# A Review Study on Cost Comparison of Normal and High-Volume Fly Ash Concrete

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*Abstract*— With the growing urbanisation and development the demand of concrete does not seem to go dormant in the future. But due to limited supply of non-renewable constituents of concrete they are needed to be preserved for the future generations, so there is utmost necessity of using supplementary waste materials in concrete With advancement in science and technology it is made possible that the waste materials like fly ash, lime stone quarry fine, silica fume, blast furnace slag etc can be used as a supplement. Here we will study the effect of replacing cement with Fly Ash on strength and economy of concrete. In this present study first of all the need, scope and advantages of using High Volume Fly Ash Concrete is discussed .The existing records of research on use of Fly Ash in concrete is followed by the tests conducted on Aggregates like Sieve Analysis, Impact Value, Water Absorption Test etc. The properties of various materials used are also discussed. After that comes experimental programme which includes tests done on concrete samples casted in the study of grade M40 and M25 in which cement is replaced by Fly Ash in different percentages (28%,50% and 70%) and the strength characteristics of High-Volume Fly Ash Concrete is checked. Last portion of this study deals with the various observations made during the tests and results obtained after it based on which interpretations are made regarding the cost of the various concrete mix used in the study and conclusion are drawn based on which we can decide whether substituting cement with is suitable for a given project or not.

***Keywords:*** Fly Ash

## I. INTRODUCTION

### A. General

Fortunately, a waste product Fly Ash can be substituted for large portions of Portland cement, significantly improving concrete's environmental characteristics. Fly Ash, consisting mostly of silica, alumina, and iron, forms a compound similar to Portland cement when mixed with lime and water. Fly ash is a non- combusted by-product of coal-fired power plants and generally ends up in a landfill. However, when high volumes are used in concrete (displacing more than 25% of the cement), it creates a stronger, more durable product and reduces concrete's environmental impact considerably. Due to its strength and lower water content, cracking is reduced.

In the HVFAC mechanism, physical and chemical factors combines at all ages to densify and bind the paste. In the early age of concrete, the important factors of strength development are

- Physical effect - fine particles of fly ash act as micro aggregates and densify the mass
- Chemical contribution of the formation of ettringite or related sulpho-aluminate production.

Concrete, typically composed of gravel, sand, water, and portland cement, is an extremely versatile building material that is used extensively worldwide. Reinforced concrete is very strong and can be cast in nearly any desired shape. Unfortunately, significant environmental problems result from the manufacture of Portland cement. Worldwide, the manufacture of Portland cement accounts for 6-7% of the total carbon dioxide (CO2) produced by humans, adding the greenhouse gas equivalent of 330 million cars driving 12,500 miles per year[1].

### B. Advantages of Fly Ash in Concrete

1) Sulfate and Alkali Aggregate Resistance: Class F and a few Class C Fly Ashes impart significant sulfate resistance and alkali aggregate reaction resistance to the concrete mixture.
2) Fly Ash has a lower heat of hydration: Portland Cement produces considerable heat upon hydration. In mass concrete placements the excess internal heat may contribute to cracking. The use of Fly Ash may greatly reduce this heat build up and reduce external cracking.
3) Fly Ash generally reduces the permeability and adsorption of concrete: By reducing the permeability of chloride ion egress, corrosion of embedded steel is greatly decreased. Also, chemical resistance is improved by the reduction of permeability and adsorption.
4) Fly Ash is economical: The cost of Fly Ash is generally less than Portland Cement depending on transportation. Significant quantities may be substituted for Portland Cement in concrete mixtures and yet increase the long term strength and durability. Thus, the use of Fly Ash may impart considerable benefits to the concrete mixture over a plain concrete for less cost.

### C. Objectives

- The main objective of the present study is to compare the strength characteristics of M40 concrete by using sample of different percentages of fly ash by mass of cementetious material, and also comparison is made between there cost. To achieve this objective following steps are to be followed:
- Design of M40 concrete mix to obtain the ratio of different components of concrete.
- By using the above calculated ratio samples for compressive and flexural strength test for 28%, 50%, 70% replacement of cement by fly ash is to be made.
- Compressive strength of 3,7 and 28 days is to be calculated by casting cubes for M40 mix at 28%, 50% and 70% fly ash replacement by cement.

– Flexural strength of 28 and 56 days is to be calculated by casting beam shaped samples of M40 mix at 28%, 50% and 70% fly ash replacement by cement.
– Comparison of the compressive and the flexural strength obtained at different percentages of fly ash is to be made.
– Cost comparison of 28%, 50% and 70% fly ash concrete is to be made.

### *D. Scope of Present Study*

The scope of present study aims at providing the M40 concrete with that optimum quantity of fly ash content which could be used in structure or road construction with acceptable strength values so, that the cost of construction can be reduced to a great extent and also by achieving this the harmful impact of fly ash on environment could be reduced.

## II. LITERATURE REVIEW

### *A. General*

This chapter deals with the reviews of the existing literature on the use of high volume fly ash concrete. The most important investigations, related to the current investigations are summarized and the salient facts which seems to emerge from the research are discussed. The discussion is generally confined to influence of fly ash addition in the properties of concrete, workability and compressive strength.

Nowadays concrete is the most widely used construction material. Durability of concrete is one of the most important considerations in the design of new structures (Roads, Buildings, Fly Overs etc.) and assessing the conditions of existing structures. The last 20 to 30 years have seen the growing awareness among the Engineers of the need to ensure that the provisions are made for durability in concrete structure. More recently, there has also been a growing awareness of the importance of sustainability in concrete construction and in particular the more effective and efficient use of material.

### *B. Brief Review of Previous Studies*

The literature studied about the Fly Ash Concrete is been presented here in three parts or stage:

1) Fresh Properties.
2) Hardened Properties.
3) Durability Properties.

#### *1) Fresh Properties:*

Owens, P.L. (1989)[6] in his paper" Fly ash and its usage in concrete" reported that with the use of fly ash containing large fraction of particles coarser than 45µm or a fly ash with high amount of unburned carbon, exhibiting loss on ignition more than 1%, higher water demand was observed.

Sivasundram, V. et al. (1990)[7] in their paper " Selected properties of high volume fly ash concretes" investigated the setting time of high-volume fly ash concrete mixes, and concluded that the initial setting time of 1.50 hours was comparable to that of the control concrete, whereas the final setting time was extended by about 3 hours as compared to that of the control concrete.

#### *2) Hardened Properties:*

Carette, G.G. and Malhotra, V.M. (1983)[8] in their research paper "Characterization of Canadian fly Ashes and their Performance in Concrete" studied the effect of Canadian fly ashes on the compressive strength of concrete mixes. Cement was replaced with 20% fly ash in all the mixes. Compressive strength was measured up to the age of 365 days. It was seen that compressive strength continued to increase with age, indicating pozzolanic action of fly ashes.

Joshi, R.C., and Lohtia, R.P. (1993)[9] in their paper " Effects of premature freezing temperatures on compressive strength, elasticity and microstructure of high volume fly ash concrete" tested a large number of fly concrete mixes made by using three different fly ashes containing about 10% calcium oxide. The replacement level varied between 40 and 60% by weight of cement. The mixes were super-plasticized and air-entrained to obtain 100 to 120 mm slump and 6 ± 1% air content. The cementitious material content varied from 380 to 466 kg/m3, water to cementitious material ratio from 0.27 to 0.37, coarse aggregate ranged from 1,012 to 1,194 kg/m3, and fine aggregate or sand varied from 712 to 643 kg/m3. They reported that at 7 days, the fly ash concretes obtained strength between 27.9 and 41.0 MPa compared to 44.1 MPa of control concrete. However at the age of 28 days, the fly ash concretes developed strength varying from 37.6 to 50.7 MPa against 58.7 MPa for control concrete. At 120 days, strength of fly ash concrete ranged from 54.8 to 74.6 MPa whereas it was 74.6 MPa of control concrete.

Lohtia et al. (1996)[10] in his paper " Creep of fly ash concrete " studied the creep and creep recovery of plain and fly ash concretes at stress-strength ratios of 20 and 35%. Fly ash content was varied between 0 and 25%. They concluded that:

1) Replacement of 15% of cement with fly ash was optimum with respect to strength, elasticity, shrinkage and creep of fly ash concrete.
2) Creep–time curves for plain and fly ash concretes were similar, and creep linearly related to the logarithm of time
3) With fly ash content up to 15%, increase in creep was negligible. However, slightly higher creep occurred with fly ash content more than 15%.
4) Creep coefficients were similar for the materials with fly ash content in the range of 0–25%.
5) Creep recovery was found to vary from 22 to 43% of the corresponding 150-day creep. For replacement beyond 15%, the creep recovery was smaller.

No definite trend of creep recovery as a function of stress-strength ratio was observed.

Haque et al. (1998)[11] investigated the shrinkage of concrete containing 40–75% cement replacement with a bituminous fly ash (CaO 10%). They concluded that drying shrinkage of concrete decreased with increase in fly ash content.

Saraswathy, V. et al. (2003)[12] in their paper " Influence of activated fly ash on corrosion– resistance and strength of concrete" investigated the influence of activated fly ash on the compressive strength of concrete. Various activation techniques, such as physical, thermal and chemical were adopted. Concrete specimens were prepared with 10, 20, 30 and 40% of activated fly ash replacement levels with cement. Compressive strength was determined at 7, 14, 28 and 90 days. They concluded that:

1) Activation of fly ash improved the strength of concrete. However, the compressive strength of fly ash concrete was less than that of ordinary portland cement (OPC) even after 90 days of curing.
2) Among the activation systems, chemically activated coal fly ash (CFA) improved the compressive strength to a certain extent, only with 10 and 20% replacements. Since the CFA surface layer is etched by a strong alkali to facilitate more cement particles to join together and also the addition of CaO which is further promoting the growth of CSH gel and Ca(OH)2 which is more advantageous to enhance the strength development.

Siddique, R. (2003)[13] in his paper "Effect of fine aggregate replacement with class F fly ash on the mechanical properties of concrete", studied the effect of partial replacement of fine aggregate (sand) with varying percentages of Class F fly ash on the compressive strength, splitting tensile strength, flexural strength and modulus of elasticity of concrete up to the age of 365 days. Fine aggregate (sand) was replaced with five levels of percentages (10, 20, 30, 40, and 50%) of Class F fly ash by weight. Control mix (without fly ash) was proportioned to have a 28-day cube compressive strength of 26.4 MPa. Based on the results, it was concluded that:

1) Compressive strength of fine aggregate (sand) replaced fly ash concrete specimens was higher than the plain concrete (control mix) specimens at all the ages. The strength differential between the fly ash concrete specimens and plain concrete specimens became more distinct after 28-days.
2) Compressive strength continued to increase with age for all fly ash replacement levels.
3) The maximum compressive strength occurs with 50% fly ash content at all ages. It was 40.0 MPa at 28-day, 51.4 MPa at 91-day, and 54.8 MPa at 365-day.
4) Splitting tensile strength, and flexural strength of fine aggregate (sand) replaced fly ash concrete specimens was higher than the plain concrete (control mix) specimens at all the ages. The strength differential between the fly ash concrete specimens and plain concrete specimens became more distinct after 28-days.
5) Both splitting and flexural strengths continued to increase with age for all fly ash percentages.
6) At all the ages, the maximum splitting tensile strength was observed with 50% fly ash content. It was 3.5 MPa at 28-day, 4.3 MPa at 91-day, and 4.4 MPa at 365-days.
7) Maximum flexural strength was found to occur with 50% fly ash content at all ages. It was 4.3 MPa at 28-day, 5.2 MPa at 91-day, and 5.4 MPa at 365-days.
8) Modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens was higher than the plain concrete (control mix) specimens at all the ages. The differential between the fly ash concrete specimens and plain concrete specimens became more distinct after 28-days.
9) Modulus of elasticity of fine aggregate (sand) replaced fly ash concrete continued to increase with age for all fly ash percentages.
10) At all ages, the maximum value of modulus of elasticity occurs with 50% fly ash content. It is 24.5 GPa at 28-day, 28.0 GPa at 91-day, and 29.0 GPa at 365-day.

Atis et al. (2004)[14] in their paper " Strength and shrinkage properties of mortar containing a nonstandard high-calcium fly ash" assessed the drying shrinkage of mortar mixtures containing high calcium non standard fly ash up to the age of 5 months. Five mortar mixtures including control Portland cement and fly ash mortar mixtures were prepared. Fly ash replaced cement on mass basis at the replacement ratios of 10, 20, 30 and 40%. Water–cementitious materials ratio was 0.4. Mixtures were cured at 65% relative humidity and 20 ± 2O C. They reported that shrinkage of Portland cement mortar at 5 months was 0.1228%. Shrinkage of fly ash mortar decreased with the increase in fly ash content. Shrinkages of mortar containing 10, 20 and 30% fly ash were 25, 37 and 43%, lower than the shrinkage of Portland cement mortar at the end of 5 months. The reduction in shrinkage with the use of fly ash in mortar could be explained by the dilution effect of fly ash. The expansive property of fly ash most probably contributed to the reduction in drying shrinkage.

Demirboga et al. (2007)[15] in their paper "Thermo-mechanical properties of concrete containing high-volume mineral admixtures" investigated the Thermal Conductivity (TC) of HVFA concretet the age of 28 days. Cement was replaced with 0, 50, 60, and 70% of Class C fly ash. They concluded that TC of concrete decreased to 32, 33, and 39% for 50, 60 and 70% fly ash replacement, respectively.

## III. FLY ASH

### *A. Fly Ash*

Fly ash is one of the residues generated in combustion as shown in Figure 3.1, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.[22]

 

Fig. 3.1: Fly Ash

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled, often used to supplement Portland cement in concrete production. Some have expressed health concerns about this. In some cases, such as the burning of solid waste to create electricity, the fly ash may contain higher levels of contaminants than the bottom ash. So, mixing the fly and bottom ash together brings the proportional levels of contaminants within the range to qualify as nonhazardous waste in a given state, whereas, unmixed fly ash would be within the range to qualify as hazardous waste.

### B. *Chemical Composition and Classification*

| Component | Bituminous | Sub bituminous | Lignite |
|---|---|---|---|
| SiO2 (%) (Silicon dioxide) | 20-60 | 40-60 | 15-45 |
| Al2O3 (%) (Aluminium oxide) | 5-35 | 20-30 | 20-25 |
| Fe2O3 (%) (Iron oxide) | 10-40 | 4-10 | 4-15 |
| CaO (%) (calcium oxide) | 1-12 | 5-30 | 15-40 |
| LOI (%) (Loss on Ignition) | 0-15 | 0-3 | 0-5 |

Table 3.1: Chemical Composition of Fly Ash

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide ($SiO_2$), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminum oxide ($Al_2O_3$) and iron oxide ($Fe_2O_3$). Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides. The above concentrations of trace elements vary according to the kind of coal combusted to form it. In fact, in the case of bituminous coal, with the notable exception of boron, trace element concentrations are generally similar to trace element concentrations in unpolluted soils.

Two classes of fly ash are defined by ASTM C618[23]: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

Not all fly ashes meet ASTM C618[23] requirements, although depending on the application, this may not be necessary. Ash used as a cement replacement must meet strict construction standards, but no standard environmental regulations have been established in the United States. 75% of the ash must have a fineness of 45 µm or less, and have a carbon content, measured by the loss on ignition (LOI), of less than 4%. In the U.S., LOI needs to be fewer than 6%. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance. This makes it necessary that, if fly ash is used in an optimal way to replace cement in concrete production, it needs to be processed using beneficiation methods like mechanical air classification. But if fly ash is used also as a filler to replace sand in concrete production, unbeneficiated fly ash with higher LOI can be also used. Especially important is the ongoing quality verification. This is mainly expressed by quality control seals like the Bureau of Indian Standards mark or the DCL mark of the Dubai Municipality.

## IV. ENVIRONMENTAL BENEFITS OF FLY ASH USE IN CONCRETE

Among the sustainability issues, the three major ones are summarized below:

### A. *Climate Change—*

In many parts of the world, extreme weather patterns are occurring with greater frequency. Most scientists believe that this phenomenon is associated with the high emission rates of green-house gases, primarily carbon dioxide, the environmental concentrations of which has increased from 280 to 370 parts per million volume mainly during the industrial age[28,29]. The transportation industry and the portland cement industry happen to be the two largest producers of carbon dioxide. The latter is responsible for approximately 7% of the world's carbon dioxide emissions[29].

### B. *Resource Productivity—*

The concrete industry is the largest consumer of virgin materials such as sand, gravel, crushed rock, and fresh water. It is consuming portland and modified portland cements at an annual rate of about 1.6 billion metric tons. The cement production consumes vast amounts of limestone and clay besides being energy-intensive.

Obviously, large amounts of energy and materials, in addition to financial resources, are wasted when structures deteriorate or fail prematurely which, in fact, has been the case with many recently built reinforced concrete bridge decks, parking garages, and marine structures throughout the world. Traditionally, most concrete structures are designed for a service life of 50 years. With the advent of high-performance concrete mixtures, some structures are now being designed and built for a service life of 100 years. In the long run, sustainable development of the concrete industry will not take place until we are able to make even more dramatic improvements in our resource productivity. In this context, it should be noted that the Factor Ten Club, a group of scientists, economists and business people have made a declaration that, within one generation, nations can achieve a tenfold increase in their resource productivity through a 90% reduction in the use of energy and materials[30].

### C. *Industrial Ecology—*

Achieving a dramatic improvement in resource productivity through durability enhancement of products is, of-course, a long-term solution for sustainable development. A short-term strategy that must be pursued simultaneously is to practice industrial ecology at a larger scale than is the case today. Simply defined, the practice of industrial ecology by a manufacturing industry involves the reclamation and re-use of its own waste products and, to the extent possible, the waste products of other industries which are unable to recycle them in their own manufacturing process.

## V. AGGREGATE USED

Aggregates used in the present study are in accordance with size as shown below:

1) Coarse Aggregates

10 mm (CA-I)

20 mm (CA-II)

2) Fine Aggregates

## VI. EXPERIMENTAL PROGRAMME

### A. *General*

The objectives of the present investigation have been outlined in Chapter- 1. To achieve the objectives, an experimental program was planned to investigate strength and durability properties of concrete containing mineral admixture as partial replacement of cement. Mineral admixture used were fly ash (FA). This chapter outlines the experimental programme, planned for the present investigation, in detail. The basic properties of concrete constituent materials, concrete mix details along with method of casting and curing, workability of concrete, details of tests performed on hardened concrete are presented.

### B. *Test Programme*

The following test programme was planned to investigate the results:

- To obtain the physical properties of the concrete constituents i.e. Pozzolanic Portland cement (PC), fine aggregates, coarse aggregate and fly ash.
- Development of various mix combinations for concrete.
- Casting and curing.
- Testing of specimens for Compressive Strength and flexural strength.

### C. *Materials*

The properties of materials used in concrete are determined in laboratory as per relevant code of practice. Different materials used in the present study were cement, coarse aggregates, fine aggregates, fly ash, water and admixture. Result of the test conducted to determine physical properties of materials are reported and discussed in the section. The materials used were having the following characteristics:

*1) Cement:*

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravels and crushed stone to make concrete. The cement and water forms a paste that binds the other materials together as the concrete hardens. The ordinary cement contains the two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. The basic composition is provided in table 5.1. In the present work Ambuja PPC was used for casting cubes and beam samples for all concrete mixes. The cement was of uniform colour i.e grey with a ligh greenish shade and was free from any hard lumps. All tests on cement were conducted, as per procedure laid down in code IS: 1489 (Part-I): 1991[36]. Summary of the results of various tests conducted on cement is provided in table 5.2

*2) Fine Aggregates:*

The material that passes through BIS test sieve no. 480 is termed as fine aggregate. Usually natural sand is used as a fine aggregate at the places where natural sand is not available crushed stone is used as as fine aggregate. The sand uses for the experimental work was locally procured sand and conformed to grading Zone III. The various tests and sieve analysis of the fine aggregate was carried out in lab as per IS: 383-1970[37] and results are provided in table 5.3

*3) Coarse Aggregates:*

The material retained on BIS test sieve no. 480 is termed as a coarse aggregate. The crushed stone is used as coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having maximum size of 10mm (CA-I) and 20 mm (CA-II) is used in the present work. The various tests and sieve analysis of CA-I and CA-II used was carried out in lab as per IS-383-1970[37] and results are shown in table 5.4 and 5.5

*4) Fly Ash:*

Fly ash is a fairly divided residue which results from the combustion of powdered bituminous coal or sub bituminous coal like lignite. It is a by product of many thermal power stations. Fly ash resembles pozzolana i.e. a substance which although not cementitious itself contains constituents which combine with lime to form a material having cementitious properties. It is acidic in nature and its main constituents are silica, alluminium oxide and ferrous oxide. The fly ash used in the present study is taken from Guru Gobind Singh Thermal Plant, at Ropar. The physical properties of the fly ash used are reported here for ready reference as obtained from GGS Thermal Plant. (see table 5.6)

*5) Water:*

As per IS-456-2000[38] portable water is considered for satisfactory mixing and curing of concrete. The water should be clean and free from harmful impurities such as oil, alkali, acid etc. In general the water is fit for drinking is used for making concrete.

 

*6) Admixture:*

Master Gilenium Sky 8233 admixture was used during the present study.

This is a water reducing admixture. Water reducers offer several advantages in their use, listed below:

- Reduces the water content by 5-10%.
- Decreases the concrete porosity.
- Increases the concrete strength by up to 25% (as less water is required for the concrete mixture to remain workable).
- Increases the workability (assuming the amount of free water remains constant).
- Reduces the water permeability (due to less water being used).
- Reduces the diffusivity of aggressive agents in the concrete and so improves the durability of concrete.
- Gives a better finish to surfaces (due to all of the above).

*7) Design of M25 Concrete Mix*

The concrete mix was designed as per code IS 10262-1982[39] and SP:23-1983[40] and the various design stipulations are enlisted below:

| | | |
|---|---|---|
| i) | Characteristic strength of concrete at 28 days (fck) | 25N/mm$^2$ |
| ii) | Maximum size of crushed aggregate | 20 mm |
| | 45 | |
| iii) | Degree of workability | Low |
| iv) | Value of statistical coefficient (K) | 1.65 |
| v) | Value of standard deviation (S) | 4.00 |
| vi) | Type of exposure | Moderate |

1) Test Data For Materials:

| | | |
|---|---|---|
| i) | Cement used | PPC |
| ii) | Specific gravity of cement | 2.75 |
| iii) | Specific gravity of coarse aggregates | 2.60 |
| iv) | Specific gravity of fine aggregates | 2.70 |
| v) | Water absorption of coarse aggregates | 1.00% |
| vi) | Water absorption of fine aggregates | 1.10% |
| vii) | Free surface moisture of coarse aggregates | 0.00 |
| viii) | Free surface moisture of fine aggregates | 1.50% |

2) Target Mean Strength of Concrete:

Target mean strength is given by ft = fck + KS

Where, ft= Target mean strength at 28 days.

fck= Characteristic compressive strength at 28 days

S = Standard coefficient

K = Statistical coefficient

Target mean strength of concrete = 25 + 1.65×4.00 = 31.6 N/mm$^2$.

3) Selection of Water Cement Ratio:

| | |
|---|---|
| Water Cement Ratio for Target Mean Strength | 0.46 |
| Maximum water cement ratio from durability consideration | 0.5 |
| Therefore, W/C ratio | 0.46 |

4) Selection of Aggregate Cement Ratio:

MAS = 20 mm

Fine Aggregates Percentage = 33.14%

Coarse Aggregates CA-I (10 mm) Percentage = 18.61%

Coarse Aggregates CA-II (20 mm) Percentage = 48.24%

Zone of Aggregates = 3

Degree of Workability = Low

Water Cement Ratio = 0.46

Aggregate Cement Ratio Fine Aggregates = 5.5

Aggregate Cement Ratio CA-I = 4.1

Aggregate Cement Ratio CA-II = 4.1

Final Aggregate Cement Ratio = (5.5+4.1+4.1)/3 = 4.56

5) Cement Content Per Meter Cube of Concrete

Cement content is calculated by the formula = Density/(1+A/C+W/C)

= 2400/(1+4.56+0.46) = 398 Kg

Here, A/C = Aggregate Cement Ratio

W/c = Water Cement Ratio

Quantities Required For The M25 Per Cubic Metre of Concrete:

Cement = 398 Kg

Total Aggregates = Cement Content x A/C Ratio = 398x4.56 = 1818 Kg

Fine Aggregates are 29.25% of Total Aggregates as per design made, so value of Fine Aggregates = 33.14% x 1818 = 599 Kg

Similarly CA-I = 18.61% x 1818 = 338 Kg

CA-II = 48.24% x 1818 = 878 Kg

Water

For water cement ratio of 0.46, water required= 182 Lt.

Extra quantity of water to be added for absorption in case of coarse aggregates@ 0.75% by mass= 9.12 litre (+).

Quantity of water to be deducted for the free moisture present in sand@ 1.5%= 8.98 litre (-).

Actual quantity of water to be added = 183+9.12-8.98 = 183 Lt (Approximately).

6) Admixture are added 1% by the weight of cementitious material.

The estimated actual mix proportion for one cubic metre of M25 concrete at 28% Fly Ash content are shown in Table 5.7(d)

### *D. Preparation of Specimens*

Standard cubical moulds of size 150mm x 150mm x150mm made of cast iron were used to cast concrete specimens to test compressive strength of concrete. Beam moulds of size 500mm x 100mm x 100mm were used to prepare concrete specimens to test flexural strength.

All the moulds were cleaned properly and then oiled on inner sides well before casting of specimens to avoid sticking of concrete to moulds. These were tightened securely to correct dimensions before casting, to avoid leak of slurry from any left over gaps.

### *E. Batching, Mixing and Casting of Specimens*

Careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and the fine aggregates were weighed first with an accuracy of 0.5 gm. The concrete mixture was prepared by hand mixing on a water tight platform. The fly ash and the cement were mixed dry to a uniform colour separately. Super plasticizer as per the requirement of workability (low) was added to required quantity of water in a container. On the water tight platform, the coarse and the fine aggregate were mixed thoroughly. To this mixture, the mixture of fly ash and cement is added and mixed thoroughly in dry state to a uniform colour. Then the water is added in an careful manner so that no water was lost during the mixing. This lead to the formation of concrete after that this concrete is filled in the oiled cube and beam moulds and vibrated for compaction until the cement slurry appeared on the top surface of the moulds. The specimens were than allowed to remain in the steel mould for atleast 24 hours under ambient conditions. After that, these were demoulded with care so that no edge were broken and were placed in curing tank. Total 27 cubes were casted for compressive strength test at 3, 7 and 28 days, and a total of 18 beams were casted for flexural strength test at 28 and 56 days.

### *F. Testing of Specimens*

#### *1) Compressive Strength Test:*

The test was conducted according to IS 516-1959[41]. Specimens were taken out from curing tank at the age of 3,7 and 28 days and tested by air drying the samples. The position of cube while testing was at right angles to that of casting position. The load was gradually applied without any shock and increased at constant rate of 14 N/mm2/minute until failure of specimen takes place. It was tested on compression testing machine.

#### *2) Flexural Strength:*

The beams were taken out from the tank at the age of 28 and 56 days of curing and tested after the specimens are air dried. The test was performed by two point loading method (IS.516-1959[41]) on flexural testing machine.

| Ingredient | Percent, Content |
|---|---|
| Lime | 60-67 |
| Sillica | 17-25 |
| Alumina | 3-8 |
| Iron Oxide | 0.5-6 |
| Magnesia | 0.1-4 |
| Alkalies | 0.4-1.3 |
| Sulphur | 1-3 |

Table 5.1: Composition Limits of Portland Cement[42]

| Characteristics | | Units | Results Obtained | Values Specified (IS: 1489 (Part-1):1991)[36] |
|---|---|---|---|---|
| Fineness (Specific Surface) | | Cm^2/g m | 3800 | 3200 (Minimum) |
| Soundness (expansion by Le-chatelier test) | | mm | 1.0 | 10 (Maximum) |
| Specific Gravity | | | 3.15 | 3.15 |
| Standard Consistency (percent of cement byweight) | | % | 34 | - |
| Setting Time | | minutes | | 30 (Minimum) |
| (i) | Initial | | 180 | 600 (Maximum) |
| (ii) | Final | | 220 | |
| Compressive Strength | | Mpa | | |
| (i) | 3 Days | | 28 | 16 (Minimum) |
| (ii) | 7 Days | | 38 | 22 (Minimum) |
| (iii) | 28 Days | | 54 | 33 (Minimum) |

Table 5.2: Physical Properties of Cement

| Fine Aggregate | | | | | | | |
|---|---|---|---|---|---|---|---|
| Determination of Particle Size & Shape by Sieve Analysis | | | | | | | |
| Date | | | | 22-01-2014 | | | |
| Sample No. | | | | 1 | | | |
| Name of Project | | | | HVFA | | | |
| Source | | | | Crusher plant | | | |
| Colour | | | | Yellowish | | | |
| Total Weight of Sample | | | | 2000 | | | |
| Particle Shape | | | | Rounded and irregular Aggregate | | | |
| I.S. Sieve | Weight Retained | % Retained | Weight Retained | % Retained | Avg. Retained % | Cumm Retained % | Cumm Passing % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 20 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 16 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 12.5 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 10.0 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 6.3 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 4.75 mm | 320 | 16.00 | 320 | 16.00 | 16.00 | 16.00 | 84.00 |
| 2.36 mm | 130 | 6.50 | 130 | 6.50 | 6.50 | 22.50 | 77.50 |
| 1.18 mm | 160 | 8.00 | 160 | 8.00 | 8.00 | 30.50 | 69.50 |
| 600 µ | 260 | 13.00 | 260 | 13.00 | 13.00 | 43.50 | 56.50 |
| 300 µ | 920 | 46.00 | 920 | 46.00 | 46.00 | 89.50 | 10.50 |
| 150 µ | 140 | 7.00 | 140 | 7.00 | 7.00 | 96.50 | 3.50 |
| 75 µ | 70 | 3.50 | 70 | 3.50 | 3.50 | 100.00 | 0.00 |
| Total | 2000 | | 2000 | | | 298.50 | |
| Fineness Modulus | | | | 2.99 | | | |
| Zone | | | | 3 | | | |
| Specific Gravity | | | | 2.70 | | | |
| Grade of Concrete | | | | M40 | | | |
| Quality Control at Site | | | | GOOD | | | |
| DLBD | | | | 1.70 | | | |
| Water Absorption | | | | 1.1% | | | |

Table 5.3: Determination of Particle Size & Shape of fine aggregate by Sieve Analysis

| Coarse Aggregate (CA I - 10 mm) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Determination of Particle Size & Shape by Sieve Analysis | | | | | | | |
| Date | | | | 22-01-2014 | | | |
| Sample No. | | | | 1 | | | |
| Name of Project | | | | HVFA | | | |
| Source | | | | Quarry | | | |
| Colour | | | | Brownish | | | |
| Total Weight of Sample | | | | 5000 | | | |
| Particle Shape | | | | Angular Crushed Aggregate | | | |
| I.S. Sieve | Weight Retained | % Retained | Weight Retained | % Retained | Avg. Retained % | Cumm Retained % | Cumm % Passing |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 20 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 16 mm | 90 | 1.80 | 90 | 1.80 | 1.80 | 1.80 | 98.20 |
| 12.5 mm | 810 | 16.20 | 810 | 16.20 | 16.20 | 18.00 | 82.00 |
| 10.0 mm | 2630 | 52.60 | 2630 | 52.60 | 52.60 | 70.60 | 29.40 |
| 6.3 mm | 1390 | 27.80 | 1390 | 27.80 | 27.80 | 98.40 | 1.60 |
| 4.75 mm | 30 | 0.60 | 30 | 0.60 | 0.60 | 99.00 | 1.00 |
| 2.36 mm | 50 | 1.00 | 50 | 1.00 | 1.00 | 100.00 | 0.00 |
| 1.18 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 600 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 300 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 150 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 75 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| Total | 5000 | 100 | 5000 | 100 | 100.00 | | |
| 4.75 Passing | | | | | 1.00% | | |
| Workability (Slump) Required | | | | 25 | | 75 | |
| Grade of Concrete | | | | M40 | | | |
| Quality Control at Site | | | | GOOD | | | |
| DLBD | | | | 1.40 | | | |
| Specific Gravity | | | | 2.6 | | | |
| Water Absorption | | | | 1% | | | |
| | | | | 52 | | | |

Impact Value Test Results: For CA1: 17.64%

Table 5.4: Determination of Particle Size & Shape of CA I - 10mm by Sieve Analysis

| Coarse Aggregate (CA II – 20 mm) Determination of Particle Size & Shape by Sieve Analysis | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | | | | 22-01-2014 | | | |
| Sample No. | | | | 1 | | | |
| Name of Project | | | | HVFA | | | |
| Source | | | | Quarry | | | |
| Colour | | | | Grey | | | |
| Total Weight of Sample | | | | 5000 | | | |
| Particle Shape | | | | Angular Crushed Aggregate | | | |
| I.S. Sieve | Weight Retained | % Retained | Weight Retained | % Retained | Avg. % Retained | Cumm % Retained | Cumm % Passing |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 20 mm | 200 | 4.00 | 200 | 4.00 | 4.00 | 4.00 | 96.00 |
| 16 mm | 1460 | 29.20 | 1460 | 29.20 | 29.20 | 33.20 | 66.80 |
| 12.5 mm | 2580 | 51.60 | 2580 | 51.60 | 51.60 | 84.80 | 15.20 |
| 10.0 mm | 650 | 13.00 | 650 | 13.00 | 13.00 | 97.80 | 2.20 |
| 6.3 mm | 90 | 1.80 | 90 | 1.80 | 1.80 | 99.60 | 0.40 |
| 4.75mm | 20 | 0.40 | 20 | 0.40 | 0.40 | 100.00 | 0.00 |
| 2.36 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 1.18 mm | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 600 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 300 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 150 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| 75 µ | 0 | 0.00 | 0 | 0.00 | 0.00 | 100.00 | 0.00 |
| Total | 5000 | 100 | 5000 | 100 | 100.00 | | |
| 20 mm Passing | | | | | 96.00% | | |
| MAS | | | | | 20 | Mm | |
| Specific Gravity | | | | 2.60 | | | |
| Grade of Concrete | | | | M40 | | | |
| Quality Control at Site | | | | GOOD | | | |
| DLBD | | | | 1.45 | | | |
| Water Absorption | | | | 1% | | | |

Impact Value Test Results: For CA1I: 12.50%

Table 5.5: Determination of Particle Size & Shape of CA II-20mm by Sieve Analysis

The following results were obtained during DLBD (Dry Loose Bulk Density) Test:

For Fine Aggregates: 1712.6 kg/m3

For CA1: 1460.75 kg/m3

For CA2: 1428.15 kg/m3

| Sr.No. | Ingredients | Percent, Content |
|---|---|---|
| 1 | Sillica | 45-89 |
| 2 | Alumina | 23-33 |
| 3 | Ferric Oxide | 0.4-0.6 |
| 4 | Titanium | 0.5-16 |
| 5 | Calcium Oxide | 5-16 |
| 6 | Magnesia | 1.5-5 |
| 7 | Sulphuric Anhydride | 2.5 |
| 8 | Loss on Ignition | 1-2 |

Table 5.6: Chemical Properties of Fly Ash under Consideration

| Material | Unit | Quantity |
|---|---|---|
| Cement | Kg | 445 |
| Total Aggregate | Kg | 1777 |
| Fine Aggregate | Kg | 520 |
| CA-I | Kg | 361 |
| CA-II | Kg | 896 |
| Water | Lt | 180 |
| Admixture | Lt | 4.45 |

Table 5.7 (a): Weight Batching Per Cubic Meter Of 28% Fly Ash M40 Concrete

| Material | Unit | Quantity |
|---|---|---|
| Cement | Kg | 308 |
| Total Aggregate | Kg | 1777 |
| Fine Aggregate | Kg | 520 |
| CA-I | Kg | 361 |
| CA-II | Kg | 896 |
| Water | Lt | 180 |
| Admixture | Lt | 4.45 |
| Fly Ash | | 136 |

Table 5.7 (b): Weight Batching Per Cubic Meter Of 50% Fly Ash M40 Concrete

| Material | Unit | Quantity |
|---|---|---|
| Cement | Kg | 185 |
| Total Aggregate | Kg | 1777 |
| Fine Aggregate | Kg | 520 |
| CA-I | Kg | 361 |
| CA-II | Kg | 896 |
| Water | Lt | 180 |
| Admixture | Lt | 4.45 |
| Fly Ash | Kg | 260 |

Table 5.7 (c): Weight Batching Per Cubic Meter Of 70% Fly Ash M40 Concrete

| Material | Unit | Quantity |
|---|---|---|
| Cement | Kg | 398 |
| Total Aggregate | Kg | 1818 |
| Fine Aggregate | Kg | 599 |
| CA-I | Kg | 338 |
| CA-II | Kg | 878 |
| Water | Lt | 183 |
| Admixture | Lt | 3.98 |

Table 5.7 (d): Weight Batching Per Cubic Meter Of 28% Fly Ash M25 Concrete

## VII. RESULTS AND DISCUSSIONS

### A. *General*

In this chapter the results of compressive and the flexural test on the concrete mixes with 28%, 50% and 70% fly ash by the mass of cement are presented and discussed. Comparison of the results are made, in order to present the ideas of the present study. First the compressive strength test results are discussed followed by the results of flexural strength test.

### B. *Compressive Strength*

The compressive strength results with different percentage replacement (28%, 50% and 70%) of cement by fly ash in concrete at 3, 7 and 28 days of curing are shown in Table 6.1 (a, b, c) and Table 6.2. These results are expressed graphically in Fig 6.1.

### C. *Flexural Strength*

The flexural strength results with different percentage replacement (28%, 50% and 70%) of cement by fly ash in concrete at 28 and 56 days of curing are shown in Table 6.3 (a, b, c) and Table 6.4. These results are expressed graphically in Fig 6.2.

### D. *Discussion*

The following points are needed to be discussed from Fig 6.1 and 6.2:

1) The compressive strength of 28 days of 50% fly ash concrete is only 12% less than the 28% fly ash concrete.

 

2) The compressive strength of 28 days of 70% fly ash concrete is much low (43%) than the 28% fly ash concrete.
3) 3) The flexural strength at 28 and 56 days for 50% fly ash concrete is 18% and 10% respectively less than the 28% fly ash concrete. This shows fly ash gives less early age strength but increases the latter age strength.
4) The flexural strength of 28 and 56 days of 70% fly ash concrete is 66% and 50% respectively less than the 28% fly ash concrete. This is a huge difference and is not accepted.
5) Results obtained of 28% and 50% fly ash concrete are good and acceptable.
6) The results obtained of 70% fly ash concrete are comparable to M25 concrete.
7) The cost comparison of these will be done in next chapter.

| Sr.No | % Fly Ash Concrete | Curing Period (days) | Compressive Strength ($N/mm^2$) | Average Compressive Strength ($N/mm^2$) |
|---|---|---|---|---|
| 1. | 28% | 3 | 25<br>22<br>26 | 24.33 |
| 2. | 28% | 7 | 34<br>28<br>35 | 32.33 |
| 3. | 28% | 28 | 46<br>45<br>47.05 | 46.60 |

Table 6.1 (a): Compressive strength of M40 concrete for 28% fly ash content

| Sr.No | % Fly Ash Concrete | Curing Period (days) | Compressive Strength ($N/mm^2$) | Average Compressive Strength ($N/mm^2$) |
|---|---|---|---|---|
| 1. | 50% | 3 | 19.5<br>20.20<br>20.50 | 20.03 |
| 2. | 50% | 7 | 27.40<br>25.80<br>25.10 | 26.10 |
| 3. | 50% | 28 | 42.00<br>41.00<br>40.00 | 41.00 |

Table 6.1 (b): Compressive strength of M40 concrete for 50% fly ash content.

| Sr.No | % Fly Ash Concrete | Curing Period (days) | Compressive Strength ($N/mm^2$) | Average Compressive Strength ($N/mm^2$) |
|---|---|---|---|---|
| 1. | 70% | 3 | 8.57<br>11.02<br>11.47 | 10.34 |
| 2. | 70% | 7 | 15.3<br>15.00<br>14.40 | 15.00 |
| 3. | 70% | 28 | 29.00<br>27.00<br>25.00 | 27 |

Table 6.1 (c): Compressive strength of M40 concrete for 70% fly ash content.

| Percent Fly Ash Concrete | 3 Days Curing (Mean Mpa) | 7 Days Curing (Mean Mpa) | 28 Days Curing (Mean Mpa) |
|---|---|---|---|
| 28% | 24.33 | 32.33 | 46.6 |
| 50% | 20 | 26.1 | 41 |
| 70% | 10.3 | 15 | 27 |

Table 6.2: Combined Table of Compressive strength of M40 concrete for 28%, 50% and 70% fly ash content.

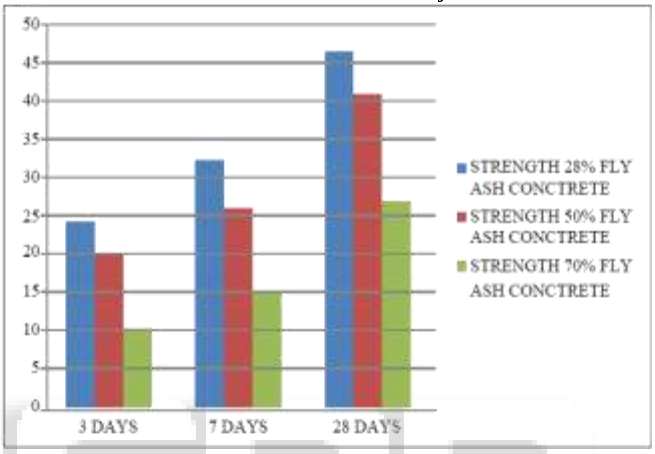


Fig. 6.1: Compressive strength comparison of M40 concrete for 28%, 50% and 70% fly ash content.

| Sr.No | % Fly Ash Concrete | Curing Period (days) | Flexural Strength ($N/mm^2$) | Average Flexural Strength($N/mm^2$) |
|---|---|---|---|---|
| 1. | 28% | 28 | 6.50<br>5.00<br>5.50 | 6.00 |
| 2. | 28% | 56 | 8.00<br>7.00<br>8.52 | 7.84 |

Table 6.3 (a): Flexural strength of M40 concrete for 28% fly ash content.

| Sr.No | % Fly Ash Concrete | Curing Period (days) | Flexural Strength ($N/mm^2$) | Average Flexural Strength($N/mm^2$) |
|---|---|---|---|---|
| 1. | 50% | 28 | 5.00<br>4.00<br>5.7 | 4.90 |
| 2. | 50% | 56 | 7.00<br>8.00<br>6.00 | 7.00 |

Table 6.3 (b): Flexural strength of M40 concrete for 50% fly ash content.

| Sr.No | % Fly Ash Concrete | Curing Period (days) | Flexural Strength ($N/mm^2$) | Average Flexural Strength($N/mm^2$) |
|---|---|---|---|---|
| 1. | 70% | 28 | 1.50<br>2.50<br>2.00 | 2 |
| 2. | 70% | 56 | 4.00<br>3.00<br>4.7 | 3.9 |

Table 6.3 (c): Flexural strength of M40 concrete for 70% fly ash content.

| Percent Fly Ash Concrete | 28 Days Curing (Mean Mpa) | 56 Days Curing (Mean Mpa) |
|---|---|---|
| 28% | 6 | 7.84 |
| 50% | 4.9 | 7 |
| 70% | 2 | 3.9 |

Table 6.4: Combined Table of Flexural strength of M40 concrete for 28%, 50% and 70% fly ash content.

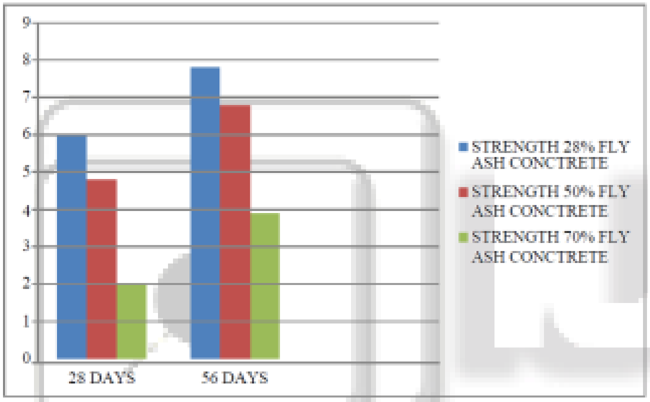


Fig. 6.2: Flexural strength comparison of M40 concrete for 28%, 50% and 70% fly ash content

## VIII. COST COMPARISON

### A. *GENERAL*

In this chapter the cost of M40 (using 28%, 50% and 70% fly ash) and M25 (using 28% fly ash) concrete is evaluated. After the evaluation comparison is made between:

1) The cost of 28%,50% and 70% M40 fly ash concrete.
2) The cost of 50% and70% fly ash M40 concrete with 28% fly ash M25 concrete.

### B. *COST EVALUATION*

The cost evaluation here will be made for per cubic meter. For evaluation of cost the quantity of various components of concrete in per cubic meter from the Table 5.7(a, b, c, d) are multiplied by the market rates of the components and added as shown in Table 7.2(a, b, c, d). The rate of the various components of concrete obtained from the market are listed in Table 7.1.

### C. *COST COMPARISON*

After the evaluation comparison is made between:

1) The cost of 28%,50% and 70% M40 fly ash concrete in Figure 7.1.
2) The cost of 50% and70% fly ash M40 concrete with 28% fly ash M25 concrete in Figure 7.2.

When the cost comparison was made it was found that:

1) The cost of concrete decreased with increase in fly ash content.
2) The lowest cost was of 70% fly ash content M40 concrete followed by 50% and 28% fly ash content M40 concrete.
3) Even the cost of 70% and 50% fly ash content M40 concrete was less than 28% fly ash content M25 concrete.

| Components of Concrete | Rates |
|---|---|
| Cement | 6 Rs/Kg |
| Fine Aggregate | 0.6 Rs/Kg |
| CA-I | 0.8 Rs/Kg |
| CA-II | 0.8 Rs/Kg |
| Fly Ash | 100 Rs/Lt |

Table 7.1: Market Rates of Various Components of Concrete.

| Components of Concrete | Quantity in Per Cubic Meter of Concrete | Rates | Cost |
|---|---|---|---|
| Cement | 445 | 6 Rs/Kg | 2670 |
| Fine Aggregate | 520 | 0.6 Rs/Kg | 312 |
| CA-I | 361 | 0.8 Rs/Kg | 289 |
| CA-II | 896 | 0.8 Rs/Kg | 717 |
| Admixture | 4.45 | 100 Rs/Lt | 445 |
| **Total** | | | **4433** |

Table 7.2 (a): Per Cubic Meter Cost of 28% Fly Ash Content M40 Concrete.

| Components of Concrete | Quantity in Per Cubic Meter of Concrete | Rates | Cost |
|---|---|---|---|
| Cement | 308 | 6 Rs/Kg | 1848 |
| Fine Aggregate | 520 | 0.6 Rs/Kg | 312 |
| CA-I | 361 | 0.8 Rs/Kg | 289 |
| CA-II | 896 | 0.8 Rs/Kg | 717 |
| Admixture | 4.45 | 100 Rs/Lt | 445 |
| Fly Ash | 136 | 2 Rs/Kg | 272 |
| **Total** | | | **3883** |

Table 7.2 (b): Per Cubic Meter Cost of 50% Fly Ash Content M40 Concrete.

| Components of Concrete | Quantity in Per Cubic Meter of Concrete | Rates | Cost |
|---|---|---|---|
| Cement | 185 | 6 Rs/Kg | 1110 |
| Fine Aggregate | 520 | 0.6 Rs/Kg | 312 |
| CA-I | 361 | 0.8 Rs/Kg | 289 |
| CA-II | 896 | 0.8 Rs/Kg | 717 |
| Admixture | 4.45 | 100 Rs/Lt | 445 |
| Fly Ash | 260 | 2 Rs/Kg | 520 |
| **Total** | | | **3393** |

Table 7.2 (c): Per Cubic Meter Cost of 70% Fly Ash Content M40 Concrete.

 

| Components of Concrete | Quantity in Per Cubic Meter of Concrete | Rates | Cost |
|---|---|---|---|
| Cement | 398 | 6 Rs/Kg | 2388 |
| Fine Aggregate | 599 | 0.6 Rs/Kg | 360 |
| CA-I | 338 | 0.8 Rs/Kg | 270 |
| CA-II | 878 | 0.8 Rs/Kg | 702 |
| Admixture | 3.98 | 100 Rs/Lt | 398 |
| **Total** | | | **4118** |

Table 7.2 (d): Per Cubic Meter Cost of 28% Fly Ash Content M25 Concrete.

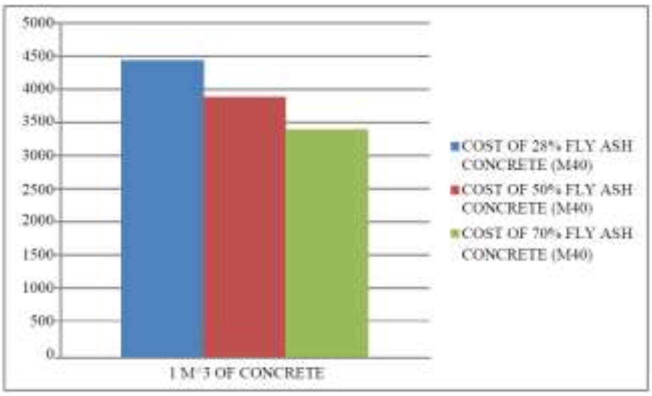


Fig. 7.2: Cost Comparison of 28% Fly Ash M 25 Concrete And 50% And 70% Fly Ash M 40 Concrete.

## IX. SCOPE OF FUTURE WORK

The future studies can be taken in the following area:

1) From this study, it can be seen that there is an immense need to carry out systematic and comprehensive research on the utilization of high calcium fly ash and other industrial wastes like gypsum, rice husk to develop a binder of sufficient strength by exploiting their inherent pozzolanic/cementing characteristics at normal temperature and evaluate the strength and durability characteristics of concrete, based on such a binder, to demonstrate the potential use, in Civil Engineering construction.
2) The comparative study can be done between the nominal bricks and the fly ash bricks.
3) The study can be made in the field of increasing the strength of fly ash.
4) The study can be made by using the fly ash in more innovative way.

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