Strength and 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 Concrete

I. INTRODUCTION

A. General

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 (CO_2) produced by humans, adding the greenhouse gas equivalent of 330 million cars driving 12,500 miles per year[1].

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 combine 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.

In the later age hydration reaction dominate in the strength development process as additional binders are generated by reaction involving fly ash. Any concrete that uses more fly ash than 25% (weight of cement) would be considered high volume fly ash concrete. With high volume fly ash concrete, you will see less early age strength, but the long-term strength is about the same as with normal concrete.

B. Need and Objective of the Present Study

1) Need

Consequent upon increased generation of electricity through thermal route involving combustion of pulverized coal/ignite, concurrent generation of fly ash in bulk quantities is a matter of serious concern not only because of issues associated with its disposal and utilization but also because of its threat to public health and ecology. At present, large quantity of fly ash is being dumped in slurry form in large areas close to the power plants without being put to gainful use in India. Only a very small percentage (<35%) of fly ash generated in India is being used for gainful applications whereas the corresponding figures of other countries may vary from 60 to 100%[2].

Although fly ash offers environmental advantages, it also improves the performance and quality of concrete. Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. Fly ash increases strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphate resistance, and reduces alkali-aggregate reaction. Fly ash reaches its maximum strength more slowly than concrete made with only portland cement. The techniques for working with this type of concrete are standard for the industry and will not impact the budget of a job. So as a Civil Engineer we should effectively try to use fly ash in construction, as it helps in saving environment with reduced construction cost along with many other advantages, but now question rises to what extent or percentage fly ash could be used in concrete for construction works, and to answer this present study have been made.

a) Advantages of Fly Ash in Concrete

The advantages of the fly ah in concrete are listed below:

1) Fly Ash is a pozzolana: A pozzolana is a siliceous or aluminosiliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland Cement to form additional calcium silicate hydrate and other cementitious compounds. The hydration reactions are similar to the reactions occurring during the hydration of Portland Cement. Thus, concrete containing Fly Ash pozzolana becomes denser, stronger and generally more durable long term as compared to straight Portland Cement concrete mixtures.
2) Fly Ash improves concrete workability and lowers water demand: Fly Ash particles are mostly spherical tiny glass beads. Ground materials such as Portland Cement are solid angular particles. Fly Ash particles provide a greater workability of the powder portion of the concrete mixture which results in greater workability of the concrete and a lowering of water requirement for the same concrete consistency. Pump ability is greatly enhanced.
3) Fly Ash generally exhibit less bleeding and segregation: than plain concretes. This makes the use of Fly Ash particularity valuable in concrete mixtures made with aggregates deficient in fines.

2) 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:

1) Design of M40 concrete mix to obtain the ratio of different components of concrete.
2) 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.
3) 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.
4) 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.
5) Comparison of the compressive and the flexural strength obtained at different percentages of fly ash is to be made.
6) Cost comparison of 28%, 50% and 70% fly ash concrete is to be made.

C. 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

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.

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.

B. Examples of Using Fly Ash in Concrete

World over fly ash has been successfully utilized in cement concrete and as component of Portland Pozzolana Cement/ Blended cement for more than 50 years. Some of the structures wherein fly ash has been utilized are as under[3]:

1) Nearly 20 lakh tones of fly ash from NTPC, Badarpur Thermal Power Station has been utilized in road embankment of Noida- Greater Noida Express Highway.
2) About 1.25 lakh tones of fly ash has been utilized in second Nizamuddin bridge embankment construction by PWD at New Delhi.
3) Fly ash concrete was used in Prudential Building the first tallest building in Chicago after World War II.
4) About 60,000 cum of fly ash concrete with an estimated saving of 3,000 ton of Ordinary Portland Cement was used in Lednock Dam construction in UK during the year 1955.
5) About 60,000 m3 of fly ash concrete with 80:20 Ordinary Portland Cement: fly ash having average slump of 175 mm was used in the piles and the foundation slab to meet the requirement of sulphate resistance concrete of Ferry bridge C power station in UK during 1964.
6) About 10,000 tonnes of fly ash from Badarpur Thermal Power has been utilized in Sarita-Vihar fly over in Delhi.
7) About 4000 m3 of pond ash and 800 m3 of bottom ash has been utilized by CPWD in construction of Okhla fly over bridge constructed at National Highway No. 2
8) Fly ash in concrete was used in construction of Euro Tunnel-second largest rail tunnel in the world during 1987-94. To meet the early stripping requirement, a concrete mix containing 30% fly ash with w/c of 0.35 using high efficient water reducing admixture at a total cementitious content of 440 kg/m3 was used in the work. The strength of concrete obtained was more than 80 MPa at 28 days and permeability coefficients were

10-13 m/s against requirement of 70 MPa and 10-11 m/s.

9) Fly ash from NTPC's Dadri Thermal power stations is being utilized in prestigious Delhi Metro Rail Corporation (DMRC) works at New Delhi. : More than 60,000 tonne of fly ash has been utilized in the work so far. In this project, the requirement of cement concrete was high strength, high durability (less shrinkage and & thermal crakes), low heat of hydration, easy placement, cohesiveness and good surface finish. Use of fly ash in concrete has fulfilled the entire above requirements. In this work the concrete of M-35 and above were used in structural works.
10) Self-Compacting concrete using fly ash from Kota thermal power station has been utilized for structural members of Rajasthan Atomic Power Project. Self-compacting concrete was used due to difficulties in placing concrete in structures having heavily congested reinforced bars and openings.
11) Recently, about 38,000 m 3 fly ash concrete has been used in main plant civil work of Rajasthan Atomic Power Project (RAPP) unit 5 &6.
12) DLF have utilized fly ash from NTPC Dadri in concrete for residential buildings at Gurgaon, Haryana.
13) Ready Mixed Concrete (RMC) plants located in Mumbai, Delhi and adjoining areas are using fly ash in concrete. These RMC plants are taking fly ash from Nasik and Dahanu thermal power stations located near Mumbai and Dadri near Delhi and supplying fly ash based concrete for various housing and infrastructure projects.

C. 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:

Low calcium Class F fly ash normally acts as a fine aggregate of spherical form in early stages of hydration whereas high calcium Class-C fly ash may contribute to the early cementing reactions in addition to its presence as fine particulate in the concrete mix. Hydration of cement is an exothermic reaction and the released heat causes a rise of temperature of fresh concrete.

Brown, J.H. (1982)[4] in his paper " The strength and workability of concrete with Fly Ash substitution" conducted several studies with fly ash replacing cement and fine aggregate at levels of 10-40% by volume. He concluded that for each 10% of ash substituted for cement, the compacting factor or workability changed to the same order as it would by increasing the water content of the mix by 3-4%. When fly ash was substituted for sand or total aggregate, workability increased to reach a maximum value at about 8% ash by volume of aggregate. Further substitution caused rapid decrease in workability.

Gebler, S.H. and Klieger, P. (1983)[5] in their paper " Effect of fly ash on the air void stability of concrete " investigated the requirements of Air Entraining Agent (AEA) for Class-C and Class-F fly ashes. They reported that:

1) Concretes made with Class C fly ash generally require less AEA than those made with Class F fly ashes.
2) For 6% air content in concrete, the AEA varied from 126 to 173% for fly ashes having more than 10% CaO, whereas it was in the range of 177 to 553% for fly ashes containing less than 10% CaO.
3) Increase in both total alkalies and SO3 contents in fly ash affect the air entrainment favorably. A concrete containing a Class F fly ash that has relative high CaO content and less organic matter or carbon tends to be less vulnerable to loss of air.

III. 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:

1) To obtain the physical properties of the concrete constituents i.e. Pozzolanic Portland cement (PC), fine aggregates, coarse aggregate and fly ash.
2) Development of various mix combinations for concrete.
3) Casting and curing.
4) 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:

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

D. Mix Design

Mix design is known as the selection of mix ingredients and their proportions required in a concrete mix. There are several methods of mix design used throughout the world. Eventually, all of these methods follow the same procedure and produce similar results. In India the most commonly used method for mix design is the Indian Standard Method. The mix design involves calculation of the amount of cement, fine aggregates and coarse aggregates in addition to other related parameter. The mix design calculations are dependent on the properties of the constituent materials.

In the present study for designing M40 and M25 concrete. The target strength is calculated, results of sieve analysis, type and strength of cement used, workability required helps in the mix design and as per Indian Standards after making all the calculations and necessary adjustments the quantity of coarse aggregate, fine aggregate, cement and water are obtained as discussed below.

1) Design of M40 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)	40N/mm^2
ii)	Maximum size of crushed aggregate	20 mm
iii)	Degree of workability	Low
iv)	Value of statistical coefficient (K)	1.65
v)	Value of standard deviation (S)	5.00
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 = 40 + 1.65×5.00 = 48.25 N/mm^2.

3) Selection of Water Cement Ratio:

Water cement ratio for Target Mean Strength	0.40
Maximum water cement ratio from durability consideration	0.50
Therefore, W/C ratio	0.40

4) Selection of Aggregate Cement Ratio:

1) MAS = 20 mm
2) Fine Aggregates Percentage = 29.25%
3) Coarse Aggregates CA-I (10 mm) Percentage = 20.30%
4) Coarse Aggregates CA-II (20 mm) Percentage = 50.45%
5) Zone of Aggregates = 3

6) Degree of Workability = Low
7) Water Cement Ratio = 0.4
8) Aggregate Cement Ratio Fine Aggregates = 4.7
9) Aggregate Cement Ratio CA-I = 3.7
10) Aggregate Cement Ratio CA-II = 3.7

Final Aggregate Cement Ratio = (4.7+3.7+3.7)/3 = 3.99

5) Cement Content Per Meter Cube of Concrete

Cement content is calculated by the formula = Density/(1+A/C+W/C)
= 2400/(1+3.99+0.4) = 445 Kg
Here, A/C = Aggregate Cement Ratio
W/c = Water Cement Ratio

6) Actual Quantities Required For The M40 Per Cubic Metre of Concrete:
   1) Cement = 445 kg
   2) Total Aggregates = Cement Content x A/C Ratio = 445x3.99 = 1777 Kg
   3) Fine Aggregates are 29.25% of Total Aggregates as per design made, so value of Fine Aggregates = 29.25% x 1777 = 520 Kg
   4) Similarly CA-I = 20.30% x 1777 = 361 Kg
   5) Water
      – For water cement ratio of 0.40, water required= 178 Lt.
      – Extra quantity of water to be added for absorption in case of coarse aggregates@ 0.75% by mass= 9.72 litre (+).
      – Quantity of water to be deducted for the free moisture present in sand@ 1.5%= 7.8 litre (-).

      Actual quantity of water to be added = 178+9.42-7.8 = 180 Lt (Approximately).
   6) Admixture are added 1% by the weight of cementitious material.

The estimated actual mix proportion for one cubic metre of M40 concrete at 28%, 50% and 70% Fly Ash content are shown in Table 5.7(a, b, c)

2) 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:
   1) MAS = 20 mm
   2) Fine Aggregates Percentage = 33.14%
   3) Coarse Aggregates CA-I (10 mm) Percentage = 18.61%
   4) Coarse Aggregates CA-II (20 mm) Percentage = 48.24%
   5) Zone of Aggregates = 3
   6) Degree of Workability = Low
   7) Water Cement Ratio = 0.46
   8) Aggregate Cement Ratio Fine Aggregates = 5.5
   9) Aggregate Cement Ratio CA-I = 4.1
   10) 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

6) Quantities Required For The M25 Per Cubic Metre of Concrete:
   1) Cement = 398 Kg
   2) Total Aggregates = Cement Content x A/C Ratio = 398x4.56 = 1818 Kg
   3) Fine Aggregates are 29.25% of Total Aggregates as per design made, so value of Fine Aggregates = 33.14% x 1818 = 599 Kg
   4) Similarly CA-I = 18.61% x 1818 = 338 Kg
      CA-II = 48.24% x 1818 = 878 Kg
   5) 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)

IV. 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) 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 increasesthe 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/mm2)	Average Compressive Strength(N/mm2)
1.	28%	3	25	24.33
			22	
			26	
2.	28%	7	34	32.33
			28	
			35	
3.	28%	28	45	46.60
			46	
			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/mm2)	Average Compressive Strength(N/mm2)
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 Average	
			Strength (N/mm2)	Compressive Strength(N/mm2)
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.

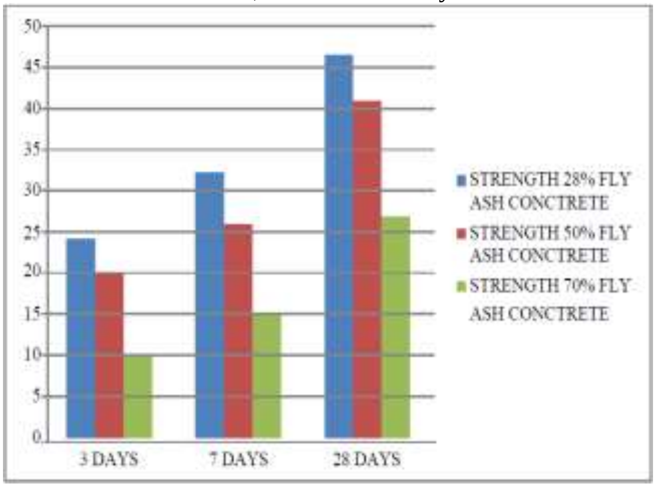

Fig. 6.1: Compressive strength comparison of M40 concrete for 28%, 50% and 70% fly ashcontent.

Sr.No	% Fly Ash Concrete	Curing Period (days)	Flexural Strength (N/mm2)	Average Flexural Strength(N/mm2)
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/mm2)	Average Flexural Strength(N/mm2)
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/mm2)	Average Flexural Strength(N/mm2)
1.	70%	28	1.50	2
			2.50	
			2.00	
2.	70%	56	4.00	3.9
			3.00	
			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 ash content.

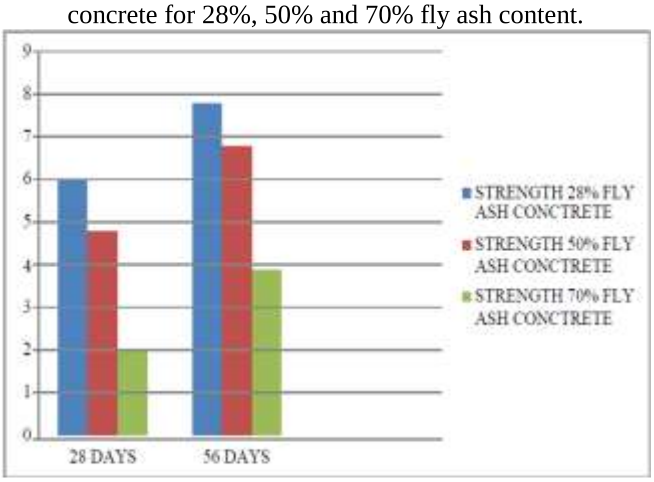

Fig. 6.2: Flexural strength comparison of M40 concrete for 28%, 50% and 70% fly ash content

V. 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

VI. Conclusion

A. General

In conclusion, the high -volume concrete offers a holistic solution to the problem of meeting the increasing demands for concrete in the future in a sustainable manner and at a reduced or no additional cost, and at the same time reducing the environmental impact of two industries that are vital to economic development namely the cement industry and the coal-fired power industry. The technology of high-volume fly ash concrete is especially significant for countries like China and India, where, given the limited amount of financial and natural resources, the huge demand for concrete needed for infrastructure, road construction and housing can be easily met in a cost-effective and ecological manner. In this chapter concluding remarks are discussed obtained from the present study and scope of future work is also given.

B. Concluding Remarks

Base on the present study following conclusions can be drawn:

1) The compressive and flexural strength of M40 concrete at 50% fly ash replacement by the mass of cement are acceptable, and therefore can be used in construction practice.
2) If we compare M25 concrete with the compressive and flexural strength of M40 concrete at 70% fly ash replacement by the mass of cement the result are acceptable and at a cost lower than M25 concrete.
3) The present study works on following three R's:
    1) Reuse
    2) Reduce
    3) Recycle

    As in this present study I have Reused the waste product i.e. fly ash, by Reducing the quantity of cement in concrete, in this way the waste product i.e fly ash, is Recycled into a much useful and cost effective concrete.
4) If more serious work is done in this field surely concrete and construction industry would be in gainful side and concrete upto some extent would be eco-friendly.

C. 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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