Comparison of Compressive Strength of M25, M30 Grades of Concrete by Partially Replacement of Fly Ash with Normal and Accelerated Curing

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***Abstract*- The advancement of concrete technology can reduce the consumption of natural resources and lessen the burden of pollutants on environment. Presently large amounts of fly ash are generated in thermal and steel industries with an important impact on environment and human health. In recent years, many researchers have established that the use of supplementary cementitious materials (SCMs) like fly ash (FA), blast furnace slag, silica fume, metakaolin (MK) and rice husk ash (RHA) etc. can, not only improve the various properties of concrete - both in its fresh and hardened states, but also can contribute to economy in construction costs. The use of fly ash in concrete formulations as a supplementary cementatious material was tested as an alternative to traditional concrete. This project work describes the feasibility of Fly Ash in concrete world. Fly Ash was collected from NTPC (National Thermal Power Corporation) which is located at paravada in Visakhapatnam. The cement has been replaced by fly ash in various dosages such as 10, 20, 30 and 40 percentages by weight of cement for M25 and M30 mixes. Concrete mixtures were produced, tested and compared in terms of compressive strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties and compressive strengths at various curing periods such as 3, 7 and 28 days. Tests conducted for fresh concrete are workability tests like slump, vee-bee consistometer and compaction factor and for hardened concrete compressive strength is done. The 28 Days Cured concrete cubes of all proportions were cured in Accelerated Curing tank for 3hours in boiled water (at 1000C) to obtain 28 days curing strength at earlier stage. From the experimental investigations it has been observed that the compressive strength of the concrete is optimum at 20% fly ash replacement with cement.**

***Index Terms*- compressive strengths, curing of concrete, percentage increasing in compressive strength, accelerated curing.**

I. INTRODUCTION

Fly Ash is a mineral portion of coal consumed in a coal fueled power plant. The particles of fly ash are spherical shaped, glassy and finer than cement particles. In recent years special attention has been devoted to industrial sectors. The industry produces large volume of solid wastes and therefore a huge problem of pollution is generated. The potential use of this waste as a cementing material for concrete is essential. Fly ash in concrete reacts with the hydraulic cement in the following ways: CH and alkali hydroxide, which are released into the pore structure of the paste, combined with the pozzolonic particles of fly ash forming a cementing medium. Heat generated by the hydration of hydraulic cement helps initiate the pozzolonic reaction and contributes to the rate of the reaction. Fly ash is one of the residues generated in coal combustion facilities, and comprises the fine particles that rise with the flue gases.

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately gets ignites, generates heat and produces a molten mineral residue. Boiler tubes extract heat from the boiler, cool the flue gases and cause the molten mineral residue to harden and form ash. Coarse ash particles, called as bottom ash or slag, fall to the bottom of the combustion chamber, and the lighter fine ash particles, termed as fly ash, remain suspended in the flue gas. Fly ash is commonly used to supplement Portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in synthesis of geo polymers and zeolite .All Fly ash includes the substantial amounts of silica (silicon dioxide) and lime (calcium oxide). Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by flue gases and collected by electrostatic precipitation. Fly ash is most used pozzolanic material all over the world.

In recent time, the importance and use of fly ash has grown so much that it has almost become a common ingredient in concrete, particularly in making high strength and high performance concrete. The use of fly ash as concrete admixture not only extends technical advantages but also contributes to the environmental pollution control. Extensive research is being carried out in most part of the world that could be accrued in the utilization of fly ash, which is basically a waste product. The volume of fly ash produced is about 75 million tons per year, the disposal of which has become a major concern. Only about 5% of the total fly ash is utilized in India the remaining of which has to be disposed. Instead of doing so, it can be utilized in a major way. The role of it plays in the field of concrete technology. In this discussion it would be interesting to discuss on fly ash from the point of concrete making.

There are two ways that the fly ash can be used: one way is to intergrind certain percentage of fly ash with cement clinker at the factory to produce Portland pozzolona cement (PPC) and the second way is to use the fly ash as an admixture at the time of mixing the concrete at the site of work. But the main problem is that the fly ash produced in the 75 thermal power plants in India is not of the similar characteristics. The suitability of fly ash used in the making of the concrete has to be further processed. The quality of fly ash should be of the standard of *IS: 3812-1981.* For better utilization of fly ash it becomes important to know the hydration reactions, pozzolanic activity evaluation, effect of fly ash on fresh and hardened concrete, durability etc.

II. LITERATURE REVIEW

Advantages of Fly Ash in Concrete

Fly Ash is a pozzolan. A pozzolan 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 pozzolan becomes denser, stronger and generally more durable long term as compared to straight Portland cement concrete mixtures **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. **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. **Sulfate and Alkali Aggregate Resistance.**

Class F and a few Class C Fly Ashes impart significant sulfate resistance and alkali aggregate reaction (ASR) resistance to the concrete mixture. **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 buildup and reduce external cracking. **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. 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.

According to Adepegba (1989), the annual cement requirement is about 8.2 million tones and only 4.6 million tons of Portland cement are produced locally. The balance of 3.6 million tons or more is imported. If alternative cheap cement can be produced locally, the demand for Portland cement will reduce. Ramme et al (1989), presented two case histories wherein 70% cement was replaced by class C fly ash to pave a 254 mm thick road way. To obtain high workability and durability a high range water reducing agent and an air entraining agent was added to the concrete mix the other case reported by the same author's involved placing of the same high performance concrete in the construction of 138KV transformer foundations. No problems were reported during or after construction in both projects and the use of high report during or after construction in both projects and the use of high volume fly ash concrete, resulted in considerable economy and technical benefits. Langley et al (1990) reported two case histories where high volume fly ash concretes were used with class fly ash constituting 55% of cementitious material along with a super plasticizer. In one case, where columns, beams and floor slab in a building complex require 50mpa concrete at 120 days, the high performance concrete yielded concrete with 74mpa compressive strength at 120 days, thus exceeding the strength requirement. No unexpected problems were reported and the high volume of fly ash proved to be an economical solution for the particular project. Malhotra et al (1990), studied in detail the properties of concrete with a wide range of Canadian fly ashes at 58% of the total cementitious materials. These concretes were tested for compressive strength, creep strain and resistance to chloride ion penetration at various ages up to one year. (Hooten RDC, 1993) investigated on influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing and thawing, and alkali silica reactivity. He reported that the maximum 28 days compressive strength was obtained at 15% silica fume replacement level, at a W/C ratio of 0.35 with variable dosages of HRWRA.The results of study by Joshi et al (1994), indicated that with fly ash replacement level up to 50% by cement weight, concrete with 28 days strength ranging from 40 to 60 Mpa and with adequate durability can be produced with cost saving of 16% by 50% replacement level. Gopalakrishnan et al. (2000) reported from their work that the 7 day compressive strength of concrete mixes, having fly ash as cement replacement material up to 25 percent is slightly less than that of the control concrete mix at the age of 28 days. Potha Raju and Janaki Rao (2001) mentioned that, the 28 day compressive strengths were equal or slightly more in 20% fly ash replaced concrete at elevated temperatures up to 250oC than in no fly ash concrete. (Lewis et al, 2001) presented a broad overview on the production of micro silica effect of standardization of micro silica concrete both in the fresh and hardened state. (Mindess, et al., 2003) In the hardened state, fly ash contributes in a number of ways, including strength and durability. While fly ash tends to increase the setting time of the concrete. The pozzolanic reaction removing the excess calcium hydroxide, produced by the cement reaction, and forming a harder CSH The present day world is witnessing the construction of very challenging and aesthetic structures. (Prasad et al, 2003), has undertaken an investigation to study the effect of cement replacement with micro silica in the production of high – strength concrete.

III. MATERIAL SELECTION

Cement:

When the quantity of cement to be batched exceeds 30% of scale capacity, the measuring accuracy should be within 1% of required mass. If measuring quantity is less than 30% i.e. for smaller batches then the measuring accuracy should be within 4% of the required quantity.

Aggregates:

If the measurement is more than 30% of the scale capacity then the measuring accuracy should be within 1%. If measurement is less than 30% then the measuring accuracy should be within less than 3%.

Water:

Water is measured in volumetric quantity as 1 litre = 1kg. In case of water, the measuring accuracy should be within 1%.

Fly Ash

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by flue gases and collected by electrostatic precipitation. Fly ash is most used pozzolonic material all over the world.

In recent time, the importance and use of fly ash has grown so much that it has almost become a common ingredient in concrete, particularly in making high strength and high performance concrete. The use of fly ash as concrete admixture not only extends technical advantages but also contributes to the environmental pollution control. Extensive research is being carried out in most part of the world that could be accrued in the utilization of fly ash, which is basically a waste product.

Batching of Concrete

It is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume.

Weigh Batching:

- Weigh batching is the correct method of measuring the materials.
- Use of weight system in batching, facilitates accuracy, flexibility and simplicity.

- Large weigh batching plants have automatic weighing equipment.
- On large work sites, the weigh bucket types of weighing equipments are used.

IV. TEST RESULTS AND ANALYSIS

Cement

The cement used for experimental purpose is Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade (Ultra Tech OPC) conforming to IS:8112-1989 is used. The cement is in dry powdery form with the good quality chemical compositions and physical characteristics. Many tests were conducted on cement; some of them are specific gravity, consistency tests, setting time tests, compressive strengths, etc.

Table no: 1 shows the physical properties of cement.

S. No	**Physical properties of cement**	**values**	**Requirement as per I.S Code (IS:8112-1989)**
1	specific gravity	2.96	3.10-3.15
2	Fineness	3.33%	< 10%
3	Normal consistency	30%	30-35%
4	Initial setting time	70min	30 Minimum
5	Final setting time	440min	600 Maximum
6	soundness	1mm	<10 mm

Aggregates

Aggregates are the chief constituents in concrete. They give body to the concrete, decrease shrinkage and achieve economy. One of the most significant factors for producing feasible concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste means less quantity of cement and less water, which are further mean increased economy, inferior shrinkage and superior durability.

Coarse Aggregate

Crushed stone were used as coarse aggregates; the fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are used. The Flakiness Index and Elongation Index were maintained well below 15%.

Fine aggregate

Locally available Narmada River sand was used as fine aggregates. Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand and crushed sand is used in mixture as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screened, to abolish deadly materials and over size particles.

Table no: 2 Shows the test results for fine aggregates and coarse aggregates.

S.no	Test	Fine Aggregate	coarse Aggregate	
			20 mm	10 mm
1	Fineness modulus	3.36	7.6	3.1
2	Specific Gravity	2.6	2.81	2.7
3	Water Absorption (%)	1.5	0.5	0.5
4	Bulk Density(gm/cc)	1753	1741	1711

Fly Ash: Properties of fly ash, various tests were done to find out the physical

Table no: 3 Shows the physical properties of fly ash.

SI. No	**Tests**	**Require ment**	**Result s**
1	Fineness- specific surface in m^2 /kg (Blaine's permeability method)	320 Min	395
2	Lime reactivity –Average compressive strength in N /mm_2	4.5 Min	6.0
3	Compressive strength at 28days , N /mm^2	Not <80% of the strength of correspon ding plain cement mortar cubes	91
4	Soundness by autoclave test Expansion of specimen %	0.8 Max	0.11
5	Particles retained on 45 micron IS: Sieve (wet sieving),% by mass	34 Max	31

Concrete:

Concrete is a composite material and is a homogeneous mixture of cement aggregates and water. The beauty of concrete is it is very simple to understand and at the same time throws challenges at every stag

Cement fly ash blends:
The fly ash is blended in cement at a rate of 10 to 40% by weight of cement in steps of 10%. The Cement - fly ash blends are then tested for following properties: consistency, setting time, soundness, workability and compressive strength, as per IS 546-2003.

Workability:
The concrete should have good workability. It is defined as the ease with which it can be fixed transported and placed in position in homogeneous state. It depends upon the quantity of water, grading of aggregate and percentage of fine materials in the mix. Slump test, compaction factor and vee-bee consistometer are some of the workability tests - conducted as shown below.

Table no: 4 Shows the variation between % of fly ash in cement and slump for M25

% fly ash in cement	Slump (mm)	Compaction factor (%)	vee-bee values(sec)
0%	85	0.95	4
10%	95	0.92	6
20%	75	0.92	17
30%	105	0.91	8
40%	75	0.92	8

It is observed that the table no: 4 slump, compaction factor and vee-bee values are changing % of fly ash in cement for M25 grade at 20% fly ash in cement gets the slump value as 75mm. The slump value decrease 10mm at 20% of fly ash replacement, the compaction factor value as 0.92 at 20% fly ash replacement. The compaction factor value decrease of 0.03 at 20% of fly ash replacement, and at the 20% fly ash in cement gets the optimum vee-bee value as 17 secs. The vee-bee value is optimum at 20% of fly ash replacement.

Table no: 5 shows the variation between % fly ash in cement and slump for M30

% fly ash in cement	slump(mm)	compaction factor(%)	vee-bee(sec)
0%	25	0.94	12
10%	20	0.95	11
20%	20	0.95	10
30%	17	0.92	10
40%	16	0.91	11

It is observed that the table no: 5 slump values changes with % fly ash in cement for M30 grade at the 20% fly ash in cement gets the optimum slump value as 20mm. The slump value decrease of 5 mm at 20% of fly ash replacement, at the 20% fly ash in cement gets the optimum compaction factor value as 0.95. The compaction factor value increase of 0.01 at 20% of fly ash replacement, and at 20% fly ash in cement gets the optimum vee-bee value as 10secs. The vee-bee value decrease of 2 sec at 20% of fly ash replacement.

Compressive strength determination:
In this test sample of concrete is filled in the mould of size 15cm x 15cm x 15cm and top of mould is strike off. A total number of 20 cubes were casted. Fly ash is added in place of cement in concrete in 4 different percentages starting from 0%, and raised mixing of fly ash up to 25%, at an interval of 10%. The specimens are covered with in normal curing tank and accelerated curing tank for 24 hours. Then after sample is removed from curing tank. At the end of curing period sample is removed and tested immediately. The testing is done under Compressive Testing Machine model no. CTM40. The load is applied smoothly and gradually. The crushing loads are noted and average compressive strength for three specimens is determined for M25 and M30 grade.

Table no: 6 Shows the variation between % fly ash in cement and compressive strength for M25

% fly ash in cement	compressive strength		
	3	7	28
0%	12	22	31.36
10%	14.3	22.9	32.16
20%	18	23.12	35.74
30%	15	20	27.36
40%	16	19.5	22.87

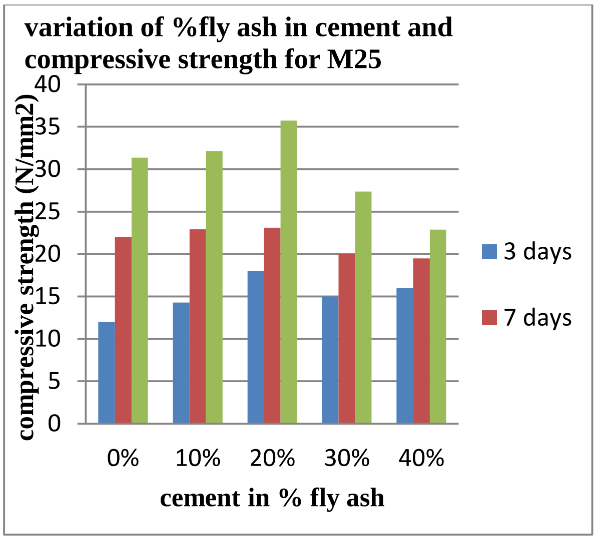


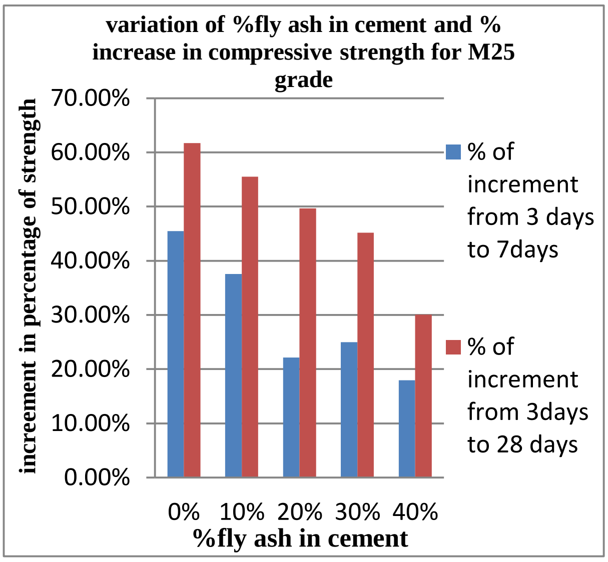
Fig no: 1 shows the graph for % fly ash in cement and compressive strength for M25.

It is observed that the table no: 6 compressive strength values changes with % of fly ash in cement for M25 grade. The above (fig 1) shows the 20% fly ash in cement gets the optimum compressive strength. The compressive strength value increases of 35.74 Mpa at 20% of fly ash replacement.

Table no: 7 Shows the variation between % fly ash in cement and % increase in compressive strength of M25

% fly ash + cement	% increase in compressive strength	
	7	28
0%	45.45%	61.73%
10%	37.55%	55.53%
20%	22.15%	49.64%
30%	25.00%	45.18%
40%	17.95%	30.04%

Fig no: 2 Shows the graph for % fly ash + cement and % increase in compressive strength for M25



It is observed that the table no: 4.18 % increase in compressive strength values changes with % of fly ash in cement for M25 grade. The above (fig 2) shows the % fly ash in cement gets the optimum compressive strength at 20% of fly ash replacement.

Table no: 8 Shows the variation between % fly ash in cement and compressive strength of M30

% fly ash in cement	compressive strength(Mpa)		
	3days	7 days	28days
0%	12	27.84	32.33
10%	13.5	28.54	34.22
20%	14	30.87	36.45
30%	13.8	26.33	31.23
40%	13.5	26.1	32

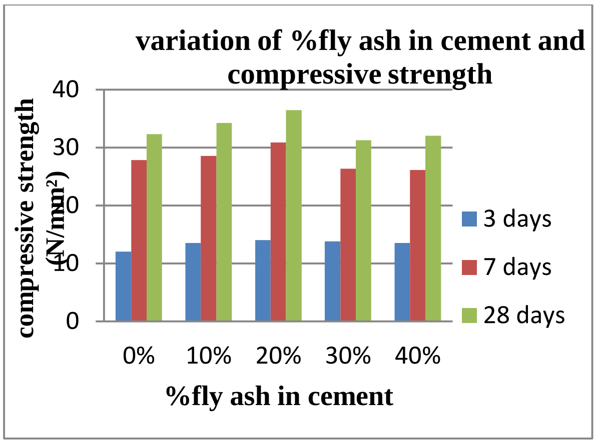


Fig no: 3 Shows the graph for % fly ash in cement and compressive strength for M30

It is observed that the table no: 8 compressive strength values varying with % of fly ash in cement for M30 grade. The above (fig 3) shows the 20% fly ash in cement gets the optimum compressive strength. The compressive strength value increase of 36.45 Mpa at 20% of fly ash replacement.

Table no: 9 Shows the variation between % fly ash in cement and % increase in compressive strength for M30

% fly ash in cement	% increase in compressive strength	
	7 days	28days
0%	56.90%	62.88%
10%	52.70%	60.55%
20%	54.65%	61.59%
30%	47.59%	55.81%
40%	48.28%	57.81%

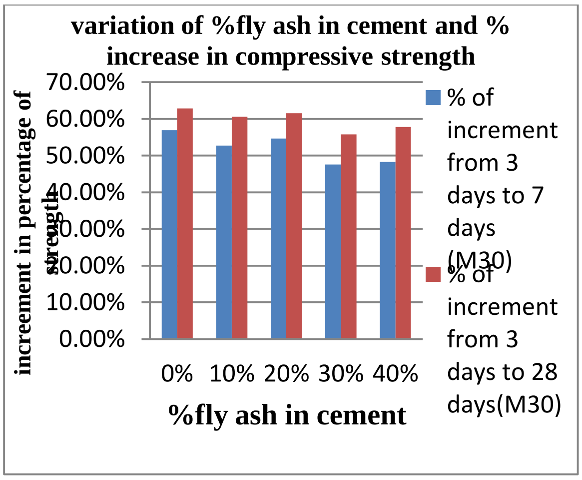


Fig no: 4 Shows the graph for % fly ash in cement and % increase in compressive strength for M30

It is observed that the table no: 9 % increase in compressive strength changing with % of fly ash in cement for M25 grade. The above (fig 4) shows the 20% fly ash in cement gets the optimum compressive strength. The percentage increasing compressive strength value is 61.59% at 20% of fly ash replacement.

Table no: 10 Shows the variation between % fly ash in cement and compressive strength for M25 and M30

% fly ash in cement	compressive strength for M25(Mpa)	compressive strength for M30 (Mpa)
0%	30.21	31.52
10%	30.66	33.45
20%	32.12	34.25
30%	28.16	29.17
40%	26.87	29.83

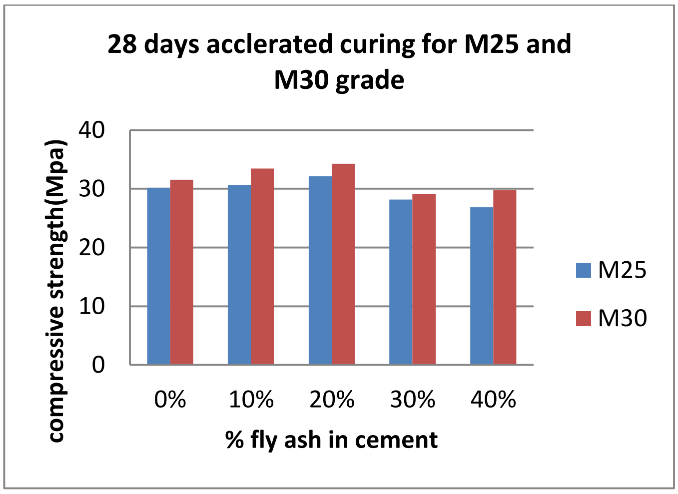


Fig no: 5 Shows the graph for variation in % fly ash in cement and compressive strength for M25 and M30.

It is observed that the table no: 10 % compressive strengths changing with % of fly ash in cement for M25 and M30 grade. The above (fig 5) shows the 20% fly ash in cement gets the optimum compressive strength. The percentage increasing compressive strength of 32.12 Mpa and 34.25 Mpa at 20% of fly ash replacement.

Table no: 11 Shows the variation between % fly ash in cement and compressive strengths of normal and accelerated curing for M25 and M30

% fly ash in cement	28 days normal curing for M25 and M30 grade		28 days accelerated curir M25 and M30 grade	
	compressive strength for M25(Mpa)	compressive strength for M30 (Mpa)	compressive strength for M25(Mpa)	compre strengtl M30 (N
0%	31.36	32.33	30.21	31.52
10%	32.16	34.22	30.66	33.45
20%	35.74	36.45	32.12	34.25
30%	27.36	31.23	28.16	29.17
40%	22.87	32	26.87	29.83

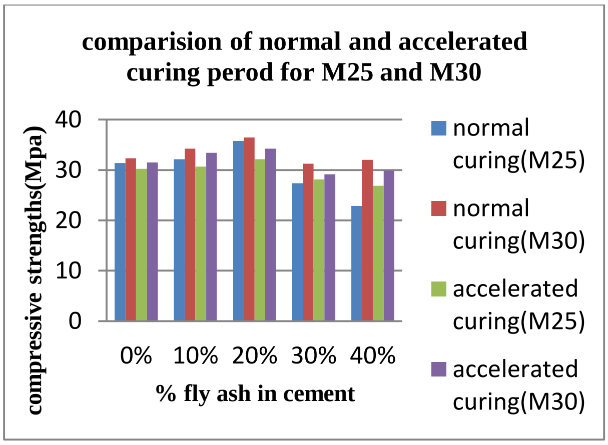


Fig no: 6 Shows the graph for variation between % fly ash in cement and compressive strengths of normal and accelerated curing for M25 and M30

From above table 11 shows the compressive strength of cubes with 28 days curing period. And the above figure 6 shows increasing the compressive strength changing with increasing the percentage of fly ash and cement for grades M25 and M30. The maximum compressive strength value gets 36.45 Mpa and 34.25 Mpa at 28 days normal curing.

Table no: 12 Shows the variation between % fly ash in cement and % loss of weights for M25 and M30

% fly ash in cement	% loss of weights(M25)	% loss of weights(M30)
0%	2.72	3.43
10%	3.09	3.17
20%	2.60	4.67
30%	5.50	4.73
40%	6.07	1.78

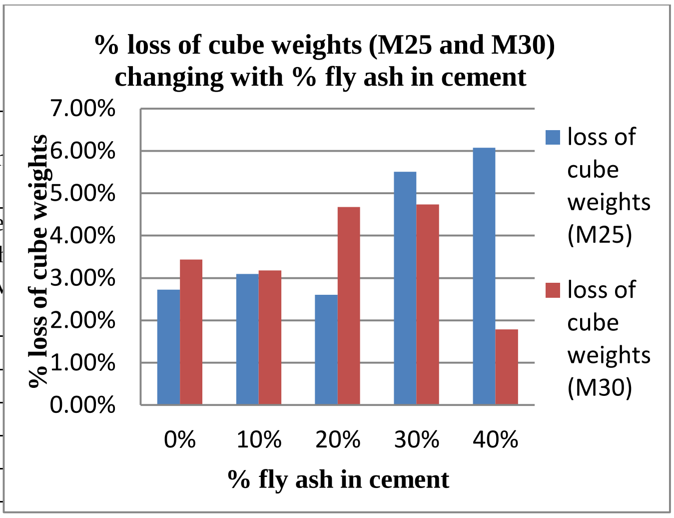


Fig no: 7 Shows the graph for variation between % fly ash in cement and % loss of weights for M25 and M30.

It is observed that the table no: 12 shows % loss of cube weight changing with % of fly ash(M25 and M30) fly ash in cement. And the above figure 7 shows the changes in % of cube weights with % fly ash in cement at the more weight loss of cube for M25 is 6.07% at 40% fly ash and less weight loss of cube is 2.60 at 20% fly ash, similarly for M30 more loss of weight is 4.73 at 30% fly ash and less loss of 1.78 at 40% fly ash.

V. CONCLUSIONS

- The optimum dosage of Fly Ash addition was decided as 20% Fly Ash in Cement for both M25 and M30 grades of Concrete.
- The maximum Compressive Strength obtained at optimum Dosage is 36.45Mpa.
- It is concluded that normal cured concrete cubes have shown better results than accelerated curing samples.
- 28 Days was considered as Optimum Curing period because maximum strengths were obtained at this period for all proportions of mixes.

REFERENCES

1. “IS: 8112-1989”. Specifications for 43-Grade Portland cement, Bureau of Indian Standards, and New Delhi, India.
2. “I.S: 516-1959”. Method of test for strength of concrete, Bureau of Indian Standards, New Delhi, 1959.
3. “I.S:2386 (Part I, IV, VI)-1988”. Indian standard Method of test for aggregate for

concrete, Bureau of Indian Standards, Reaffirmed, New Delhi, 2000.
4. "IS: 1199-1959". Indian Standards Methods of Sampling and Analysis of Concrete, Bureau of Indian Standards, New Delhi, India.
5. "Effect of partial replacement of cement with fly ash on the strength and durability of HPC" Gopalakrishna, S., Rajamane, N.P., Neelamegam, M., Peter, J.A. and Dattatreya, J.K. 2001. The Indian Concrete Journal, pp. 335-341.
6. **"**Nucleation and Pozzolanic Factors in Strength Development of Class F Fly Ash Concrete**"**, Gopalan, M. K. (1993), ACI Materials Journal, Vol.90, No.2, pp. 117 – 121.
7. **"**Effects of water / powder ratio, mixing ratio of fly ash, and curing temperature on pozzolanic reaction of fly ash in cement paste**"**, Hanehara, S., Tomosawa, F., Kobayakawa, M., Hwang, K. (2001), Cement and Concrete Research, Vol.31, pp. 31 – 39.
8. **"**Prediction model of compressive strength development of fly ash concrete**"**, Hwang, K., Noguchi, T., Tomosawa, F. (2004), Cement & Concrete Research, Vol.34, pp. 2269 – 2276.