

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 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 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.

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 45 μ m 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

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.

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 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
SiO ₂ (%) (Silicon dioxide)	20-60	40-60	15-45
Al ₂ O ₃ (%) (Aluminium oxide)	5-35	20-30	20-25
Fe ₂ O ₃ (%) (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 (SiO₂), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminum oxide (Al₂O₃) and iron oxide (Fe₂O₃). 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.

IV. EXPERIMENTAL PROGRAMME

A. 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

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 light 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 used 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 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. 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.. The physical properties of the fly ash used are reported here for ready reference as obtained from GGS Thermal Plant. (see table 5.6)

Water:

As per IS-456-2000^[38] potable water is considered for satisfactory mixing and curing of concrete. The water should be clean and free from harmful impurities such as oil, alkali

5) *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).

6) *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 $f_t = f_{ck} + K S$

Where, f_t = Target mean strength at 28 days.

f_{ck} = Characteristic compressive strength at 28 days

S = Standard coefficient

K = Statistical coefficient

Target mean strength of concrete = $25 + 1.65 \times 4.00 = 31.6 \text{ N/mm}^2$.

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 = $\text{Density}/(1+A/C+W/C)$

= $2400/(1+4.56+0.46) = 398 \text{ Kg}$

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 =

$398 \times 4.56 = 1818 \text{ Kg}$

Fine Aggregates are 29.25% of Total Aggregates as per

design made, so value of Fine Aggregates = $33.14\% \times 1818 = 599 \text{ Kg}$

Similarly CA-I = $18.61\% \times 1818 = 338 \text{ Kg}$

CA-II = $48.24\% \times 1818 = 878 \text{ Kg}$

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 = $183 + 9.12 - 8.98 = 183 \text{ Lt}$ (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)

B. Preparation of Specimens

Standard cubical moulds of size 150mm x 150mm x 150mm 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.

C. 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. 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 a 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 then allowed to remain in the steel mould for at least 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.

D. 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			30 (Minimum)
(i) Initial	minutes	180	600 (Maximum)
(ii) Final		220	
Compressive Strength			
(i) 3 Days	Mpa	28	16 (Minimum)
(ii) 7 Days		38	22 (Minimum)
(iii) 28 Days		54	33 (Minimum)

Table 5.2: Physical Properties of Cement

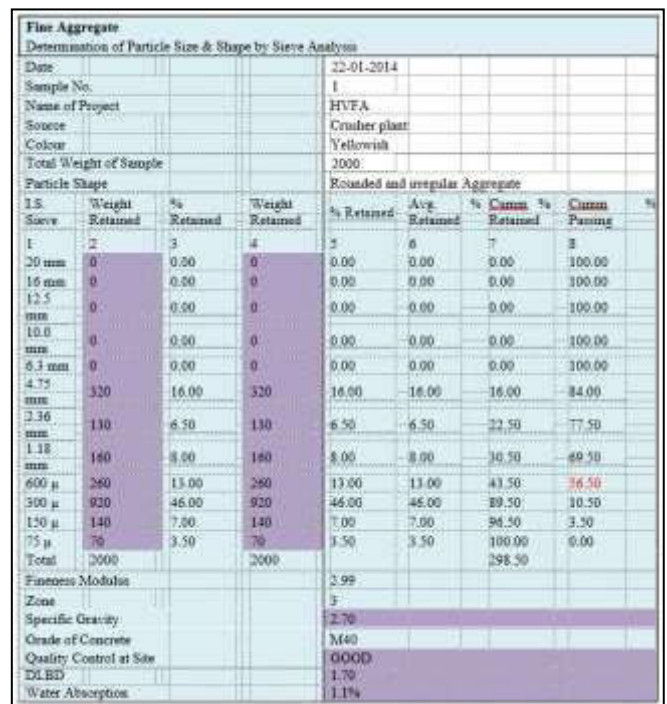


Table 5.3: Determination of Particle Size & Shape of fine aggregate by Sieve Analysis



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	% Cumulative Retained	% Cumulative 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
4.75 mm	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 CAII: 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

V. 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 (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	24.33
			22	
			26	
2.	28%	7	34	32.33
			28	
			35	
3.	28%	28	46	46.60
			45	
			47.05	

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	20.03
			20.20	
			20.50	
2.	50%	7	27.40	26.10
			25.80	
			25.10	
3.	50%	28	42.00	41.00
			41.00	
			40.00	

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	10.34
			11.02	
			11.47	
2.	70%	7	15.3	15.00
			15.00	
			14.40	

3.	70%	28	29.00	27
			27.00	
			25.00	

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.

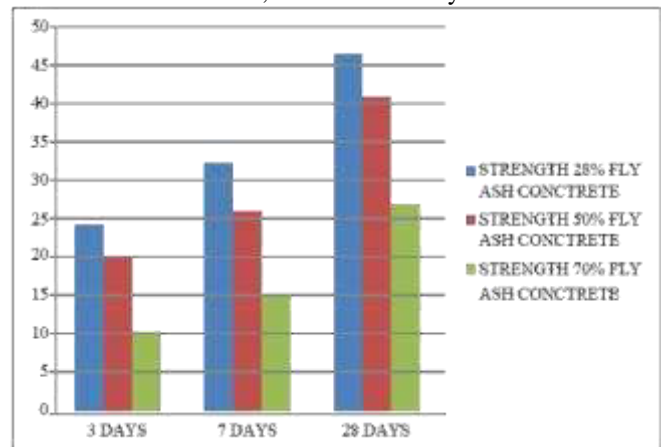


Fig. 6.1: Compressive strength comparison of M40 concrete for 28%, 50% and 70% fly ash content.

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

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	4.90
			4.00	
			5.7	
2.	50%	56	7.00	7.00
			8.00	
			6.00	

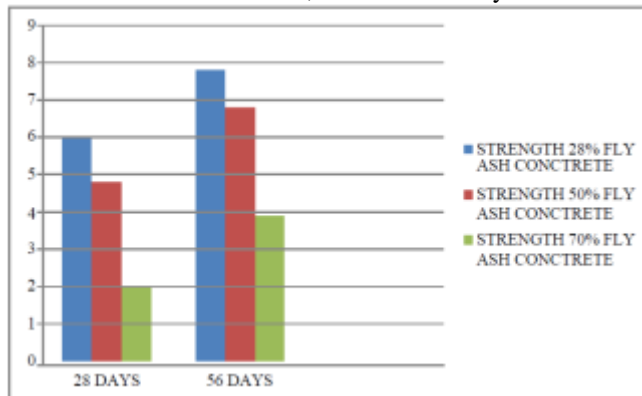
Table 6.3 (b): Flexural strength of M40 concrete for 50% fly ash content.

Sr.No	% Fly Ash Concrete	Curing Period (days)	Flexural Strength (N/mm ²)	Average Flexural Strength (N/mm ²)
1.	70%	28	4.58	2
			2.58	
			2.08	
2.	70%	56	4.08	3.8
			3.08	
			4.7	

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 a



sh content.

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

VI. 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% and 70% 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

- 2) The cost of 50% and 70% 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

Figure 7.1.

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.

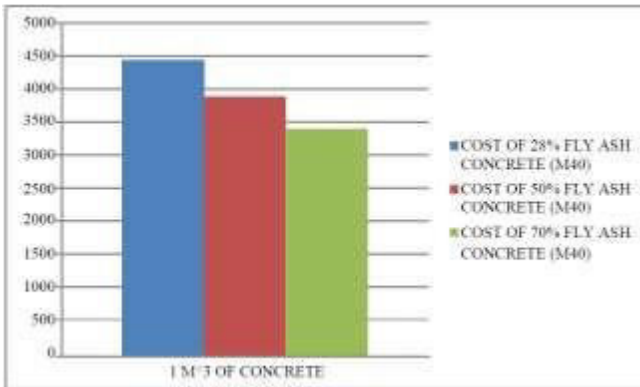


Fig. 7.2: Cost Comparison of 28% Fly Ash M 25 Concrete And 50% And 70% Fly Ash M 40 Concrete.

VII. 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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