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Research Paper

High Volume Fly Ash Concrete

Engineering

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ABSTRACT

Millions of tons of cement is used every year that adversely affects environment. Cement is also an important building material for infrastructure development. Cement can be suitably replaced with low cost and so called waste materials like fly ash favoring environment and saving cement. For a variety of reasons, the concrete construction industry is not sustainable. First, it consumes huge quantities of virgin materials. Second, the principal binder in concrete is portland cement, the production of which is a major contributor to green-house gas emissions that are implicated in global warming and climate change. Third, many concrete structures suffer from lack of durability which has an adverse effect on the resource productivity of the industry. Because the high-volume fly ash concrete system addresses all three sustainability issues, its adoption will enable the concrete construction industry to become more sustainable. 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. In this paper, a brief review is presented of the theory and the design of M40 concrete mixture containing 28%, 50%, 70% fly ash by mass of cementitious material. The compressive strength of 3, 7 and 28 days and flexural strength of 28 and 56 days of 28%, 50% and 70% fly ash content M40 concrete cubes and beam sample respectively are compared.

1. INTRODUCTION

The world uses more than 1,350 million tones of cement every year. Also the production of one tone of Portland cement releases about one tone of CO_2 into the atmosphere. If we conserve Portland cement, an essential and most expensive component of concrete, and replace more than 50% of it with low-cost ASTM Class F fly ash, we not only make less expensive concrete, but also can significantly reduce greenhouse gas emissions.

Fly ash can act as a fine aggregate and impart as a cementitious compound due to its pozzolanic activity. Rheological properties of fresh concrete and the strength, finishes, porosity and durability of hardened concrete are all reported to be affected by addition of fly ash. It has now become possible to obtain durable and high strength concrete with 50 % or more fly ash replacing the cement, which is costly, and energy extensive material.

By the year 2015, the availability of fly ash in India will increase from about 90 million tones in the year 2001 to about 180 millions tones annually. Thus, sufficient quantities of fly ash will be available to meet the projected needs of the proposed infrastructure programs.

In the present work, a brief review is presented of the theory and the design of M40 concrete mixture containing 28%, 50%, 70% fly ash by mass of cementitious material. The compressive strength of 3, 7 and 28 days and flexural strength of 28 and 56 days of 28%, 50% and 70% fly ash content M40 concrete cubes and beam sample respectively are compared.

1.1 HYDRATION OF CEMENT

The figure 1.1 shows the hydration of cement at low and high water-cement ratios respectively. It has been observed experimentally that a particle of cement on complete hydration requires 2.31 times the original volume. But, due to space constraint inside the concrete matrix, the water is unable to completely hydrate the cement when the w/c ratio is low. The unhydrated cement remains inside the concrete matrix as a filler and does not contribute to the strength and is thus a waste.

If the total quantity of cement in concrete is reduced for the same water content, higher degree of hydration is achieved. Pozzolanic material like fly ash if used as partial replacement of cement lead to higher hydration of cement as it does not increase in volume and enough space is available for cement to occupy on hydration. This pozzolanic material is a friendly material in concrete matrix, which leads to the delayed strength of concrete, as well as the increase in the durability and decrease in the permeability of concrete. A Pozzolana is a siliceous or siliceous and aluminous material which in itself possesses little or very no cementitious value but which will, in finally divided form and in the presence of moisture chemically react with the calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.

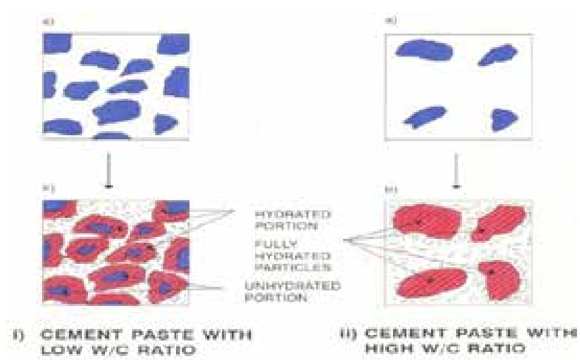


Figure 1.1: Hydration of Cement.

The fly ash makes concrete more impermeable and denser as compared to Ordinary Portland Cement. The long-term strength (90 days and above) of fly ash concrete is better compared to plain concrete. The Pozzolanic material in fly ash react with calcium hydroxide liberated by the hydrating Portland cement and forms cementitious compounds generally known as C-S-H gel. The reaction can be given as under:

C_3S + 6H ---------	> $C_3S_2H_3$ + 3 Ca $(OH)_2$		
$2C_2S$ + 4 H ------	> C_3S_2H3 + Ca $(OH)_2$		
$Ca(OH)_2$ + (SiO_2 + Al_2O_3)		------> $C_3S_2H_3$	+ Other
Components			

The fly ash converts $Ca(OH)_2$ in to useful cementitious compound ($C_3S_2H_3$) thereby increasing the properties of hardened concrete.

1.2 MIX DESIGN[1]
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. The calculated actual mix proportion for one cubic meter of M40 concrete at 28%, 50% and 70% Fly Ash content are shown in Table 1.1 (a, b, c).

NOTE: Cement used in this study is PPC which already contains 28% fly ash.

Table 1.1 (a): Weight Batching Per Cubic Meter Of 28% Fly Ash M40 Concrete.

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 1.1 (b): Weight Batching Per Cubic Meter Of 50% 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 1.1 (c): Weight Batching Per Cubic Meter Of 70% 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

2. 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 leftover gaps. 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 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 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. Three specimens were tested for single result.

2.1 COMPRESSIVE STRENGTH TEST
The test was conducted according to IS 516-1959[2]. 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. 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 2.1.

TABLE-2.1 COMPRESSIVE STRENGTH OF M40 CONCRETE FOR 28%, 50% AND 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

2.2 FLEXURAL STRENGTH TEST
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[2]) on flexural testing machine. 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 2.2. These results are expressed graphically in Fig 2.2.

TABLE-2.2 FLEXURAL STRENGTH OF M40 CONCRETE FOR 28%, 50% AND 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

3. COST COMPARISION
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 1.1 (a, b, c) are multi-

plied by the market rates of the components and then added as shown in Table 3.2(a, b, c). The rate of the various components of concrete obtained from the market are listed in Table 3.1. Figure 3.1 shows the graphical comparison of cost of 28%, 50% and 70% Fly Ash content concrete.

TABLE-3.1 MARKET RATES OF COMPONENTS OF 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-3.2(a) PER CUBIC METER COST OF 28% FLY ASH CONTENT M40 CONCRETE.

Components of Concrete	Quantity in Quantity in Per Cubic Meter of Concrete	Rates	Cost (Rs.)
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

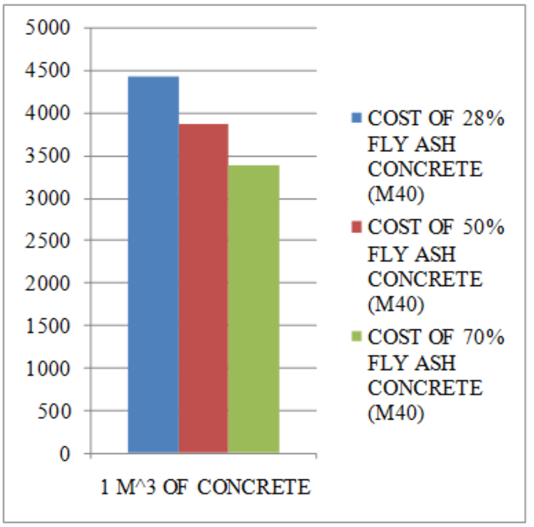
TABLE-3.2(b) PER CUBIC METER COST OF 50% FLY ASH CONTENT M40 CONCRETE.

Components of Concrete	Quantity in Per Cubic Meter of Concrete	Rates	Cost (Rs.)
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-3.2(c) PER CUBIC METER COST OF 70% FLY ASH CONTENT M40 CONCRETE.

Components of Concrete	Quantity in Per Cubic Meter of Concrete	Rates	Cost (Rs.)
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

Figure 3.1: Cost comparison of M 40 grade concrete for 28%, 50% and 70% fly ash content.

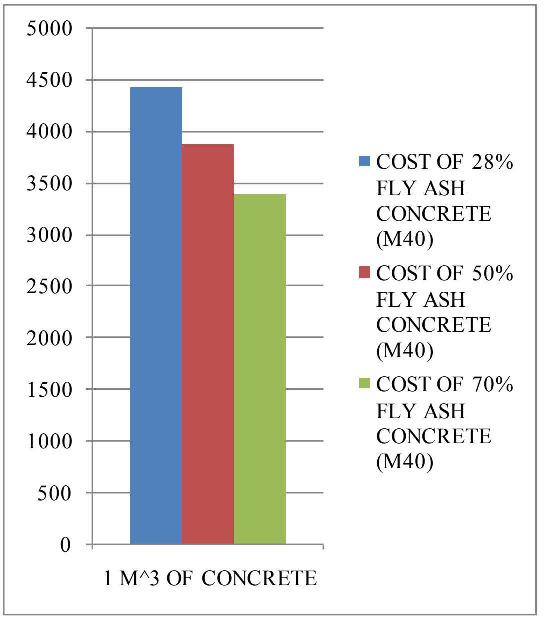


The cost of M40 grade concrete at 50% and 70% Fly Ash content when compared with M25 grade concrete at 28% Fly Ash content is far less. As shown in Table 3.3 and compared in Figure 3.2.

TABLE-3.3 PER CUBIC METER COST OF 28% FLY ASH CONTENT M25 CONCRETE.

Components of Concrete	Quantity in Per Cubic Meter of Concrete	Rates	Cost (Rs.)
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

Figure 3.2: Cost Comparison of 28% Fly Ash M 25 Concrete And 50% And 70% Fly Ash M 40 Concrete.



4. CONCLUSIONS

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 and housing can be easily met in a cost-effective and ecological manner.

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) The results obtained of M40 for 70% Fly Ash content are not satisfactory or of the level of M40 grade of concrete.
3) The cost of M40 concrete at 50% and 70% Fly Ash content is less than M25 concrete at 28% Fly Ash content.
4) The present study works on following three R's:
a) Reuse
b) Reduce
c) 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.

5) 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.

REFERENCE

1) Ambuja, "Concrete Mix Design", Ambuja Technical Literature Series 79, Ambuja Cement Ltd. | 2) IS: 516-1959: "Methods of tests for strength of concrete." Bureau of Indian Standards, New Delhi. 1999. |