the cement and fine aggregate(sand) by fly ash in concrete mixtures and identify the properties of the mixture, its durability, expansion, and also its fresh and hardened properties.

3.2. PROPERTIES OF CONCRETE

As mentioned in the previous sections above, that the properties of concrete are classified into two categories: Fresh and hardened.

3.2.1 Fresh Concrete Properties

Fresh concrete properties include slump, workability, bleeding, setting time, water demand and air content. However, not all the tests can be conducted at the lab. In this experiment, a slump test was conducted to test the workability of concrete specimens with different ratio of fly ash.

3.2.2 Hardened Concrete Properties

Compressive and tensile strength of concrete are the main hardened concrete properties. In order to determine these, compression test and tensile tests can be conducted. However, for this particular research tensile strength of fly ash concrete was not tested as concrete is not strong in tension as in compression unless reinforcement exists which is not the case in this research. As a result only a compression test was performed to test the effects of fly ash on the concrete's strength.

3.3. MATERIALS AND MIX PROPORTIONS

3.3.1 Materials



Figure 3.1: Fly Ash Powder



Figure 3.2: Fine Aggregate(sand)



Figure 3.3: Cement



Figure 3.4: Coarse Aggregate

3.3.2 Mixture Proportions for the Cement Replacement

A total of 3 concrete mixes were prepared; one of the mixes was made of 100% ordinary Portland cement (no Fly ash content). The remaining 2 mixes were prepared by adding fly ash content as partial replacement to cement i.e. 5%, 10%. The amount of water, coarse aggregate and fine aggregate were constant for all the mixes.

Table 3.1 Dimensions of the Cylinder

	Diameter(inch)	Height (inch)	Volume (cft)
Cylinder	4	8	0.0573

Table 3.2 Concrete Mix Proportions

Mix Description	Ordinary Portland cement	Fly Ash	Water Cement Ratio	Coarse Aggregate	Fine Aggregate	Water	Samples
0% FA	5.60	0	0.45	19.30	8.80	2.52	9
5%FA	5.32	0.28	0.45	19.30	8.80	2.52	9
10%FA	5.04	0.56	0.45	19.30	8.80	2.52	9

Note: All the units are in Kilograms

3.3.3 Water Cement Ratio

The water cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix and has an important influence on the quality of concrete produced. In both experiments the water cement was constant 0.45.

3.4. Mixing Process

All the ingredients of concrete were weighed then they get mixed using a concrete drum mixer, then concrete was poured into the cylinders. At first only one third of the cylinder was

filled and then manually compacted by a rod by 25 times ramming, again, the cylinder was filled two third portion and then compacted by 25 times ramming, then the cylinder was fully filled and then manually compacted by a rod by 25 times ramming, after compaction the top surface of the cylinders was scraped to have a level and even surface and the sealed with a lid to avoid the loose of the moist/water.



Figure 3.5: Cylinder Sample Mixing



Figure 3.6: Cylinder Sample Mixing



Figure 3.7: Pouring of Concrete into the Cylinders

3.5. Curing

As was mentioned previously in section 3.2.5 the overall performance of the hardened concrete is greatly affected by the type and duration of the curing. There are several techniques of concrete curing however, for this research only two techniques could have been used either dry-air curing or water curing. For this research all the concrete mixes were cured by water as it is considered more efficient than dry-air curing.

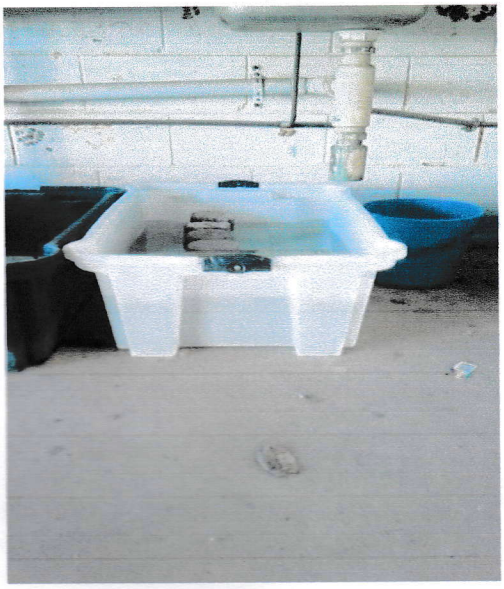


Figure 3.8: Curing of Samples in Water

3.6. Compressive Strength Test

3.6.1 Purpose of the Test

In order to determine the compressive strength of the concrete samples made with replacement of cement by fly ash. A compressive strength can be conducted; this test was done as described in the ACI standard.

3.6.2 Testing Machine

Testing machine should comply with the requirements required by the ACI standards the machine that was used for testing complied with the requirements, a picture of the used machine is shown below.



Figure 3.9 Universal Testing Machine (UTM)

3.6.3 Testing Procedure

The testing procedure that was undertaken in the lab followed the procedure that is specified in ACI. The test procedure was carried out as follows.

1. The testing was done immediately after removing the samples from the curing environment (in this case the water tank was the curing environment).
2. Loose particles on the ends of the specimens were removed.
3. Platens of the machine were cleaned.
4. A rubber cap was placed and centered on the bottom platen of the machine.

5. The specimens were placed and centered on the top of the rubber cap.

6. Another rubber cap was placed and centered on the top of the specimen.

7. A force was applied and increased continuously.

8. The maximum force applied to the specimen was recorded as indicated by the testing machine.

9. The compressive strength of the specimen is calculated by dividing the maximum applied force on the specimen by its cross sectional area.

Equation 7 Compressive Strength

$$Compressive\ Strength\ \frac{\text{m}}{(mm)^2} = \frac{\text{Maximum Applied Forces}}{\text{Cross Sectional Area}(mm)^2} = \frac{F_{max}}{A}$$

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CHAPTER-4
LABORATORY INVESTIGATION

4.1 INTRODUCTION

For a good design , a good concrete is a must . It is not very difficult to make a good concrete . The only necessary thing is to have through idea about the physical properties of concrete. More than sixty factors can affect the quality of concrete and for that reason vigorous investigation are needed. The design of concrete mix by traditional method requires the properties of concrete materials I.e. coarse and fine aggregate ,such as specific gravity ,unit weight ,fineness ,modulus etc. Hence information should be available about the properties of different elements of concrete.

4.2 SIEVE ANALYSIS

Sieve analysis helps to determine the particle size distribution of the coarse aggregates. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

4.2.1 COURSE AGGREGATE (Jaflong)

Total Materials – 2000 gm.

Table 4.1 Course aggregate sieve analysis

Sieve Number	Sieve Opening (mm)	Materials Retained (gm)	% Materials Retained	Cumulative % Retained	Percent Finer
3/4	19.05	750	37.5%	37.5	62.5
3/8	9.5	1186	59.3%	46.8	3.2
4	4.75	64	3.2	100	0
			100	234.3	

Fineness Modulus = 284.3 / 100 = 2.343 say 2.3

4.2.2 AIV = Aggregate Impact Value (Jaflong)

Weight of mold	= 1962 gm
Sample + mold weight	= 2645 gm
Sieve (8 No)- 2.36mm Retain	= 503 gm
Passing	= 95 gm

Table 4.2 Aggregate Impact Value (Jaflong)

Description	Calculation
Weight of Sample (surface dry) "A" gm	598 gm.
Weight of Materials Retained on 2.36mm Sieve "C"gm	503 gm
Weight of Materials Passing 2.36mm Sieve "B" gm	95 gm
AIV = B/Ax100 =95/598x100	15.89%

4.3 SPECIFIC GRAVITY AND ABSORPTION CAPACITY OF COARSE AGGREGATE (Jaflong).

Table 4.3 Specific gravity and absorption capacity of coarse aggregate (Jaflong)

Wt. of S.S.D Sample in Air, B (gm)	Wt. of S.S.D Sample in Water, C (gm)	Wt. of S.S.D Sample in Air, A (gm)
900	600	860

Tests	Formula	Calculation	Results
Apparent Specific Gravity	A/(A-C)	860/(860-600)	3.30
Bulk Specific Gravity (S.S.D. basis	B/(B-C)	900/(900-600)	3.00
Bulk Specific Gravity (Oven dry Basis)	A/(B-C)	860/(900-600)	2.86
Absorption Capacity, D%	(B-A)*100/A	(900-860)*100/ 860	4.65

4.4 SPECIFIC GRAVITY AND ABSORPTION CAPACITY (Fine Aggregate).

Test No	1	Remarks
Wight of Sample (A)	583 gm	
Wt. of Materials Retained (e)	498 gm	
Weight of Retained Passing (B)	85	
AIV = B/A X 100	(58/583) X 100 = 14.57 = 15%	

4.4.1 SPECIFIC GRAVITY AND ABSORPTION CAPACITY OF FINE AGGREGATE (Syhlet Sand).

A) Sample (Sylhet sand)

Data Sheet

Wt. of pycnometer filled with water to calibration mark. (B gm)	Over Dry Wt. in Air (A gm)	Wt. of pycnometer with specimen and water to calibration mark (C gm)	Wt. of S.S.D sample in AirS gm
1213 gm	425gm	1478 gm	500 gm

Tests	Formula	Calculation	Results
Apparent Specific Gravity	$\frac{A}{B+A-C}$	$\frac{425}{1213+425-1478}$	= 2.65
Bulk Specific Gravity (Oven Dry Basis)	$\frac{A}{B+S-C}$	$\frac{425}{1213+500-1478}$	=1.80
Absorption Capacity ,D%	$\frac{S-A}{A}$	$\frac{500-425}{425}$	=17.64%
Bulk Specific Gravity (S.S.D. Basis), G	$\frac{S}{B+S-C}$	$\frac{500}{1213+425-1478}$	=3.125

B) Sample (Sylhet sand wt= 500 gm)

Table 4.4 Fine aggregate sieve analysis

Sieve Number	Sieve opening (mm)	Materials Retained (gm)	% Materials Retained	Cumulative % Retained	Percent finer
4	4.75	0	0	0	
8	2.36	11	2.2	2.2	
16	1.19	100	20.0	22.2	
30	0.59	162	32.4	54.6	
50	0.30	180	36	90.6	
100	0.15	40	8.0	98.6	
Pan		7	1.4	100	
	=268.20				

Results : Fineness Modulus= 268.20/100 =2.68 say 2.60

CHAPTER-5
RESULT AND DISCUSSION

5.1. INTRODECTION

This Chapter contains the results obtained from the compression test and the slump test. It presents the results in a graphical format in order to make the comparison between results easier to be understood. In addition, this chapter discusses and analyses some possible factors that may have affected the result.

5.2. EXPECTED RESULTS FROM THE EXPERIMENT

Inclusion of fly ash in the concrete mixture as replacement of cement will influence the mechanical properties of concrete. The following are the expected results from the experiment due to replacing cement with fly ash.

- Using fly ash in concrete as a replacement of cement will improve the workability of concrete.
- Setting time of concrete becomes longer when fly ash is present in the mix.
- Fly ash concrete will have lower compressive strength than conventional concrete at early age; however it achieves higher ultimate strength than can be achieved with conventional concrete.

5.3. RESULTS

5.3.1 Compressive Strength

Compressive strength of concrete mixes made with different ratios of fly ash as replacement of cement to determine at 7, 14 and 28 days of curing. The test results are given in tables 5.1, 5.2 and 5.3 and shown in figures 5.1 and 5.2.

5.3.1.1 Compressive Strength Results of Cement Replacement

Figure 5.1 shows the variation of compressive strength with age for several fly ash percentages as replacement of Cement, and figure 5.2 shows the variation of compressive strength with fly ash percentages at different ages.

From the test results, it can be seen from figure 5.1 that the compressive strength of fly ash concrete mixes with 5% and 10% cement replacement with fly ash are lower than the control mix (0% Fly ash) at all ages. It is evident from table and figure that the compressive strength of all mixes continued to increase with the increase in age. For example after 28 days of curing all concrete mixes except the last mix (10% Fly ash) have lower compressive strength than the control mix.

From table and figure 5.2 it can be seen that the concrete mix with 0% Fly ash replacement of cement has the highest compressive strength among all the fly ash mixes at all ages. It is also clear that as the percentage of fly ash in a concrete mix goes over 10% the compressive strength increases. For example 10% Fly ash mix at 7, 14, 28 days of curing the compressive strength values were 1788, 2036 and 2236 psi respectively.

Table 5.1 Result of 7 Days Compressive Strength

Sl No.	Specimen Designation/ Frog Mark	Fly Ash (%)	Water Cement Ratio	Mix Ratio	Compressive Strength (psi)	Average Compressive Strength (psi)
1	1	0	0.45	1:1.5:3	1788	1908
2	2		0.45	1:1.5:3	2057	
3	3		0.45	1:1.5:3	1878	
4	1	5	0.45	1:1.5:3	1790	1793
5	2		0.45	1:1.5:3	1805	
6	3		0.45	1:1.5:3	1784	
7	1	10	0.45	1:1.5:3	1788	1788
8	2		0.45	1:1.5:3	1788	
9	3		0.45	1:1.5:3	1788	

Table 5.2 Result of 14 Days Compressive Strength

Sl No.	Specimen Designation/ Frog Mark	Fly Ash (%)	Water Cement Ratio	Mix Ratio	Compressive Strength (psi)	Average Compressive Strength (psi)
1	1	0	0.45	1:1.5:3	2146	**2325**
2	2		0.45	1:1.5:3	2504	
3	3		0.45	1:1.5:3	2325	
4	1	5	0.45	1:1.5:3	2146	**2236**
5	2		0.45	1:1.5:3	2325	
6	3		0.45	1:1.5:3	2236	
7	1	10	0.45	1:1.5:3	2025	**2036**
8	2		0.45	1:1.5:3	2035	
9	3		0.45	1:1.5:3	2050	

Table 5.3 Result of 28 Days Compressive Strength

Sl No.	Specimen Designation/ Frog Mark	Fly Ash (%)	Water Cement Ratio	Mix Ratio	Compressive Strength (psi)	Average Compressive Strength (psi)
1	1	0	0.45	1:1.5:3	2593	**2593**
2	2		0.45	1:1.5:3	2593	
3	3		0.45	1:1.5:3	2593	
4	1	5	0.45	1:1.5:3	2460	**2440**
5	2		0.45	1:1.5:3	2450	
6	3		0.45	1:1.5:3	2410	
7	1	10	0.45	1:1.5:3	2325	**2236**
8	2		0.45	1:1.5:3	2236	
9	3		0.45	1:1.5:3	2146	

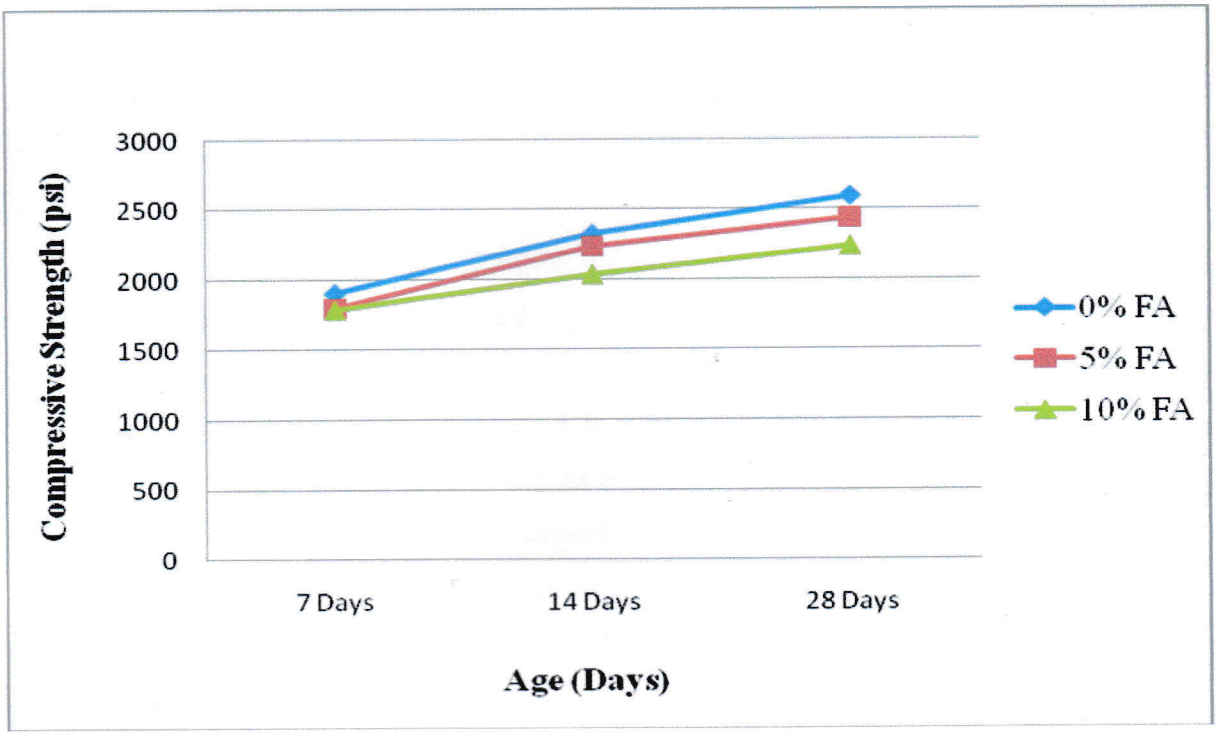


Figure 5.1 Compressive Strength Versus Age

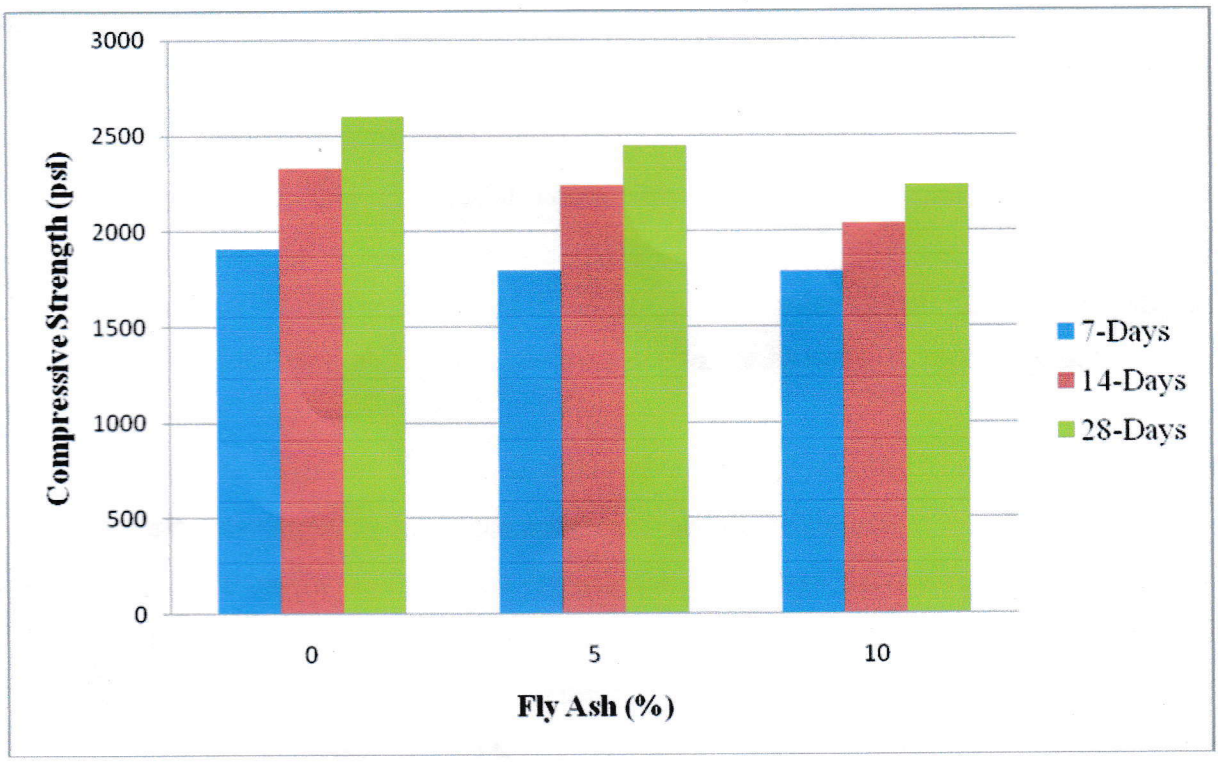


Figure 5.2 Compressive Strength Versus Fly Ash Percentage

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CHAPTER-6
CONCLUSIONS

6.1. INTRODUCTION

Fly ash is one of the residues created during the combustion of coal. It is generally considered to be a waste material. The production of fly ash is expected to increase to up to 2000 million tonnes per year in 2020. 12 million tonnes of fly ash are produced annually in Australia alone with an anticipation of increasing. Around 40% of this ash is used in different engineering applications, whereas the rest is disposed as waste. However, disposal of fly ash is a major concern as it affects the environment directly. The utilization of fly ash in concrete as a replacement of cement is gaining a great interest as it improves the durability of concrete, increases its long term compressive strength and it is cost effective.

This research was completed with the purpose of discovering the feasibility of using fly ash as a replacement of cement and fine aggregate in concrete. Achieving this scope required intensive research about the main components of this thesis (fly ash and cement), and the effects on the mechanical properties of concrete due to the inclusion of fly ash into a concrete mixture. As part of the investigation, concrete mixes with different contents of fly ash as replacement of cement are made and cast into concrete cylinders then cured in water. The compressive strength of the concrete mixes was obtained at three different ages (7, 14 and 28 days) through conducting a uniaxial compressive test. Experimental results show the following outcomes:

- Regardless of the replacement level for all the mixes, inclusion of fly ash has improved the workability of a concrete due to the fineness and spherical shape of its particles.
- Having fly ash in a concrete mix as a replacement of cement decreases its compressive strength due to the pozzolanic activity of the ash.
- The compressive strength of a fly ash concrete keeps decreasing over a long time because the fly ash retards the hydration process of cement, whereas ordinary concrete reaches its maximum compressive strength after around 28 days.
- 5% fly ash as replacement of cement has achieved 5.90% lower compressive strength than the 0% of fly ash.
- 10% fly ash as replacement of cement has achieved 13.76% lower compressive strength than the 0% of fly ash after 28 days curing.

6.2. RECOMMENDATIONS

1. The quality of fly ash is important–but it can vary. Poor-quality fly ash can have a negative effect on concrete. The principle advantage of fly ash is reduced permeability at a low cost, but fly ash of poor quality can actually increase permeability. Some fly ash, such as that produced in a power plant, is compatible with concrete. Other types of fly ash must be beneficiated, and some types cannot be improved sufficiently for use in concrete.

2. Some concrete will set slowly when fly ash is used. Though this might be perceived as a disadvantage, it can actually be a benefit by reducing thermal stress. When cement sets, it produces 100 calories per gram so that the temperature of a structure may rise 135 degrees. Certain fly ash can be used to keep the temperature from rising too high (less than 45 degrees). However, concrete with fly ash can set up normally or even rapidly, since many other factors control the set and strength development.

3. Durability may not be acceptable with the use of fly ash in concrete. The amount of air entrained in the concrete controls the freeze-thaw durability, and the high carbon content in certain fly ash products absorbs some air entraining agents, reducing the amount of air produced in the concrete, making the concrete susceptible to frost damage. High-carbon fly ash materials tend to use more water and darken the concrete as well. It is not recommended to use a high-carbon (greater than 5 percent) content fly ash, but if it must be used, the proper air content can be reached by increasing the dosage of an air-entraining agent.

4. It reveals that the replacement of Ordinary Portland Cement (OPC) by fly ash in concrete is reducing the compressive strength day by day. Although the 5% replacement of cement by fly ash the compressive strength is very near to the 0% fly ash so that we can use 5% replacement of cement by fly ash as long time durability of the concrete.

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