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"Analysis of Compressive Strength of M-25 Grade Concrete Using Fly Ash as Partial Replacement of Cement"

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ABSTRACT
The use of Portland cement in concrete construction is under critical review due to high amount of carbon dioxide gas released to the atmosphere during the production of cement. In recent years, attempts to increase the utilization of fly ash to partially replace the use of Portland cement in concrete are gathering momentum. Most of this by-product material is currently dumped in landfills, creating a threat to the environment.
Fly ash based concrete is a 'new' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and Aluminium (Al), are activated by alkaline liquids to produce the binder.
This project reports the details of development of the process of making fly ash-based concrete. Due to the lack of knowledge and know-how of making of fly ash based concrete in the published literature, this study adopted a rigorous trial and error process to develop the technology of making, and to identify the salient parameters affecting the properties of fresh and hardened concrete. As far as possible, the technology that is currently in use to manufacture and testing of ordinary Portland cement concrete were used.
Fly ash was chosen as the basic material to be activated by the geo-polymerization process to be the concrete binder, to totally replace the use of Portland cement. The binder is the only difference to the ordinary Portland cement concrete. To activate the Silicon and Aluminium content in fly ash, a combination of sodium hydroxide solution and sodium silicate solution was used.
Manufacturing process comprising material preparation, mixing, placing, and compaction and curing is reported in the thesis. Naphthalene-based super plasticiser was found to be useful to improve the workability of fresh fly ash-based concrete, as well as the addition of extra water. The main parameters affecting the compressive strength of hardened fly ash-based concrete are the curing temperature and curing time, the molar H2O-to-Na2O ratio, and mixing time.
Fresh fly ash-based concrete has been able to remain workable up to at least 120 minutes without any sign of setting and without any degradation in the compressive strength. Providing a rest period for fresh concrete after casting before the start of curing up to five days increased the compressive strength of hardened concrete.
The elastic properties of hardened fly ash-based concrete, it the modulus of elasticity, the Poisson's ratio, and the indirect tensile strength, are similar to those of ordinary Portland cement concrete. The stress-strain relations of fly ash-based concrete fit well with the expression developed for ordinary Portland cement concrete.
In this study, cement has been partially replaced by fly ash (0%, 5%, 10%, 15%, and 20% by weight of cement for M-25 mix with .50 water-cement ratio. Test on hardened concrete is done i.e. Compressive strength at 7th, 14th and 28th day respectively.

I. INTRODUCTION

After wood, concrete is the most often used material by the community. Concrete is conventionally produced by using the ordinary Portland cement (OPC) as the Primary Binding Material. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the amount of energy required to produce OPC is only next to steel and aluminium. On the other side, Electricity is the key for development of any country. Coal is a major source of fuel for production of electricity in many countries in the world. In the process of electricity generation large quantity of fly ash get produced and becomes available as a by product of coal-based power stations. It is a fine powder resulting from the combustion of powdered coal - transported by the flue gases of the boiler and collected in the Electrostatic Precipitators (ESP). Conversion of waste into a resource material is an age-old practice of civilization. The fly ash became available in coal based thermal power station in the year

1930 in USA. For its gainful utilization, scientist started research activities and in the year 1937, R.E.Davis and his associates at university of California published research details on use of fly ash in cement concrete. This research had laid foundation for its specification, testing &usages.

1.1 Aims Of The Project :-

The present study deals with the manufacture of low calcium (ASTM Class F) fly ash-based concrete, the parameters influencing the mixture proportioning, and the short-term engineering properties in the fresh and hardened states. The research reported in this thesis is the first stage of a research project on fly ash-based concrete currently in progress in the Faculty of Engineering and Computing at Curtin University of Technology, Perth, Australia.

The aims of the project are:

(a) To develop a mixture proportioning process of making fly ash-based concrete.

(b) To identify and study the effect of salient parameters that affects the properties of fly ash-based concrete.

(c) To study the short-term engineering properties of fresh and hardened fly ash based concrete.

1.2 Various Usage Of Ash :-

Pulverized Fuel Ash is versatile resource material and can be utilized in variety of application. The pozzolanic property of fly ash makes it a resource for making cement and other ash based products. The Geo-technical properties of bottom ash,pond ash & coarse fly ash allow it to use in construction ofembankets, structural fills, reinforced fills low lying area development etc. The physic chemical properties of pond ash is similar to soil and it contains P, K, Ca, Mg, Cu, Zn, Mo, and Fe, etc. which are essential nutrients for plant growth. These properties enable it to be used as a soil amender & source of micronutrients in Agriculture/ Soil Amendment.

The major utilization areas of PFA are as under: -

(a) Manufacture of Portland Pozzolona Cement & Performance improver in Ordinary Portland Cement (OPC).

(b) Part replacement of OPC in cement concrete.

(c) High volume fly ash concrete.

(d) Roller Compacted Concrete used for dam & pavement construction.

(e) Manufacture of ash bricks and other building products.

(f) Construction of road embankments, structural fills, low lying area development.

(g) As a soil amender in agriculture and wasteland development.

1.3 Cement Concrete :-

Cement concrete - most widely used construction material in the world over, commonly consists of cement, aggregates (fine and course) and water. It is the material, which is used more than any other man made material on the earth for construction works. In the concrete, cement chemically reacts with water and produces binding gel that binds other component together and creates stone type of material. The reaction process is called 'hydration' in which water is absorbed by the cement. In this process apart from the binding gel, some amount of lime [Ca (OH) 2] is also liberated. The coarse and fine aggregates act as filler in the mass. The main factors which determine the strength of concrete is amount of cement used and the ratio of water to cement in the concrete mix. However, there are some factors which limits the quantity of cement and ratio of water / cement to be used in the concrete. Hydration process of cement is exothermic and large amount of heat is liberated. Higher will be the cement content greater will be the heat liberation leading in distress to concrete. Water is the principal constituent of the concrete mix. Once the concrete is hardened, the entrapped water in the mass is used by cement mineralogy for hydration and some water is evaporated, thus leaving pores in the matrix. Some part of these pores is filled with hydrated products of cement paste. It has been observed that higher the ratio of water / cement, higher is the porosity resulting in increased permeability. Use of Portland cements In Concrete Started about 180Years Ago. The Concept of High Strength Mean Higher Durability Developed with Low-Grade Cement Inculcated Confidence and Portland cement Became Unique Construction Material of the World.

After the World War II, the need of high-speed construction necessitated the development of high- grade cement providing early high strength. The high-grade cements have been developed by changing the ratio of mineralogical constituents of the cement particularly by increasing the ratio of Tricalcium Silicate (C3S) to Dicalcium Silicate (C2S) and increasing the fineness of the cement. Actually, these changes have resulted in high early strength rather than high strength cement. It has been found out that buildings constructed using high grade cement during 1940-50 have ceded premature distress within 10- 20 years. When the detailed analysis was carried out, it was revealed that:

(a) As the hydration of cement takes place progressively, lime is also liberated gradually. A small quantity of this liberated lime is used to maintain pH of the concrete and the major portion remains unused/ surplus and makes concrete porous.

(b) The high-grade cement which has high C S, releases higher amount of surplus lime resulting in higher porosity in the concrete mass.

(c) Further, higher heat of hydration, higher water content and high porosity increases the susceptibility of concrete mass when it is exposed to a range of external and internal aggressive environment. This disturbs the soundness of the concrete and result in reduced durability.

(d) To mitigate the above problem subsequent research work was carried out which established that use of fly ash or Pozzolana helps to solve all problems related to durability of concrete mass.

II. LITERATURE REVIEW

This chapter presents a background to the needs on the development of a fly ash based technology. The available published literature on fly ash based concrete technology is also briefly reviewed.

2.1 Concrete andEnvironment:-

The trading of carbon dioxide (CO2) emissions is a critical factor for the industries, including the cement industries, as the greenhouse effect created by the emissions is considered to produce an increase in the global temperature that may result in climate changes. The 'tradeable emissions' refers to the economic mechanisms that are expected to help the countries worldwide to meet the emission reduction targets established by the 1997 Kyoto Protocol. Speculation has arisen that one ton of emissions can have a trading value about US$10 **(Malhotra 1999; Malhotra 2004).**

The climate change is attributed to not only the global warming, but also to the paradoxical global dimming due to the pollution in the atmosphere. Global dimming is associated with the reduction of the amount of sunlight reaching the earth due to pollution particles in the air blocking the sunlight. With the effort to reduce the air pollution that has been taken into implementation, the effect of global dimming may be reduced, however it will increase the effect of global warming **(Fortune 2005).** In this view, the global warming phenomenon should be considered more seriously, and any action to reduce the effect should be given more attention and effort.

The production of cement is increasing about 3% annually (McCaffrey 2002). The production of one ton of cement liberates about one ton of CO2 to the atmosphere, as the result of de carbonation of limestone in the kiln during manufacturing of cement and the combustion of fossil fuels **(Roy 1999).**

The contribution of Portland cement production worldwide to the greenhouse gas emission is estimated to be about 1.35 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere (Malhotra 2002). Cement is also among the most energy-intensive construction materials, after aluminium and steel. Furthermore, it has been reported that the durability of ordinary Portland cement (OPC) concrete is under examination, as many concrete structures, especially those built in corrosive environments, start to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life **(Mehta and Burrows 2001).**

The concrete industry has recognized these issues. For example, the U.S. Concrete Industry has developed plans to address these issues in 'Vision 2030: A Vision for the U.S. Concrete Industry'. The document states that 'concrete technologists are faced with the challenge of leading future development in a way that protects environmental quality while projecting concrete as a construction material of choice. Public concern will be responsibly addressed regarding climate change resulting from the increased concentration of global warming gases.' In this document, strategies to retain concrete as a construction material of choice for infrastructure development, and at the same time to make it an environmentally friendly material for the future have been outlined **(Mehta 2001; Plenge 2001).**

In order to produce environmentally friendly concrete, **Mehta (2002)** suggested the use of fewer natural resources, less energy, and minimise carbon dioxide emissions. He categorised these short-term efforts as 'industrial ecology'. The long-term goal of reducing the impact of unwanted by-products of industry can be attained by lowering the rate of material consumption. Likewise, McCaffrey (2002) suggested three alternatives to reduce the amount of carbon dioxide (CO2) emissions by the cement industries, i.e. to decrease the amount of calcined material in cement, to decrease the amount of cement in concrete, and to decrease the number of buildings using cement.

2.2 Fly Ash: -

According to the American Concrete Institute (ACI) Committee 116R, fly ash is defined as 'the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system' (ACI Committee 232 2004). Fly ash is removed from the combustion gases by the dust collection system, either mechanically or by using electrostatic precipitators, before they are discharged to the atmosphere. Fly ash particles are typically spherical, finer than Portland cement and lime, ranging in diameter from less than 1 µm to no more than 150 µm.

The types and relative amounts of incombustible matter in the coal determine the chemical composition of fly ash. The chemical composition is mainly composed of the oxides of silicon (SiO2), aluminium (Al2O3), iron (Fe2O3), and calcium (CaO), whereas magnesium, potassium, sodium, titanium, and sulphur are also present in a lesser amount. The major influence on the fly ash chemical composition comes from the type of coal. The

combustion of sub-bituminous coal contains more calcium and less iron than fly ash from bituminous coal. The physical and chemical characteristics depend on the combustion methods, coal source and particle shape.
The chemical compositions of various fly ashes show a wide range, indicating that there is a wide variation in the coal used in power plants all over the world **(Malhotra and Ramezanianpour 1994).**
Fly ash that results from burning sub-bituminous coals is referred as ASTM Class C fly ash or high calcium fly ash, as it typically contains more than 20 percent of Cao. On the other hand, fly ash from the bituminous and anthracite coals is referred as ASTM Class F fly ash or low calcium fly ash. It consists of mainly an alum inosilicate glass, and has less than 10 percent of Cao. The colour of fly ash can be tan to dark grey, depending upon the chemical and mineral constituents **(Malhotra and Ramezanianpour 1994; ACAA 2003).** The typical fly ash produced from Australian power stations is light to mid-grey in colour, similar to the colour of cement powder.
The majority of Australian fly ash falls in the category of ASTM Class F fly ash, and contains 80 to 85% of silica and alumina **(Heidrich 2002).**
Aside from the chemical composition, the other characteristics of fly ash that generally considered are loss on ignition (LOI), fineness and uniformity. LOI is a measurement of unburnt carbon remaining in the ash. Fineness of fly ash mostly depends on the operating conditions of coal crushers and the grinding process of the coal itself. Finer gradation generally results in a more reactive ash and contains less carbon.
In 2001, the annual production of fly ash in the USA was about 68 million tons. Only 32 percent of this was used in various applications, such as in concrete, structural fills, waste stabilisation/solidification etc. (ACAA 2003). Ash production in Australia in 2000 was approximated 12 million tons, with some 5.5 million tons have been utilised **(Heidrich 2002)**. Worldwide, the estimated annual production of coal ash in 1998 was more than 390 million tons. The main contributors for this amount were China and India. Only about 14 percent of this fly ash was utilized, while the rest was disposed in landfills **(Malhotra 1999)**. By the year 2010, the amount of fly ash produced worldwide is estimated to be about 780 million tons annually **(Malhotra 2002)**. The utilization of fly ash, especially in concrete production, has significant environmental benefits, pozolana improved concrete durability, reduced use of energy, diminished greenhouse gas production, reduced amount of fly ash that must be disposed in landfills, and saving of the other natural resources and materials (ACAA 2003).

III. MATERIALS AND METHODLOAGY

3.1. Materials:

3.1.1. Portland Cement:

Portland cement is made from four basic compounds, tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminate (C3A), and tetra calciumaluminoferrite (C4AF). The cements used in Minnesota are made either from limestone and clay, limestone and shale, or limestone and slag. The manufacturing process known as the dry process is the most widely used at present. This consists of grinding the individual raw materials and feeding at controlled amounts into a rotary kiln and burning until they fuse into small lumps or balls called clinkers. In the wet process, a slurry of the blend is fed into the rotary kiln. The clinkers are cooled and then ground in two operations. Between the first and the final grind, a quantity of gypsum (usually 2 to 3% by mass (weight) of cement) is added to regulate the setting properties of the cement.

3.1.2. Aggregates

Aggregates used in concrete are obtained from either natural gravel deposits or are manufactured by crushing quarried rock. Natural deposits of sand and gravel may contain large amounts of deleterious aggregates such as shale and iron oxides. Therefore, some of these deposits do not meet concrete aggregate specifications. Beneficiating equipment can sometimes remove these undesirable materials during production. During processing, oversized material is either eliminated or reduced to usable size by crushing. Crushed rock is generally obtained from quarried granite, quartzite, limestone, or trap rock. Trap rock is a general classification given to fine-grained, dark colored igneous rock. Crushed rock of the type classified as Class A, per Specification 3137.2B1, is not generally washed but is merely crushed and screened. Limestone can vary considerably in quality even in the same formation and careful selection by ledges is often necessary.
Fine aggregate (sand) produced by crushing quarried rock is not permitted.

3.1.3. Aggregates size:

Aggregates are divided into two general group sizes, fine and coarse. In many instances more than two actual sizes of material are used, due to a further subdivision by size of material within one or both of the groups.

(a) Fine Aggregate:

Fine aggregate is normally considered material that will pass through a 4.75 mm sieve. Specifications require washed, natural sand, unless otherwise provided by the Special Provisions. In some instances, fine aggregate of two or three different sizes or from more than one deposit are used.

(b)Coarse Aggregates:

Coarse aggregate is considered the material that is retained on a 4.75 mm sieve. Two sizes of coarse aggregate are required whenever the maximum size of the aggregate is 25 mm or larger.

3.1.4. Fly ash:

Fly ash is a by-product from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters. The fine powder does resemble Portland cement but it is chemically different. Fly ash chemically reacts with the by-product calcium hydroxide released by the chemical reaction between cement and water to form additional cementitious products that improve many desirable properties of concrete.

3.1.5. Water:

Water used for mixing and curing shall be clean and free from injurious quantities of alkalies, acids, oils, salts, sugar, organic materials, vegetable growth or other substance that may be deleterious to bricks, stone, concrete or steel. Potable water is generally considered satisfactory for mixing.

3.2. Fly Ash Works with Cement:

3.2.1 Reduced Heat of Hydration: -

In concrete mix, when water and cement come in contact, a chemical reaction initiates that produces binding material and con solidities the concrete mass. The process is exothermic and heat is released which increases the temperature of the mass When fly ash is present in the concrete mass, it plays dual role for the strength development. fly ash reacts with released lime and produces binder as explained above and render additional strength to the concrete mass.The unreactive portion of fly ash act as micro aggregates and fills up the matrix to render packing effect and result in increased strength. The large temperature rise of concrete mass exerts temperature stresses and can lead micro cracks. When fly ash is used as part of cementitious material, quantum of heat liberated is low and staggers through pozzolanic reactions and thus reduces micro concrete mass.

3.2.2. Workability of Concrete:-

Fly ash particles are generally spherical in shape and reduces the water requirement for a given slump. The spherical shape helps to reduce friction between aggregates and between concrete and pump line and thus increases workability and improve pump ability of concrete. Fly ash use in concrete increases fines volume and decreases water content and thus reduces bleeding of concrete.

3.2.3. Permeability and Corrosion Protection: -

Water is essential constituent of concrete preparation. When concrete is hardened, part of the entrapped water in the concrete mass is consumed by cement mineralogy for hydration. Some part of entrapped water evaporates, thus leaving porous channel to the extent of volume occupied by the water. Some part of this porous volume is filled by the hydrated products of the cement paste. The remaining part of the voids consists capillary voids and give way for ingress of water.

Similarly, the liberated lime by hydration of cement is water-soluble and is leached out from hardened concrete mass, leaving capillary voids for the ingress of water. Higher the water cement ratio, higher will be the porosity and thus higher will be the permeability. The permeability makes the ingress of moisture and air easy and is the cause for corrosion of reinforcement. Higher permeability facilitate ingress of chloride ions into concrete and is the main cause for initiation of chloride induced corrosion. Additional cementitious material results from reaction between liberated surplus lime and fly ash, blocks these capillary voids and also reduces the risk of leaching of surplus free lime and thereby reduces permeability of concrete.

3.3. How Fly Ash Can Be Used in Cement Concrete? :-

The main objective of using fly ash in most of the cement concrete applications is to get durable concrete at reduced cost, which can be achieved by adopting one the following two methods:

(a) Using Fly ash based Portland Pozzolana Cement (PPC) conforming to IS:1489 Part-1 in place of Ordinary Portland Cement.

(b) Using fly ash as an ingredient in cement concrete.

(c) The first method is simplest method, since PPC is factory-finished product and does not requires any additional quality check for fly ash during production of concrete. In this method the proportion of fly ash and cement is, however, fixed and limits the proportioning of fly ash in concrete mixes.

(d) The addition of fly ash as an additional ingredient at concrete mixing stage as part replacement of OPC and fine aggregates is more flexible method. It allows for maximum utilization of the quality fly ash as an important component (cementitious and as fine aggregates) of concrete.

There are three basic approaches for selecting the quantity of fly ash in cement concrete:

1. Partial Replacement of Ordinary Portland Cement (OPC)- the simple replacement method.
2. Addition of fly ash as fine aggregates the addition method.
3. Partial replacement of OPC, fine aggregate, and water- a modified replacement method.

3.3.1. Simple Replacement Method: -

In this method a part of the OPC is replaced by fly ash on a one to one basis by mass of cement. In this process, the early strength of concrete is lower and higher strength is developed after 56-90 days. At early ages fly ash exhibits very little cementing value. At later ages when liberated lime resulting from hydration of cement, reacts with fly ash and contributes considerable strength to the concrete. This method of fly ash use is adopted for mass concrete works where initial strength of concrete has less importance compared to the reduction of temperature rise.

3.3.2. Addition Method: -

In this method, fly ash is added to the concrete without corresponding reduction in the quantity of OPC. This increases the effective cementitious content of the concrete and exhibits increased strength at all ages of the concrete mass. This method is useful when there is a minimum cement content criteria due to some design consideration.

3.3.3 Modified Replacement Method: -

This method is useful to make strength of fly ash concrete equivalent to the strength of control mix (without fly ash concrete) at early ages i.e. between 3 and 28 days. In this method fly ash is used by replacing part of OPC by mass along with adjustment in quantity of fine aggregates and water. The concrete mixes designed by this method will have a total weight of OPC and fly ash higher than the weight of the cement used in comparable to control mix i.e. without fly ash mix. In this method the quantity of cementitious material (OPC + Fly ash) is kept higher than quantity of cement in control mix (without fly ash) to offset the reduction in early strength.

3.4. Effects:

3.4.1. Effect of Fly Ash on Carbonation of Concrete: -

Carbonation phenomenon in concrete occurs when calcium hydroxides (lime) of the hydrated Portland cement react with carbon dioxide from atmospheres in the presence of moisture and form calcium carbonate. To a small extent, calcium carbonate is also formed when calcium silicate and aluminates of the hydrated Portland cement react with carbon dioxide from atmosphere. Carbonation process in concrete results in two deleterious effects (i) shrinkage may occur (ii) concrete immediately adjacent to steel reinforcement may reduce its resistance to corrosion. The rate of carbonation depends on permeability of concrete, quantity of surplus lime and environmental conditions such as moisture and temperature. When fly ash is available in concrete; it reduces availability of surplus lime by way of pozzolanic reaction, reduces permeability and as a result improves resistance of concrete against carbonation phenomenon.

3.4.2. Sulphate Attack: -

Sulphate attacks in concrete occur due to reaction between sulphate from external origins or from atmosphere with surplus lime leads to formation of etrringite, which causes expansion and results in volume destabilization of the concrete. Increase in sulphate resistance of fly ash concrete is due to continuous reaction between fly ash and leached out lime, which continue to form additional C-S-H gel. This C-S-H gel fills in capillary pores in the cement paste, reducing permeability and ingress of sulphate ions.

3.4.3. Corrosion ofSteel: -

Corrosion of steel takes place mainly because of two types of attack. One is due to carbonation attack and other is due to chloride attack. In the carbonation attack, due to carbonation of free lime, alkaline environment in the concrete comes down which disturbs the passive iron oxide film on the reinforcement. When the concrete is permeable, the ingress of moisture and oxygen infuse to the surface of steel initiates the electrochemical process and as a result-rust is formed. The transformation of steel to rust increases its volume thus resulting in the concrete expansion, cracking and distress to the structure.

In the chloride attack, Chloride ion becomes available in the concrete either through the dissociation of chlorides-associated mineralogical hydration or infusion of chloride ion. The sulphate attack in the concrete decomposes the chloride mineralogy thereby releasing chloride ion. In the presence of large amount of chloride, the concrete exhibits the tendency to hold moisture. In the presence of moisture and oxygen, the resistivity of the concrete weakens and becomes more permeable thereby inducing further distress. The use of fly ash reduces availability of free limes and permeability thus result in corrosion prevention.

3.4.4. Reduced Alkali- Aggregate Reaction: -
Certain types of aggregates react with available alkalis and cause expansion and damage to concrete. These aggregates are termed as reactive aggregates. It has been established that use of adequate quantity of fly ash in concrete reduces the amount of alkali aggregate reaction and reduces/ eliminates harmful expansion of concrete. The reaction between the siliceous glass in fly ash and the alkali hydroxide of Portland cement paste consumes alkalis thereby reduces their availability for expansive reaction with reactive silica aggregates.
In a nutshell, it can be summarized that permeability and surplus lime liberated during the hydration of Portland cement are the root causes for deleterious effect on the concrete.Impermeability is the foremost defensive mechanism for making concrete more durable and is best achieved by using fly ash as above.

Fig. 3.1 mixing of concrete

3.4.5. Environmental Benefits of Fly Ash Use In Concrete: -
Use of fly ash in concrete imparts several environmental benefits and thus it is eco-friendly. It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc required for manufacture of cement. Manufacture of cement is high-energy intensive industry. In the manufacturing of one tonne of cement, about 1 tonne of CO is emitted and goes to atmosphere. Less requirement of cement means less emission of CO2 result in reduction in greenhouse gas emission.
Due to low calorific value and high ash content in Indian Coal, thermal power plants in India, are producing huge quantity of fly ash. This huge quantity is being stored / disposed off in ash pond areas. The ash ponds acquire large areas of agricultural land. Use of fly ash reduces area requirement for pond, thus saving of good agricultural land.

3.4.6. Physical Properties: -
The fly ash particles are generally glassy, solid or hollow and spherical in shape. The hollow spherical particles are called as cenospheres. The fineness of individual fly ash particle rage from 1micron to 1mm size. The fineness of fly ash particles has a significant influence on its performance in cement concrete. The fineness of particles is measured by measuring specific surface area of fly ash by Blaine's specific area technique. Greater the surface area more will be the fineness of fly ash. The other method used for measuring fineness of fly ash is dry and wet Sieving.
The specific gravity of fly ash varies over a wide range of 1.9 to 2.55.

3.4.7. Pozzolanic Properties of Fly Ash: -

Fly Ash is a pozzolanic material which is defined as siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value, chemically react with Calcium Hydroxide (lime) in presence of water at ordinary temperature and form soluble compound comprises cementitious property similar to cement.
The pozzolana term came from Roman. About 2,000 years ago, Roman used volcanic ash along with lime and sand to produce mortars, which possesses superior strength characteristics & resistances to corrosive water. The best variety of this volcanic ash was obtained from the locality of Pezzoli and thus the volcanic ash had acquired the name of Pozzolana.

3.4.8. PozzolanicActivity: -
Pozzolanic activity of fly ash is an indication of the lime fly ash reaction. It is mostly related to the reaction between reactive silica of the fly ash and calcium hydroxide which produce calcium silicate hydrate (C-S-H) gel which has binding properties. The alumina in the pozzolana may also react in the fly ash lime or fly ash cement system and produce calcium aluminate hydrate, ettringite, gelignite and calcium monosulpho-aluminate hydrate. Thus the sum of reactive silica and alumina in the fly ash indicate the pozzolanic activity of the fly ash.

3.5. Properties of Fly Ash:
3.5.1. Physical Properties of Fly Ash

Colour	Whitish Grey
Bulk Density (g/cm)	1.28
Specific gravity	1.86
A verge particle size	0.1 u m

Table 3.1 Physical Properties of Fly Ash

3.5.2 Chemical Properties of Fly Ash

`COMPOUND	% BY WEIGHT
SiO_2	50.50%
Al_2O_3	26.57%
Fe_2O_3	13.77%
CaO	2.13%
MgO	1.54%
SO_3	0.41%
K_2O	0.77%
(P_2O_5)	1.0%
LOI	4.0%

Table 3.2 Chemical Properties of Fly Ash

3.6. Test Data for Materials:

3.6.1. Normal Consistency of Cement

NORMAL CONSISTENCY OF CEMENT	
Simple OPC	32%
5% fly ash with OPC	37%

10% fly ash with OPC	38%
15% fly ash with OPC	40%
20% fly ash with OPC	37%

Table 3.3 Normal Consistency of Cement

3.6.2. Initial & Final Setting Time of Cement

SAMPLE NAME	INITIAL SETTING TIME	FINAL SETTING TIME
OPC	30 Minutes	10 Hours
5% fly ash with cement	35 Minutes	10 Hours
10% fly ash with cement	28 Minutes	10 Hours
15% fly ash with cement	26 Minutes	10 Hours
20% fly ash with cement	29 Minutes	10 Hours

Table 3.4 Initial & Final Setting Time of Cement

3.6.3. Sieve Analysis of Fine Aggregate

Sieve Size (mm)	Percentage of passing Aggregate	Percentage of retained Aggregate
4.75 mm	100 %	0%
2.36 mm	100%	0%
1.18 mm	73 %	27%
600 micron	58%	15%
300 micron	15%	43%
150 micron	6%	9%
90 micron	0%	6%

Table 3.5 Sieve Analysis of Fine Aggregate

3.6.4. Sieve Analysis of Coarse Aggregate

Sieve Size (mm)	Percentage (%) of passing Aggregate	Percentage (%) of retained Aggregate

20 mm	60 %	40%
10 mm	3%	57%
4.75 mm	0 %	3%

Table 3.6 Sieve Analysis of Coarse Aggregate

3.6.5. Percentage of Fly Ash as Replacement of Cement

Sr. No.	Cement	Fly ash
1.	100%	0%
2.	95%	5%
3.	90%	10%
4.	85%	15%
5.	80%	20%

Table 3.7 Percentage of Fly Ash as Partial Replacement of Cement

3.7. Calculation Related to Material

Grade of Concrete- M-25 (1:1:2)
Water/Cement Ratio= 0.50

3.7.1 P.C.C:
In P.C.C, we have casted 9 cubes for which we casted 76.5 kg concrete because approx. 8.5 kg concrete comes in a cube on the basis of work done in past. 3 cubes on 7th day, 3 cubes on 14th day, and 3 cubes on 28th day have been tested. Quantity of material is given below: -

a) Cement: 19.12 kg
b) Fine Aggregate: 19.12 kg
c) Coarse Aggregate: 38.25 kg
d) Weight of concrete: 76.5 kg Approx.

3.7.2. 5% F.C.C:
In 5% F.C.C, 5% fly ash is used by weight of cement and we have casted 9 cubes for which we casted 76.5 kg concrete because approx 8.5 kg concrete comes in a cube on the basis of work done in past. 3 cubes on 7th day, 3 cubes on 14th day, 3 cubes on 28th day have been tested. Quantity of material is given below: -

a) Cement: 18.16 kg + Fly ash: 956 gm = 19.12 kg
b) Fine Aggregate: 19.12 kg
c) Coarse Aggregate: 38.25 kg
d) Weight of concrete: 76.5 kg (Approx.)

3.7.3. 10% F.C.C
In 10% F.C.C, 10% fly ash is used by weight of cement and we have casted 9 cubes for which we casted 76.5 kg concrete because approx. 8.5 kg concrete comes in a cube on the basis of work done in past. 3 cubes on 7th day, 3 cubes on 14th day, 3 cubes on 28th day have been tested. Quantity of material is given below: -

a) Cement: 17.20 kg + Fly ash: 1.92 kg = 19.12 kg
b) Fine Aggregate: 19.12 kg
c) Coarse Aggregate: 38.25 kg
d) Weight of concrete: 76.5 kg Approx.

3.7.4. 15% F.C.C:

In 15% F.C.C, 15% fly ash is used by weight of cement and we have casted 9 cubes for which we casted 76.5 kg concrete because approx. 8.5 kg concrete comes in a cube on the basis of work done in past. 3 cubes on 7th day, 3 cubes on 14th day, 3 cubes on 28th day have been tested. Quantity of material is given below: -

a) Cement: 16.26 kg + Fly ash: 2.86 kg = 19.12 kg
b) Fine Aggregate: 19.12 kg
c) Coarse Aggregate: 38.25 kg
d) Weight of concrete 76.5 kg Approx.

3.7.5. 20% F.C.C:

In 20% F.C.C, 20% fly ash is used by weight of cement and we have casted 9 cubes for which we casted 76.5 kg concrete because approx. 8.5 kg concrete comes in a cube on the basis of work done in past. 3 cubes on 7th day, 3 cubes on 14th day, 3 cubes on 28th day have been tested. Quantity of material is given below: -

a) Cement: 15.30 kg + Fly ash: 3.82 kg = 19.12 kg
b) Fine Aggregate: 19.12 kg
c) Coarse Aggregate: 38.25 kg
d) Weight of concrete: 76.5 kg Approx.

3.8. The Compressive Strength of Cubic Concrete Specimens

3.8.1. Scope:

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to moulded cubes at a rate which is within a prescribed range until failure occurs. The compressive strength is calculated by dividing the maximum load attained during the test by the cross sectional area of the specimen.

3.8.2. Apparatus:

(a) Weights and weighing device.
(b) Tools and containers for mixing.
(c) Tamper (square in cross section)
(d) Testing machine.
(e) Three cubes (150 mm side)

3.8.3. Procedure:

(a) Prepare a concrete mix as mentioned in (test No. 3) with the proportions suggested Such as: 1: 1:2 with w/c = 55% by mechanical mixer.
(b) Prepare three testing cubes; make sure that they are clean and greased or oiled thinly.
(c) Metal moulds should be sealed to their base plates to prevent loss of water.
(d) Fill the cubes in three layers, tamping each layer with (35) strokes using a tamper, square in cross-section with 2.54 cm side and 38.1 cm length, weighing 1.818 kg.
(e) While filling the moulds, occasionally stir and scrape together the concrete remaining in the mixer to keep the materials from separating.
(f) Fill the moulds completely, smooth off the tops evenly, and clean up any concrete outside the cubes.
(g) Mark the specimen by a slip of paper on which is written the date and the Specimen identification. Leave the specimens in the curing room for 24 hours.
(h) After that open the moulds and immerse the concrete cubes in a water basin for 7 days.
(i) Before testing, ensure that all testing machine bearing surfaces are wiped clean.
(j) Carefully centre the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube.
(k) Without shock, apply and increase the load continuously at a nominal rate within the range of (0.2 N/mm2 .s to 0.4 N/mm2 .s) until no greater load can be sustained. On manually controlled machines, as failure is approached, the loading rate will decrease, at this stage operate the controls to maintain, as far as possible, the specified loading rate. Record the maximum load applied to each cube.

3.8.4. Calculations: - Calculate the cross-sectional area of the cube face from the checked nominal dimensions. Calculate the compressive strength of each cube by dividing the by the cross-sectional area. Calculate the average for the three cubes.

Fig. 3.2 the moulds and vibrating the cube.

IV. TABULATION FORM OF TESTED RESULTS

4.1. Plain Cement Concrete (M25):

4.1.1. Compressive Strength at 7 Day (P.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	208	9.24	15.09
2.	150x150	342	15.20	
3.	150x150	469	20.84	

Table 4.1 Compressive Strength at 7th Day (P.C.C) M-25

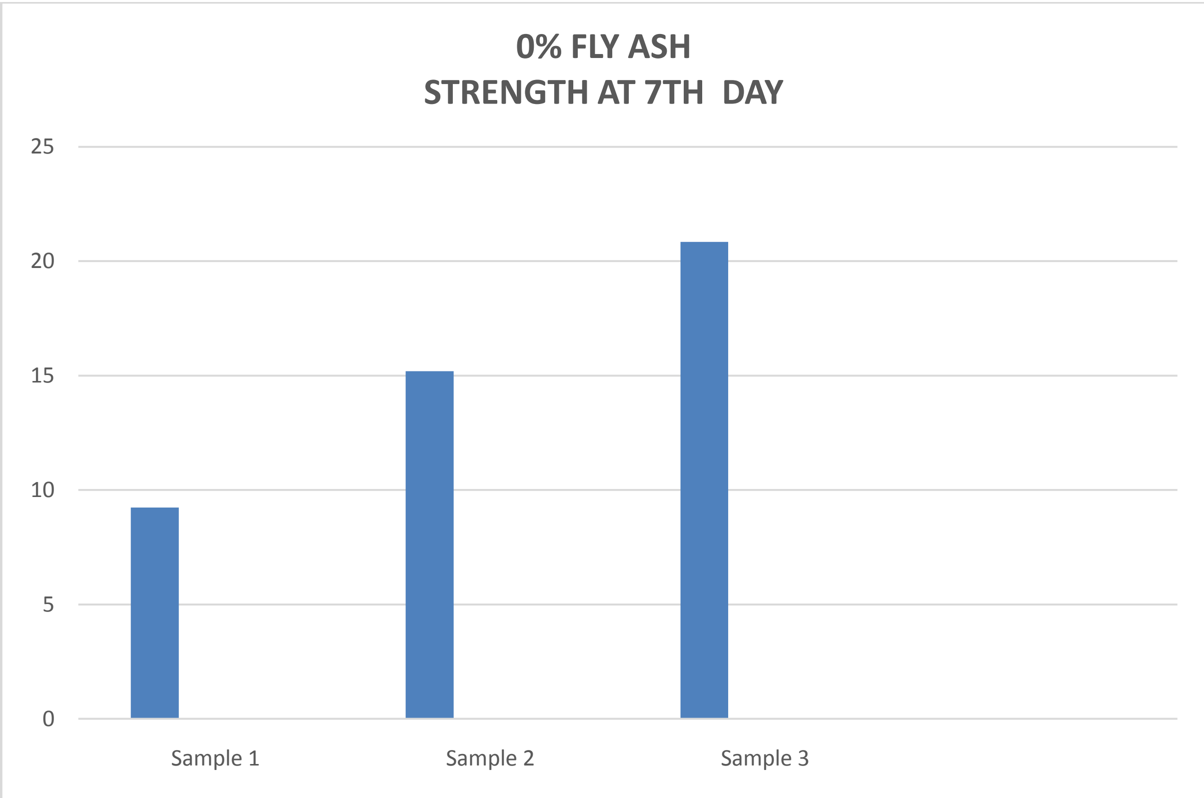

Fig. 4.1 Compressive Strength at 7th Day (P.C.C) M-25

4.1.2. Compressive Strength at 14th Day (P.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)

1.	150x150	387	17.2	17.65
2.	150x150	416	18.48	
3.	150x150	389	17.28	

Table 4.2 Compressive Strength at 14th Day (P.C.C) M-25

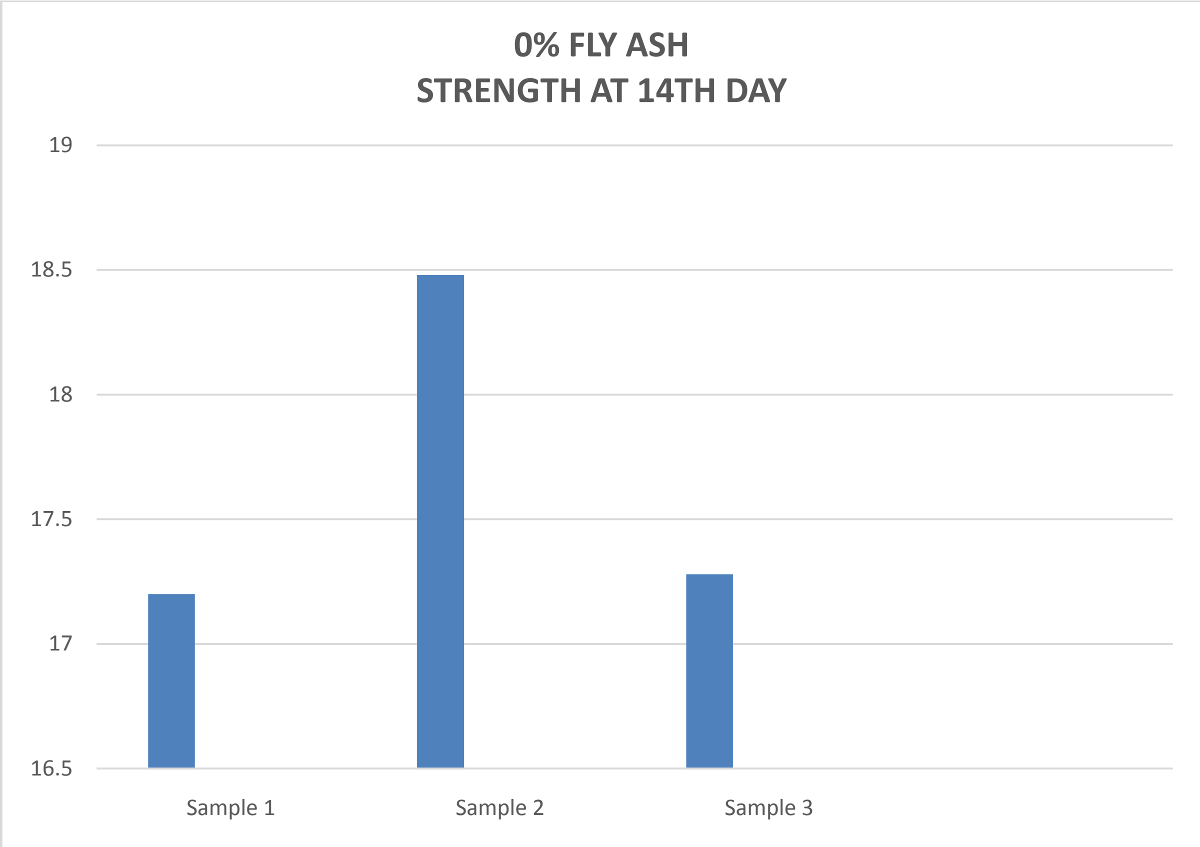

Fig. 4.2 Compressive Strength at 14th Day (P.C.C) M-25

4.1.3. Compressive Strength at 28th Day (P.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	524	23.28	22.69
2.	150x150	509.2	22.63	
3.	150x150	498.1	22.13	

Table 4.3 Compressive Strength at 28th Day (P.C.C) M-25

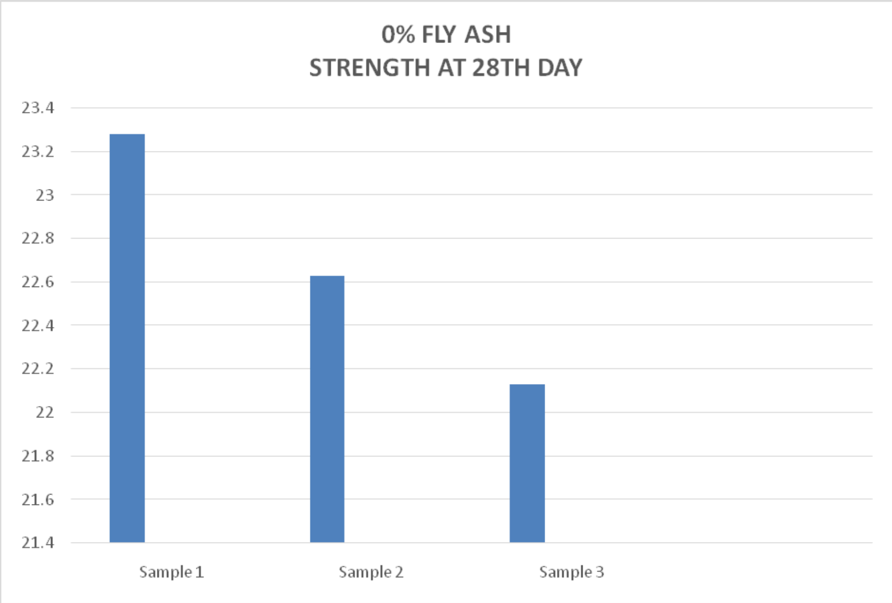

Fig. 4.3 Compressive Strength at 28th Day (P.C.C) M-25

4.2. 5% Fly Ash Mixed Cement Concrete (M25):

4.2.1. Compressive Strength at 7th Day (5% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	293	13.02	14.14
2.	150x150	326.2	14.49	
3.	150x150	336.1	14.93	

Table 4.4 Compressive Strength at 7th Day (5% F.C.C) M-25

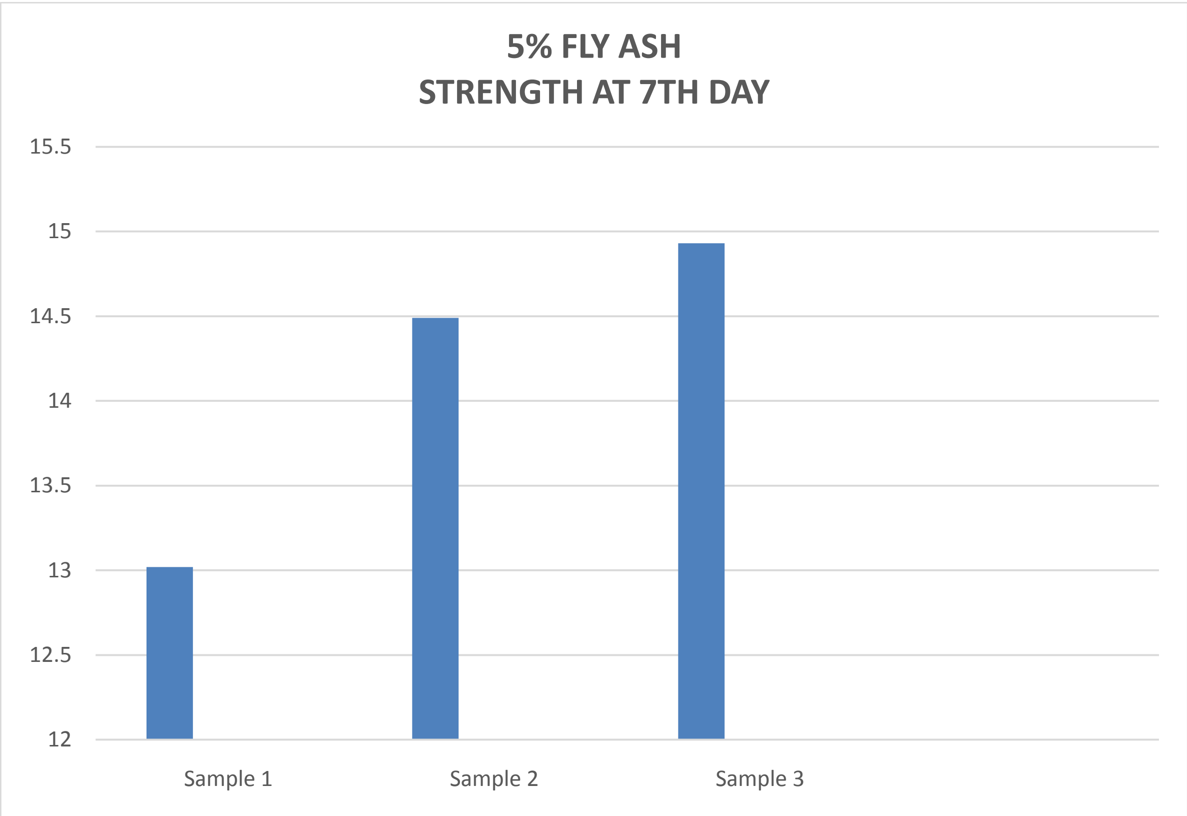

Fig. 4.4 Compressive Strength at 7th Day (5% F.C.C) M-25

4.2.2. Compressive Strength at 14th Day (5% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	336	14.93	16.17
2.	150x150	390	17.33	
3.	150x150	366	16.26	

M-25 Table 4.5 Compressive Strength at 14th Day (5% F.C.C)

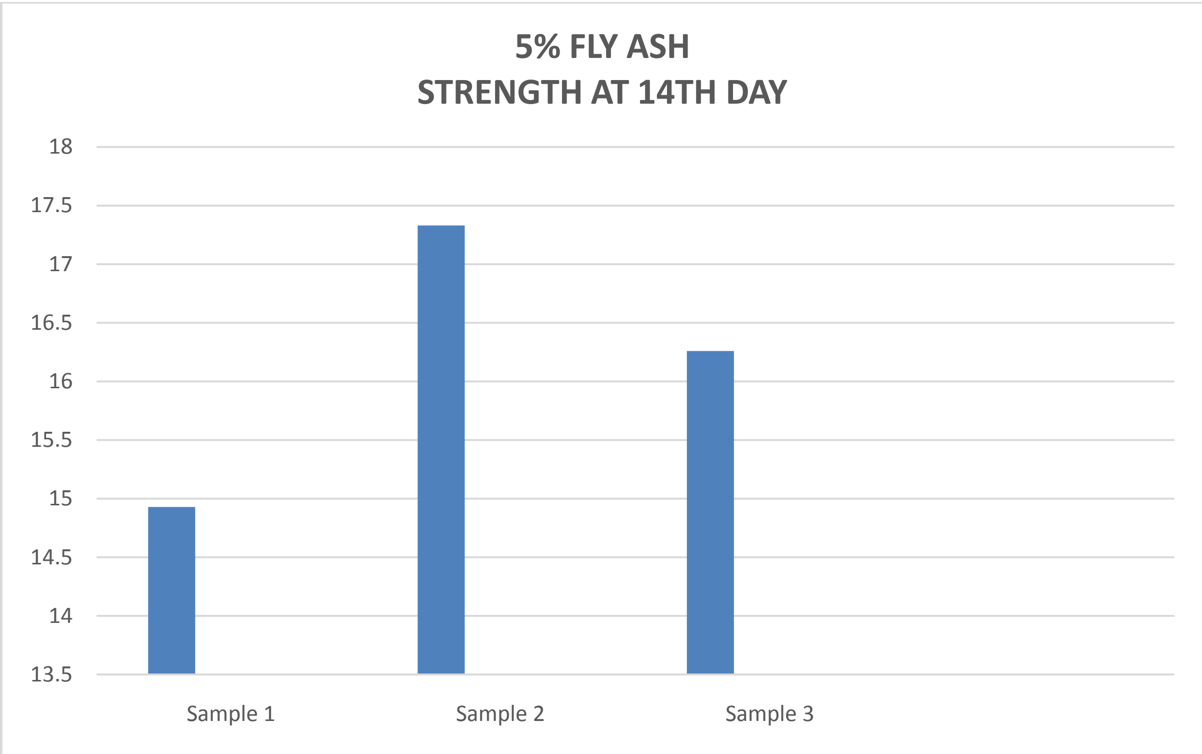

Fig. 4.5 Compressive Strength at 14th Day (5% F.C.C) M-25

4.2.3. Compressive Strength at 28th Day (5% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength ($N/mm^{2)}$)	Mean (N/mm^2)
1.	150x150	465	20.66	21.04
2.	150x150	498.4	22.15	
3.	150x150	457	20.31	

Table 4.6 Compressive Strength at 28th Day (5% F.C.C) M-25

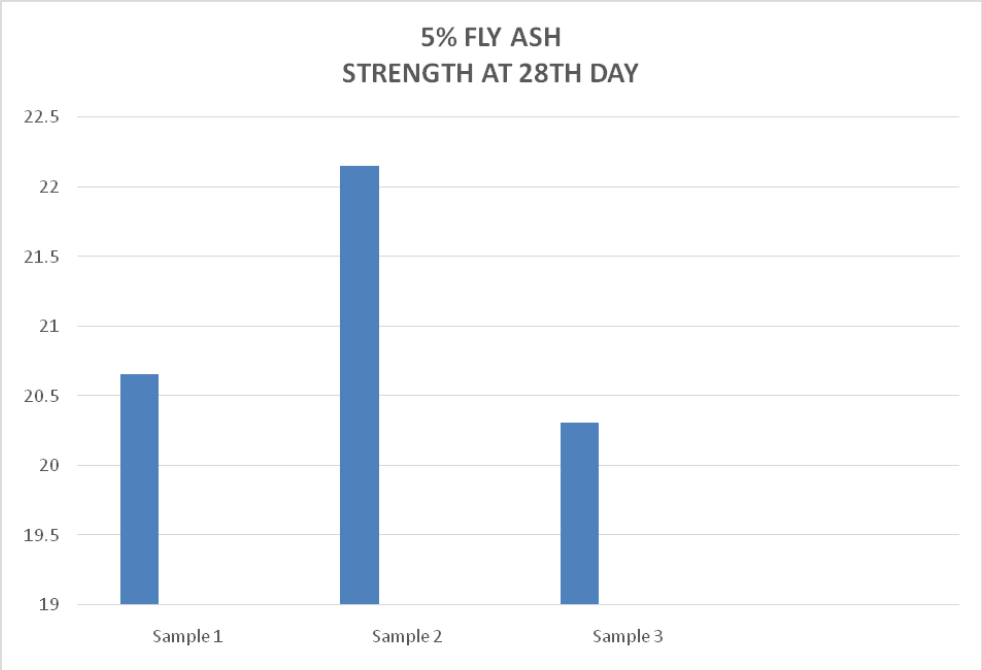

Fig. 4.6 Compressive Strength at 28th Day (5% F.C.C) M-25

4.3. 10% Fly Ash Mixed Cement Concrete (M25):

4.3.1. Compressive Strength at 7th Day (10% F.C.C) M-25

S.No.	Area(mm^2)	Reading(CTM)	Compressive Strength N/mm^2	Mean N/mm^2
1.	150x150	310	13.77	13.15
2.	150x150	296	13.15	
3.	150x150	282.2	12.54	

Table 4.7 Compressive Strength at 7th Day (10% F.C.C) M-25

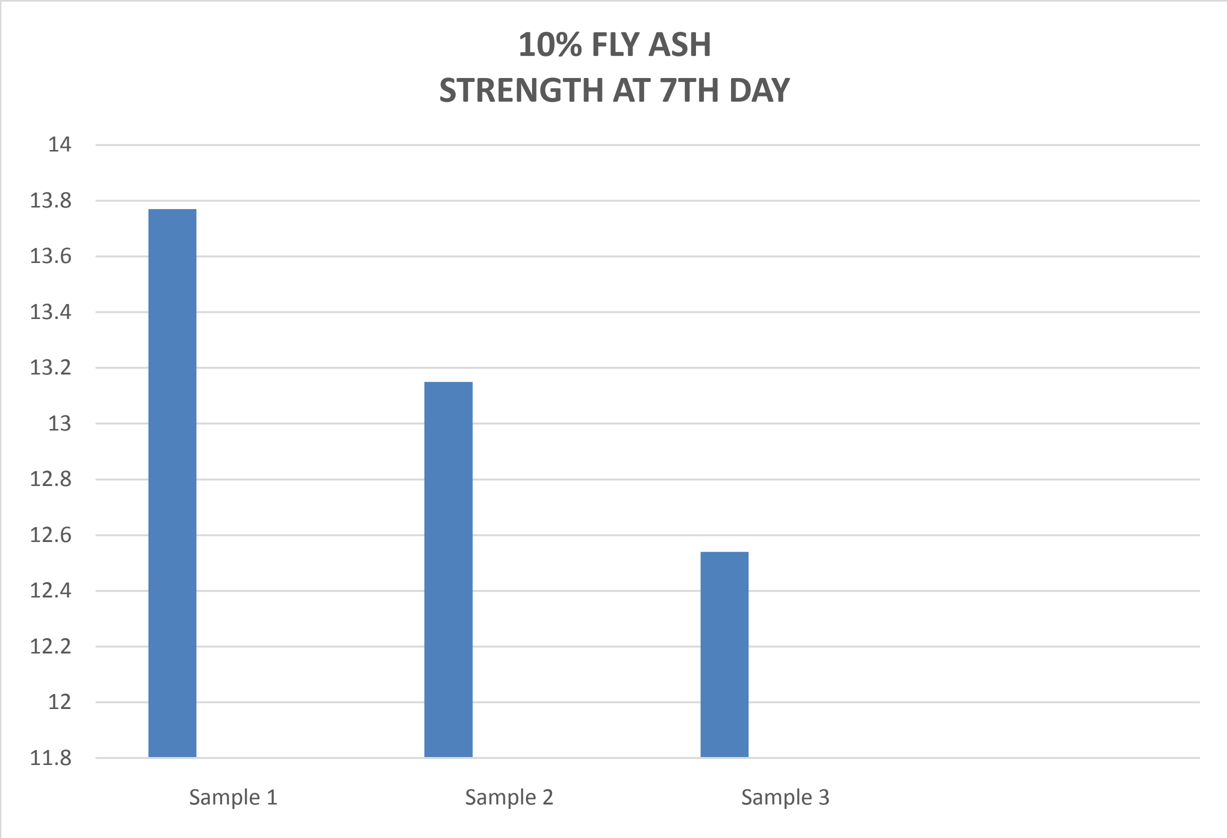

Fig. 4.7 Compressive Strength at 7th Day (10% F.C.C) M-25

4.3.2. Compressive Strength at 14th Day (10% F.C.C) M-25

S.No.	Area (mm²)	Reading(CTM) (kN)	Compressive Strength (N/mm²)	Mean (N/mm²)
1.	150x150	353.40	15.70	16.04
2.	150x150	345	15.33	
3.	150x150	380.67	16.91	

Table 4.8 Compressive Strength at 14th Day (10% F.C.C) M-25

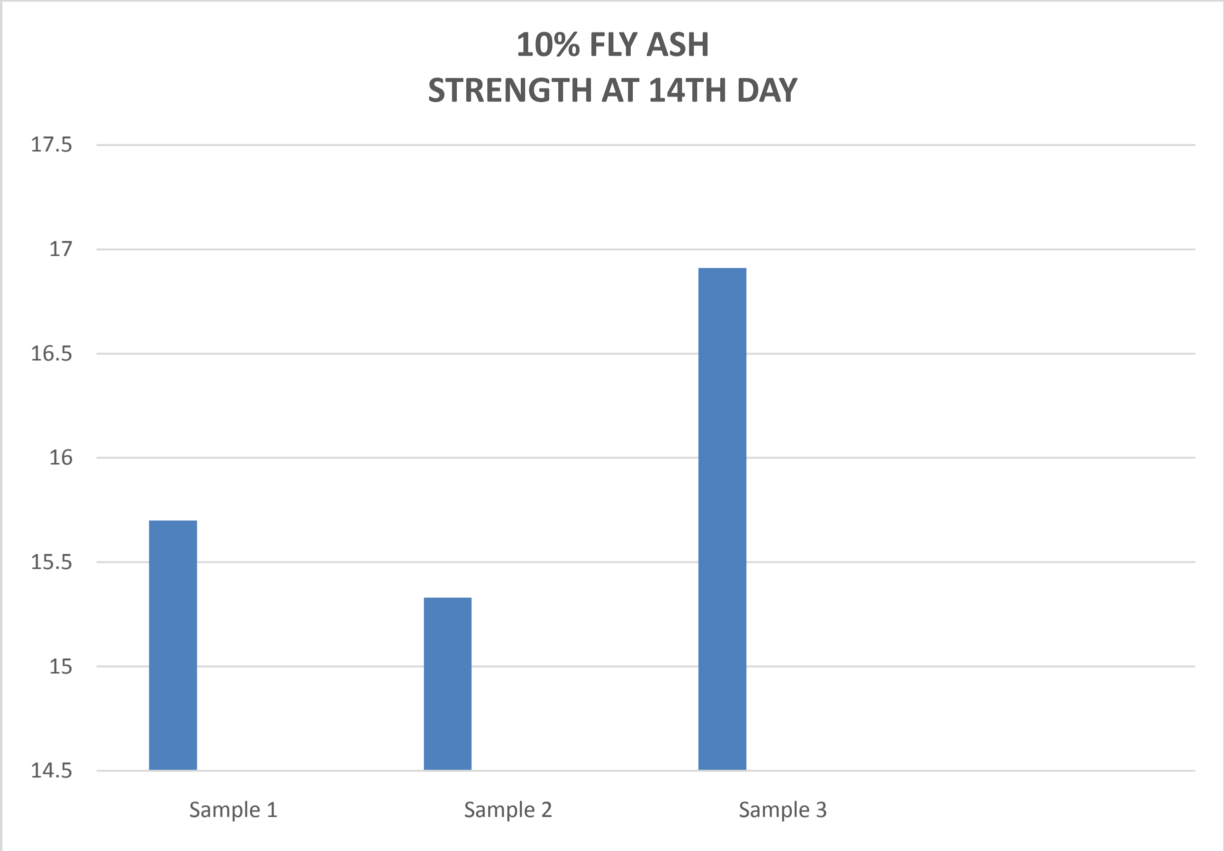

Fig. 4.8 Compressive Strength at 14th Day (10% F.C.C) M-25

4.3.3. Compressive Strength at 28 Days (10% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	454.67	20.20	19.87
2.	150x150	399.6	17.76	
3.	150x150	487.30	21.65	

Table 4.9 Compressive Strength at 28th Day (10% F.C.C) M-25

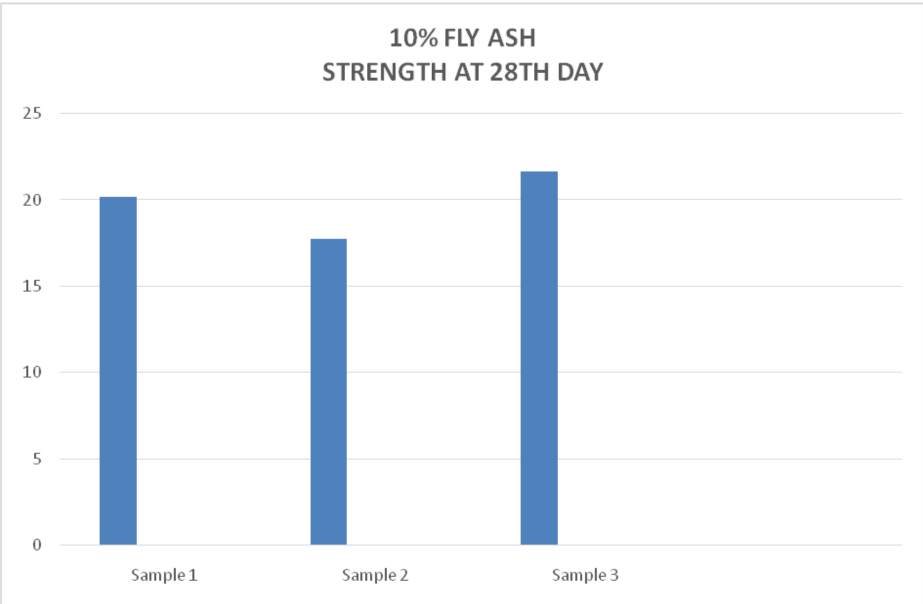

Fig. 4.9 Compressive Strength at 28th Day (10% F.C.C) M-25

4.4. 15% FLY ASH MIXED CEMENT CONCRETE (M25):

4.4.1. Compressive Strength at 7th Day (15% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	301.26	13.38	12.98
2.	150x150	283.56	12.60	
3.	150x150	291.73	12.96	

Table 4.10 Compressive Strength at 7th Day (15% F.C.C) M-25

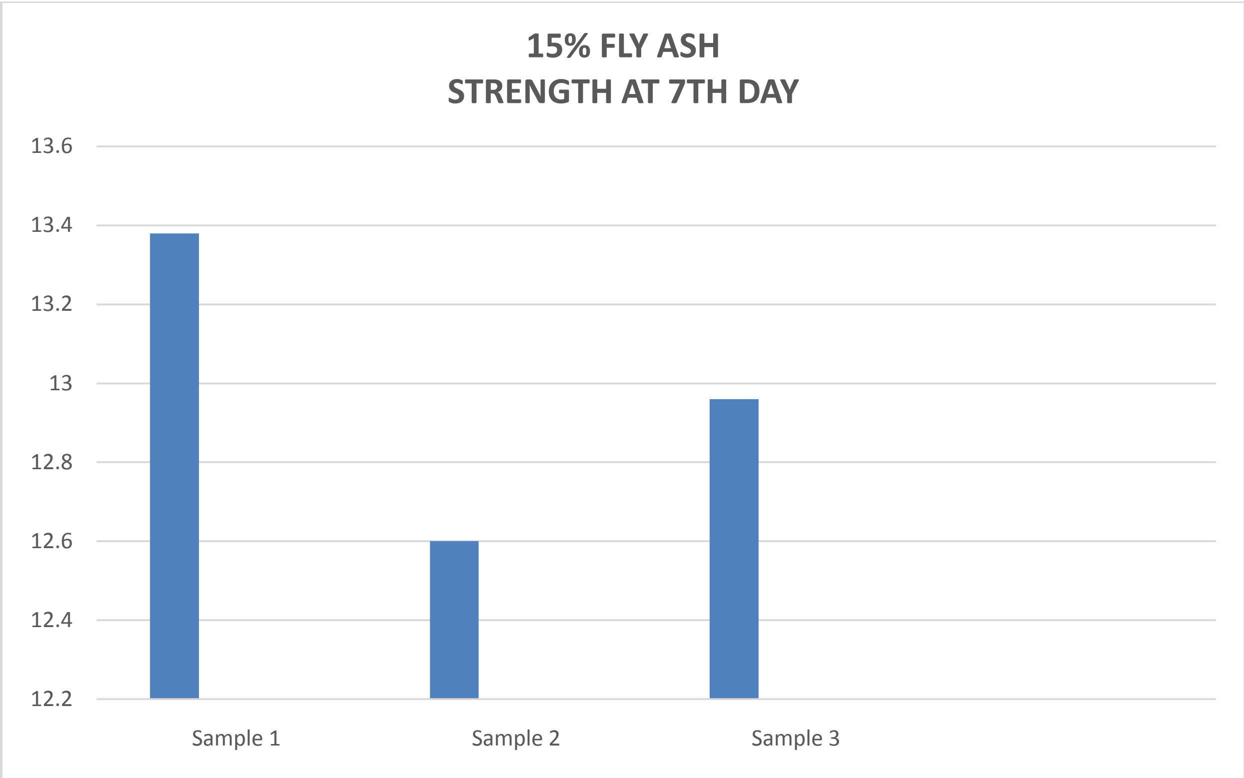

Fig. 4.10 Compressive Strength at 7th Day (15% F.C.C) M-25

4.4.2. Compressive Strength at 14th Day (15% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	336.19 KN	14.94	14.98
2.	150x150	317.40 KN	14.10	
3.	150x150	357.78 KN	15.90	

Table 4.11 Compressive Strength at 14th Day (15% F.C.C) M-25

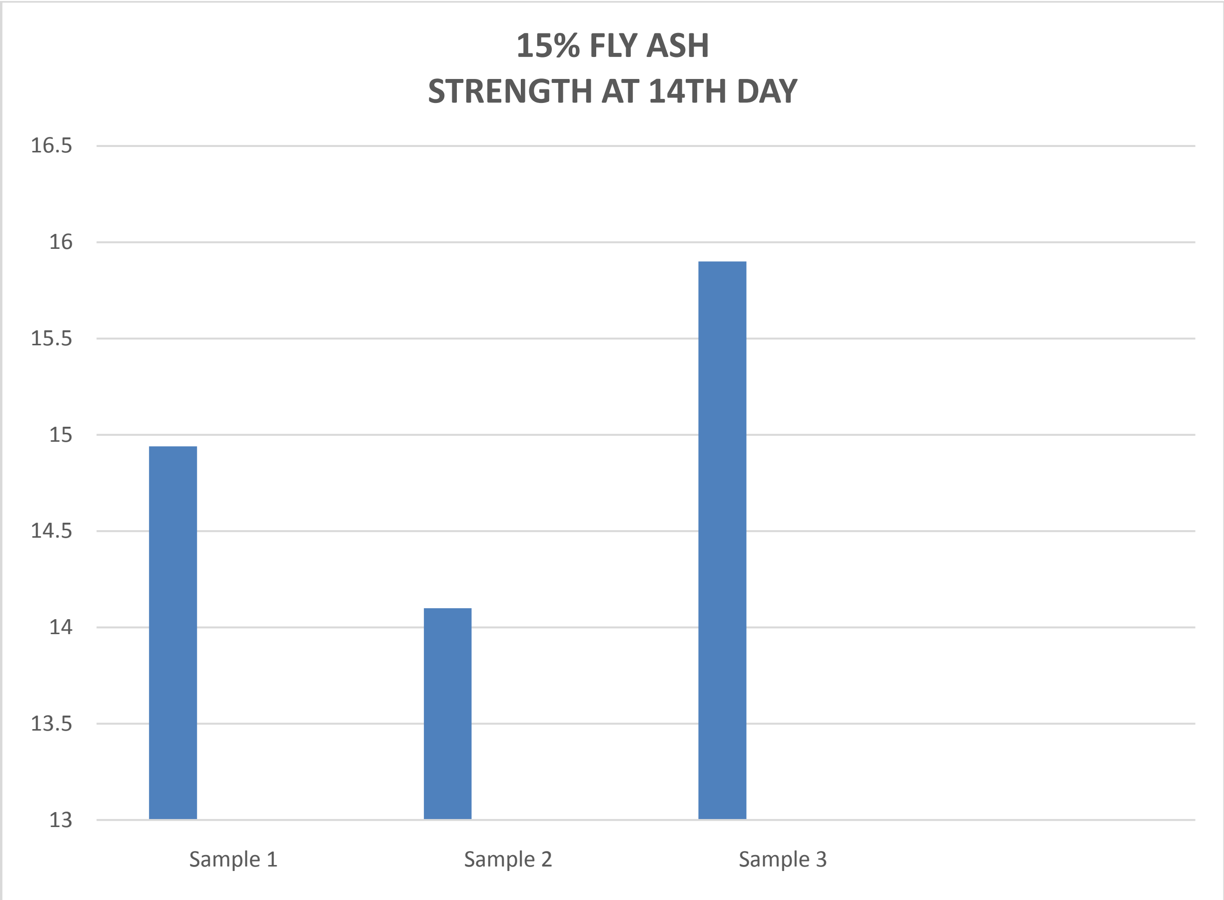

Fig. 4.11 Compressive Strength at 14th Day (15% F.C.C) M-25

4.4.3. Compressive Strength at 28th Day (15% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	378.94	16.84	18.95
2.	150x150	437.59	19.44	
3.	150x150	463.23	20.58	

Table 4.12 Compressive Strength at 28th Day (15% F.C.C) M-25

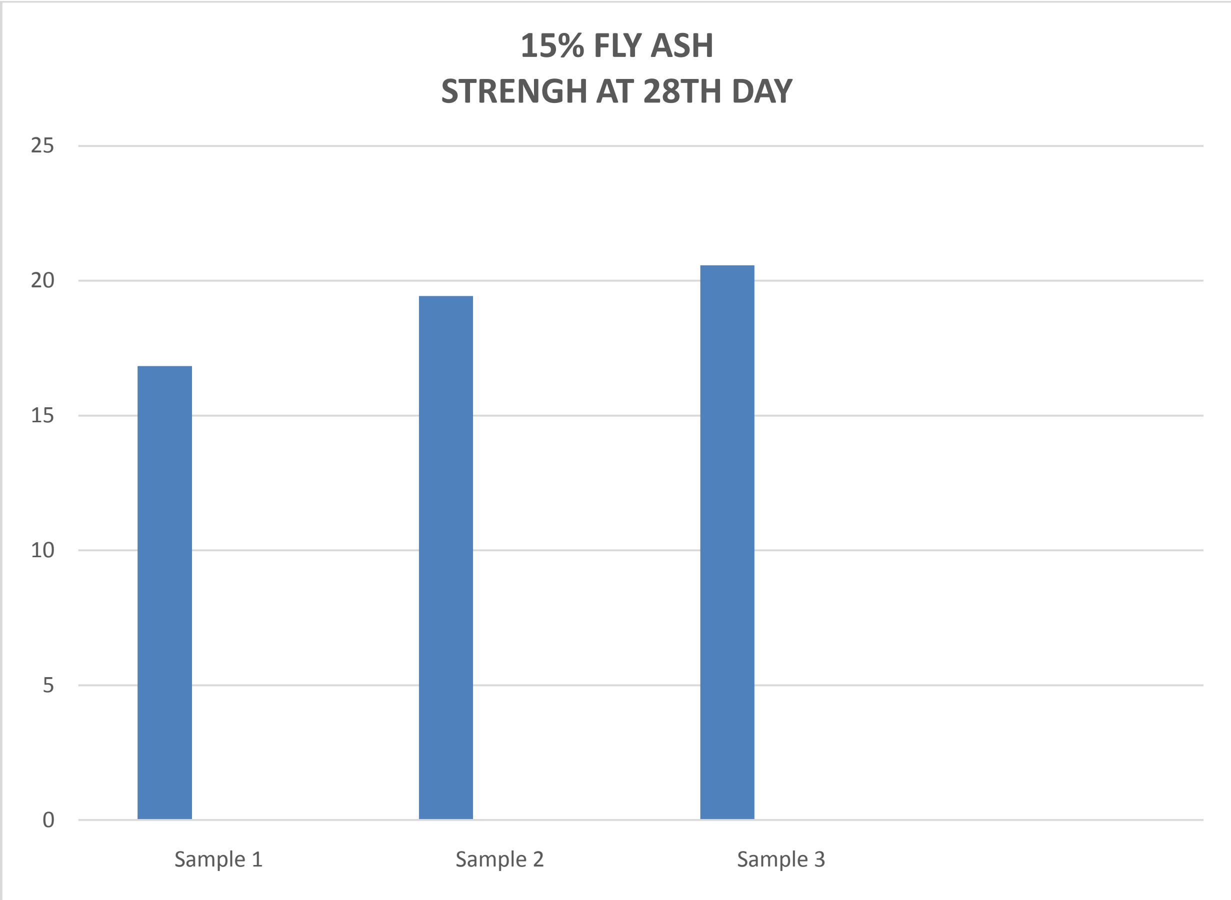

Fig. 4.12 Compressive Strength at 28th Day (15% F.C.C) M-25

4.5. 20% Fly Ash Mixed Cement Concrete (M25):

4.5.1 Compressive Strength at 7th Day

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	218.67	9.71	11.27
2.	150x150	279.10	12.40	
3.	150x150	253.30	11.70	

Table 9.13 Compressive strength at 7th day (20% F.C.C) M-25

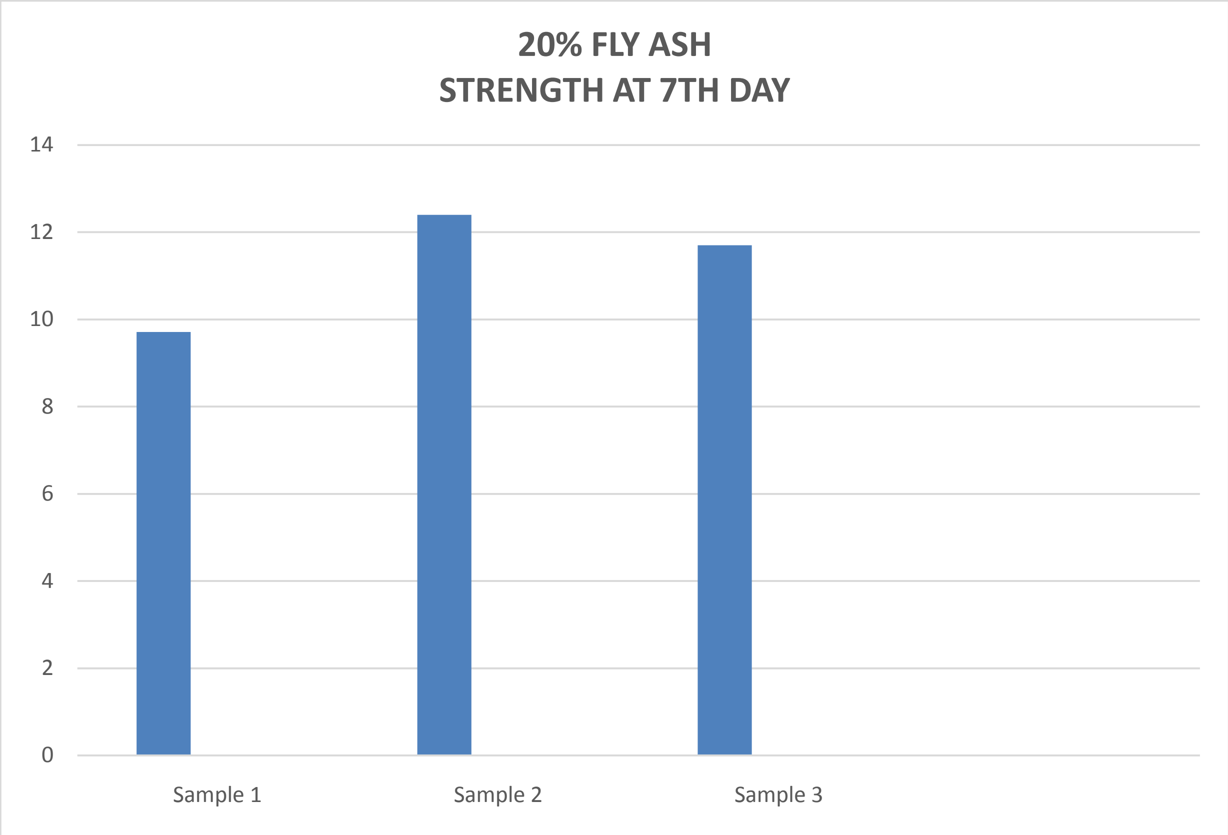

Fig. 4.13 Compressive Strength at 7th Day (20% F.C.C) M-25

4.5.2. Compressive Strength at 14th Day (20% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	307.50	13.66	14.22
2.	150x150	343.14	15.95	
3.	150x150	291.19	13.07	

Table 4.14 Compressive Strength at 14th Day (20% F.C.C) M-25

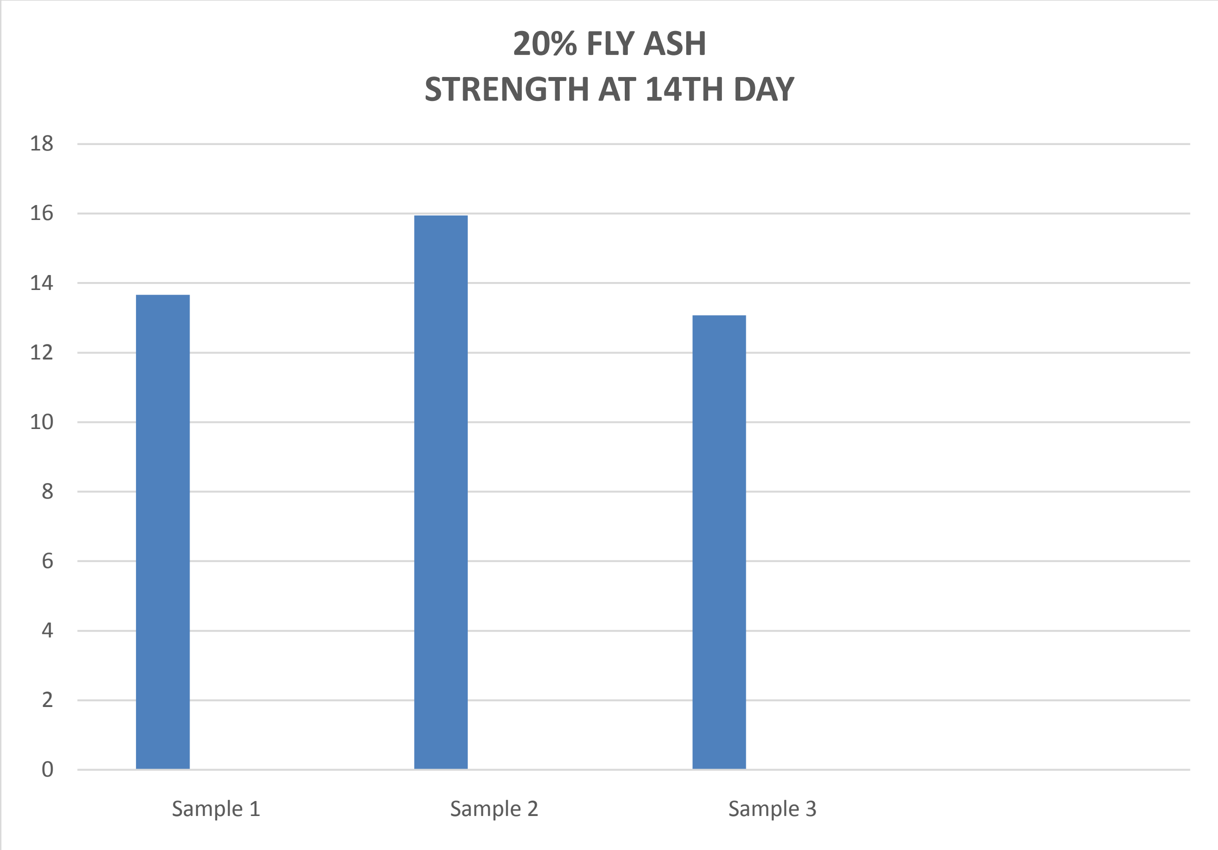

Fig. 4.14 Compressive Strength at 14th Day (20% F.C.C) M-25

4.5.3. Compressive Strength at 28th Day (20% F.C.C) M-25

S.No.	Area (mm^2)	Reading(CTM) (kN)	Compressive Strength (N/mm^2)	Mean (N/mm^2)
1.	150x150	357.56	15.89	16.75
2.	150x150	389	17.28	
3.	150x150	384.40	17.08	

Table 4.15 Compressive Strength at 28th Day (20% F.C.C) M-25

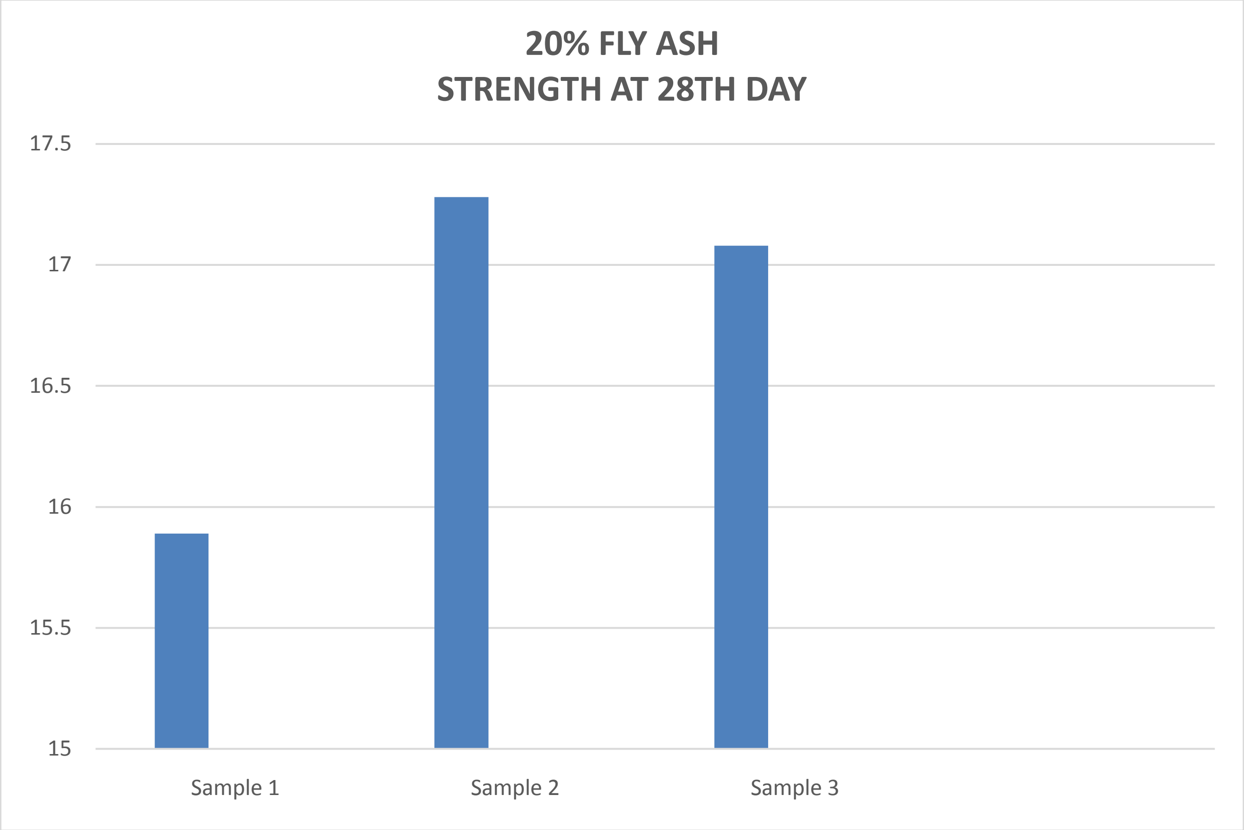

Fig. 4.15 Compressive Strength at 28th Day (20% F.C.C) M-25

9.6 Difference between Normal Concrete & Fly Ash Mixed Concrete.

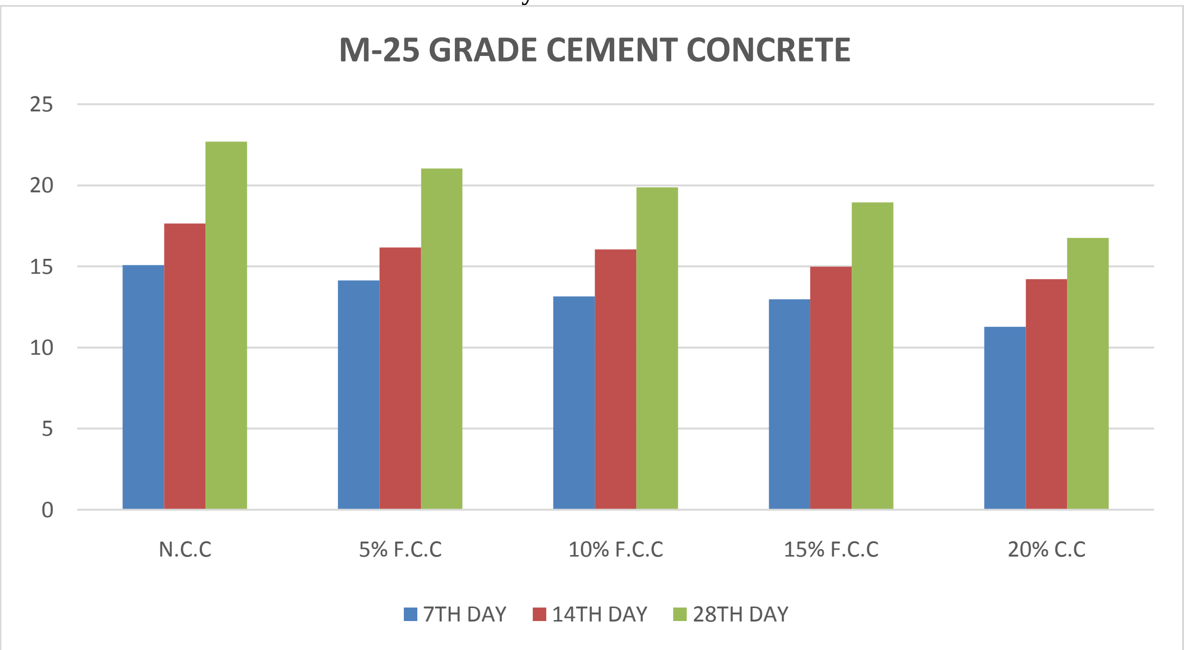

Fig. 4.16 Difference between N.C.C & fly ash mixed concrete(M-25)

V. CONCLUSION

The following conclusions can be drawn from the experimental investigation carried out:

1. The normal consistency of OPC is achieved at 32% of water, while the normal consistency of 5% fly ash with cement is achieved at 37% of water, while the normal consistency of 10% fly ash with cement is achieved at 39% of water, while the normal consistency of 15% fly ash with cement is achieved at 40% of water, while the normal consistency of 20% fly ash with cement is achieved at 37% of water.

2. The Initial & Final setting time of OPC is 30 Minutes & 10 Hours, while the Initial & Final setting time of 5% fly ash with cement is 35 Minutes & 10 Hours Approx., while the Initial & Final setting time of 10% fly ash with cement is 35 Minutes & 10 Hours Approx., while the Initial & Final setting time of 15% fly ash with cement is 36 Minutes & 10 Hours Approx., while the Initial & Final setting time of 20% fly ash with cement is 29 Minutes & 10 Hours Approx.

3. As per the sieve analysis test of fine aggregate, aggregate is used of size 90 micron to 4.75 mm. As per the sieve analysis test of coarse aggregate, aggregate is used of size 10 mm to 20 mm.

4. The compressive strength of concrete cube (N.C.C) at 7^{th} day is 15.09 N/mm^2, the compressive strength of concrete cube (N.C.C) at 14^{th} day is 17.65 N/mm^2 , while the compressive strength of concrete cube (N.C.C) at 28^{th} day is 22.69 N/mm^2 .

5. The compressive strength of concrete cube (5% F.C.C) at 7^{th} day is 15.09 N/mm^2.the compressive strength of concrete cube (5% F.C.C) at 14^{th} day is 17.65 N/mm^2. while the compressive strength of concrete cube (5% F.C.C) at 28^{th} day is 22.69 N/mm^2 .

6. The compressive strength of concrete cube (10% F.C.C) at 7^{th} day is 15.09 N/mm^2.the compressive strength of concrete cube (10% F.C.C) at 14^{th} day is 17.65 $N/mm^{2.}$While the compressive strength of concrete cube (10% F.C.C) at 28^{th} day is 22.69 $N/mm^{2.}$

7. The compressive strength of concrete cube (15% F.C.C) at 7^{th} day is 15.09 N/mm^2.the compressive strength of concrete cube (15% F.C.C) at 14^{th} day is 17.65 N/mm^2. While the compressive strength of concrete cube (15% F.C.C) at 28^{th} day is 22.69 $N/mm^{2.}$

8. The compressive strength of concrete cube (20% F.C.C) at 7^{th} day is 15.09 N/mm^2. the compressive strength of concrete cube (20% F.C.C) at 14^{th} day is 17.65 N/mm^2 . while the compressive strength of concrete cube (20% F.C.C) at 28^{th} day is 22.69 N/mm^2 .

9. Compressive strength of M-25 grade concrete of all types of mixes (0%. 5%. 10%. 15%. 20% fly ash) decreases as the quantity of fly ash is increase in cement.

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