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1. INTRODUCTION:

The power requirement of the country is rapidly increasing with increase in growth of the industrial sectors. India depends on Thermal power as its main source (around 75% of power produced is thermal power), as a result the quantity of Ash produced shall also increase. Indian coal on an average has 35 % ash and this is one of the prime factors which shall lead to increased ash production and hence, Ash utilization problems for the country.

Out of the total ash produced, fly ash contributes to a small percentage, majority being pond ash and bottom ash.

Fly ash is one of the numerous substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards. it is also contains trace amounts of toxic metals which may have negative effect on human health and on plants and the land where the fly ash decomposed not gets reused.

The fly ash is disposed off either in the dry form or mixed with water and release in slurry into locations called ash ponds. Occasional failure of such ash ponds not only affects vast tracts of agricultural land nearby but also pollutes river water even up to 100 kilometers endanger aquatic and human life.

Four countries, namely, China, India, United State and Poland alone produce more than 270 million tons of fly ash each year.

Such a huge quantity does pose challenging problems, in the form of land usage, health hazards, and environmental dangers. Both in disposal, as well as in utilization, utmost care has to be taken, to safeguard the interest of human life, wild life, and environment.

Several factors have impeded fly ash utilization in India, while it is being extensively used globally. Coal-based thermal power stations have been operational for more than 50 years but the concept of developing environment-friendly solutions for fly ash utilization is only about 15 years old. Overall fly ash utilization in India stands at a fairly low level of about 30 per cent of the quantity generated.

2. FLY ASH:

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. When coal is consumed in a power plant, it is first ground to the fineness of powder. Blown into the power plant's boiler, the carbon is consumed — leaving molten particles rich in silica, alumina and calcium.

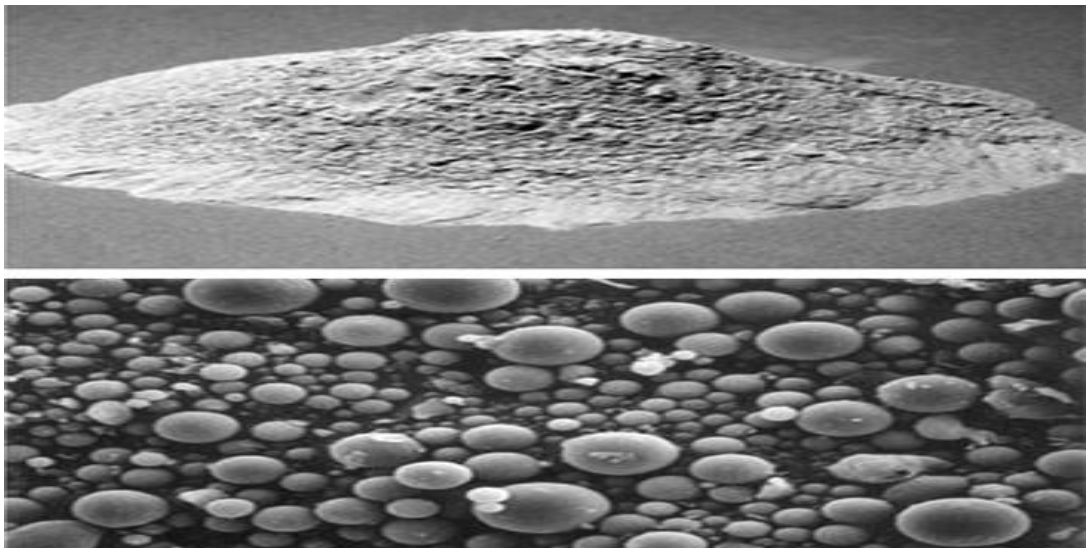

Figure: 1 Fly ash: The modern pozzolana

These particles solidify as microscopic, glassy spheres (see fig.1) that are collected from the power plant's exhaust before they can "fly" away — hence the product's name: Fly Ash. Chemically, fly ash is a pozzolana.

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.

Chemically, fly ash is a pozzolana. When mixed with lime (calcium hydroxide), pozzolanas combine to form cementitious compounds. Concrete containing fly ash becomes stronger, more durable, and more resistant to chemical attack.

2.1CHEMICAL COMPOSITION:

Fly ash particles are in general spherical in shape and range in size from 0.5 μm to 100 μm. They consist mainly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3). Fly ashes are in general highly heterogeneous, consisting of a concoction of glassy particles with various exacting crystalline phases such as quartz, mullite, and various iron oxides.

Fly ash also contain environmental toxins in major amounts, jointly with

Arsenic -43.4 ppm,	Barium -806 ppm,	Beryllium -5 ppm,
Boron -311 ppm,	Cadmium -3.4 ppm,	Chromium-136ppm,
Chromium VI -90 ppm,	Cobalt -35.9 ppm,	Copper- 112 ppm,
Fluorine -29 ppm,	Lead 56 –ppm,	Manganese -250 ppm,
Nickel- 77.6 ppm,	Selenium -7.7 ppm,	Strontium -775 ppm;
Thallium -9 ppm,	Vanadium -252 ppm,	and Zinc -178 ppm.

2.2 CLASSIFICATION:

There are two basic types of fly ash:

- *Class* C *fly ash*
- *Class* F *fly ash*

Both types react in concrete in similar ways.The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely subjective by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

2.2.1 CLASS C FLY ASH:

- Normally produced from the combustion of lignite or sub-bituminous coals.
- possesses cementitious properties in addition to pozzolanic properties.
- In the presence of water, Class C fly ash will harden and gain strength over time.
- Class C fly ash generally contains **more than** 20% lime (CaO).

2.2.2 CLASS F FLY ASH:

- Normally produced from the combustion of bituminous or anthracite coals
- This fly ash is pozzolanic in nature, and contains ***less than*** 20% lime (CaO).
- Possessing pozzolanic properties, the glassy silica and alumina of Class F flyash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds

3. HOW FLY ASH HELP IN CONCRETE?

- **3.1 Reduced Heat of Hydration.**

In concrete mix, when water and cement come in contact, a chemical reaction Initiates that produces binding material and consolidates the concrete mass. The process is and heat is released which increases the temperature of the mass When fly ash is present in the concrete mass, it plays dual role for the strength development. Fly ash reacts with released lime and produces binder as explained above and render additional strength to the concrete mass. The unreactive portion of fly ash act as micro aggregates and fills up the matrix to render packing effect and results in increased strengthh. The large temperature rise of concrete mass exerts temperature stresses and can lead micro crackes. When fly ash is used a s part of cementitious material, quantum of heat liberated is low and staggers through pozzolanic reactions and thus reduces micro-cracking and improves soundness of concrete mass.

- **3.2 Workability of Concrete**

Fly ash particles are generally spherical in shape and reduces the water requirement for a given slump. The spherical shape helps to reduce friction between aggregates and between concrete and pump line and thus increases workability and improve pumpability of concrete. Fly ash use in concrete increases fines volume and decreases water content and thus reduces bleeding of concrete.

- **3.3 Permeability and corrosion protection**

Water is essential constituent of concrete preparation. When concrete is hardened, part of The entrapped water in the concrete mass is consumed by cement mineralogy for hydration. Some part of entrapped water evaporates, thus leaving porous channel to the extent of volume occupied by the water. Some part of this porous volume is filled by the hydrated products of the cement paste. The remaining part of the voids consists capillary voids and give way for ingress of water. Similarly,
the liberated lime by hydration of cement is water-soluble and is leached out from hardened concrete mass, leaving capillary voids for the ingress of water. Higher the water cement ratio, higher will be the porosity and thus higher will be the permeability. The permeability makes the ingress of moisture and air easy and is the cause for corrosion of reinforcement. Higher permeability facilitate ingress of chloride ions into concrete and is the main cause for initiation of chloride induced corrosion. Additional cementitious material results from reaction between liberated surplus lime and fly ash, blocks these capillary voids and also reduces the risk of leaching of surplus free lime and thereby reduces permeability of concrete.

- **3.4 Sulphate Attack**

Sulphate attacks in concrete occur due to reaction between sulphate from external origins or from atmosphere with surplus lime leads to formation of etrringite, which causes expansion and results in volume destabilization of the concrete . Increase in sulphate resistance of fly ash concrete is due to continuous reaction between fly ash and leached out lime, which continue to form additional C-S-H gel. This C-S-H gel fills in capillary pores in the cement paste, reducing permeability and ingress of sulphate ions.

- **3.5 Corrosion of steel**

Corrosion of steel takes place mainly because of two types of attack. One Is due to Carbonation attack and other is due to chloride attack. In the carbonation attack, due carbonation of free lime, alkaline environment in the concrete comes down which to disturbs the passive iron oxide film on the reinforcement. When the concrete is permeable, the ingress of moisture and oxygen infuse to the surface of steel initiates the electrochemical processs and as a result-rust is formed. The transformation of steel to rust increases its volume thus resulting in the concrete expansion, cracking and distress to the structure. In the chloride attack, Chloride ion becomes available in the concrete either through The dissociation of chlorides-associated mineralogical Hydration or infusion of Chloride ion. The sulphate attack in the concrete. Decomposes the chloride Mineralogy thereby releasing chloride ion. In the presence of large amount of chloride, the concrete exhibits the tendency to hold Moisture. In the presence of moisture and oxygen, the resistivity of the concrete Weakens and becomes more permeable thereby inducing further distress. The use of fly ash reduces availability of free limes and permeability thus result in corrosion prevention.

- **3.6 Reduced alkali- aggregate reaction**

Certain types of aggregates react with available alkalis and cause expansion and Damage to concrete. These aggregates are termed as reactive aggregates. It has Been established that use of adequate quantity of fly ash in concrete reduces the Amount of alkali aggregate reaction and reduces eliminates harmful expansion of Concrete. The reaction between the siliceous glass in fly ash and the alkali hydroxide Of Portland cement paste consumes alkalis thereby reduces their availability for Expansive reaction with reactive silica aggregates.

In a nutshell, it can be summarized that permeability and surplus lime Liberated during the hydration of Portland cement are the root causes for Deleterious effect on the concrete. Impermeability is the foremost defensive Mechanism for making concrete more durable and Is best achieved by using Fly ash as above.

4. HOW FLY ASH WORKS WITH CEMENT CONCRETE ?

Ordinary Portland Cement (OPC) is a product of four principal mineralogical phases. These phases are Tricalcium Silicate-C S (3CaO.SiO), Dicalcium Silicate - C_2S (2CaO.SiO), Tricalcium Aluminate- C A (3CaO.Al O) and Tetracalcium alumino-ferrite - C AF(4CaO. Al O Fe O). The setting and hardening of the OPC takes place as a result of reaction between these principal compounds and water. The reaction between these compounds and water are shown as under:

$2C_3S$ + 6H → $C_3S_2H_3$ + 3CH

Tricalcium silicate water C-S-H gel Calcium hydroxide

$2C_2S$ +4H → $C_3S_2H_3$ +CH

Dicalcium silicate + water C-S-H gel Calcium hydroxide

The hydration products from C_3S and C_2S are similar but quantity of calcium Hydroxide (lime) released is higher inC_3S as compared to C_2S. The reaction of C_3A With water takes place in presence of sulphate ions supplied By dissolution of Gypsum present in OPC. This reaction is very fast and is shown As under:

C_3A + $3(CSH_2)$ + 26H → C_3 A $(CS)_3$ H_{32}

Tricalcium alluminate + gypsum + water → ettringite

C_3A + CSH_2 + 10H → $C3ACSH_{12}$

Monosulphoaluminate hydrate

Tetracalcium alumino-ferrite forms hydration product similar to those of C3A, with iron substituting partially for alumina in the crystal structures of ettringite and Monosulpho-aluminate hydrate.

Above reactions indicate that during the hydration process of cement, lime is Released out and remains as surplus in the hydrated cement. This leached out Surplus lime renders deleterious effect to concrete such as make the concrete Porous, give chance to the development of micro- cracks, weakening the bond with Aggregates and thus affect the durability of concrete.

If fly ash is available in the mix, this surplus lime becomes the source for Pozzolanic reaction with fly ash and forms additional C-S-H gel having similar binding properties in the concrete as those produced by hydration of cement paste. The reaction of fly ash with surplus lime continues as long as lime is present in the pores of liquid cement paste. The process can also be understood as follows:

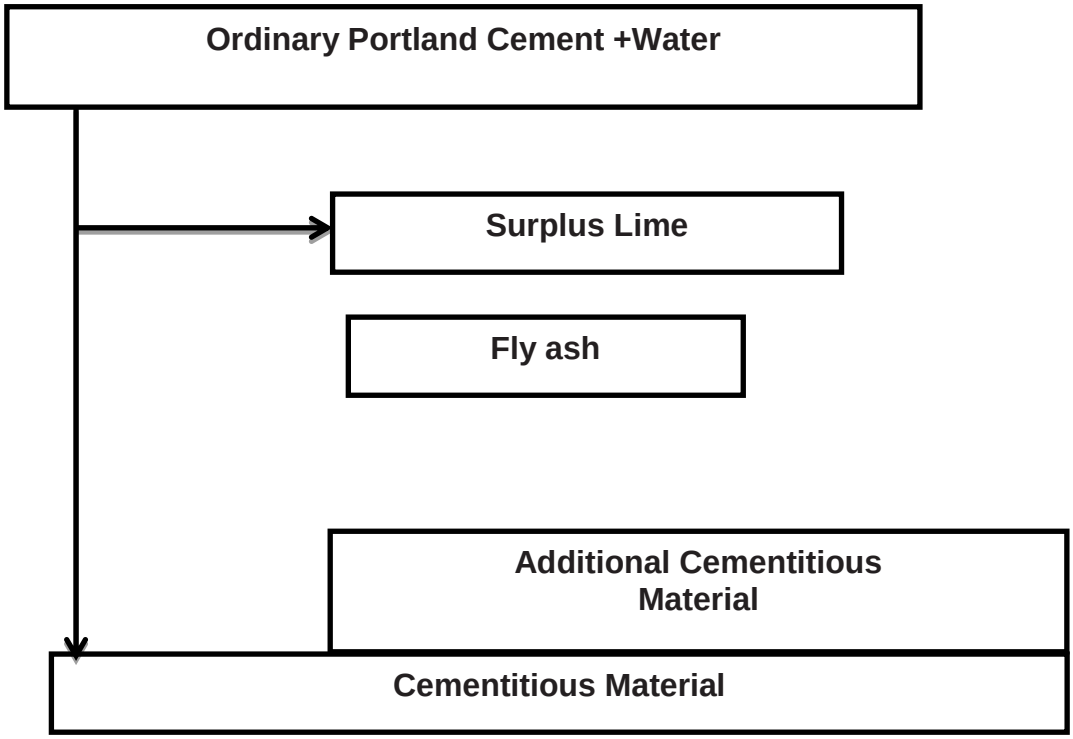

Fig2: Fly ash works with cement concrete

5. Salient advantage of using fly ash in cement concrete

- ✓ Reduction in heat of hydration and thus reduction of thermal cracks and
- ✓ Improves soundness of concrete mass.
- ✓ Improved workability / pumpabilty of concrete
- ✓ Converting released lime from hydration of OPC into additional binding
- ✓ Material – contributing additional strength to concrete mass.
- ✓ Pore refinement and grain refinement due to reaction between fly ash and
- ✓ Liberated lime improves impermeability.
- ✓ Improved impermeability of concrete mass increases resistance against
- ✓ Ingress of moisture and harmful gases result in increased durability.
- ✓ Reduced requirement of cement for same strength thus reduced cost of Concrete.

6. Environmental benefits of fly ash use in concrete

- Use of fly ash in concrete imparts several environmental benefits and thus it is eco-friendly.
- It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc. required for manufacture of cement.
- Manufacture of cement is high-energy intensive industry.
- In the manufacturing of one tonne of cement, about 1 tonne of CO is emitted and goes to atmosphere.
- Less requirement of cement means less emission of result in reduction in greenhouse gas emission.
- Due to low calorific value and high ash content i n Indian Coal, thermal power plants in India, are producing huge quantity of fly ash.

  This huge quantity is being stored / disposed of in ash pond areas. The ash ponds acquire large CO_2

Fig:3 View of tunnel of Delhi Metro Rail Corporation Where fly ash has been used.

7. EXPERIMENTAL:-

7.1 MATERIALS:-

7.1.1 CEMENT:-

- Ordinary Portland cement available in local market (Siddhi Cement) was used in the investigation. Care has been taken to see that the procurement made from a single batch and is stored in airtight containers to prevent it is being affected by atmospheric, monsoon moisture and humidity. The specific gravity was 3.10 and fineness was 3200 m^2/Kg. The details are given in Table 3. The cement confirms to 53 Grade.
- Cement was obtained from the. Construction site of civil department GEC BHAVANAGAR.

Fig. 4: Cement

7.1.2 SAND:-

- The locally available river sand was used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. The sand is tested for its properties like Specific Gravity; Bulk Density etc. in accordance with IS 2386-1963.

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Fig 5: Sand.

7.1.3 AGGREGATE:-

- Machine Crushed angular granite metal of maximum size of 20mm retained on 4.75mm I.S. sieve confirming to I.S. 383-1970 was used in the present investigation. It is free from impurities such as dust, clay particles and organic matter etc.

Fig 6: Aggregate.

7.1.4 FLY ASH:-

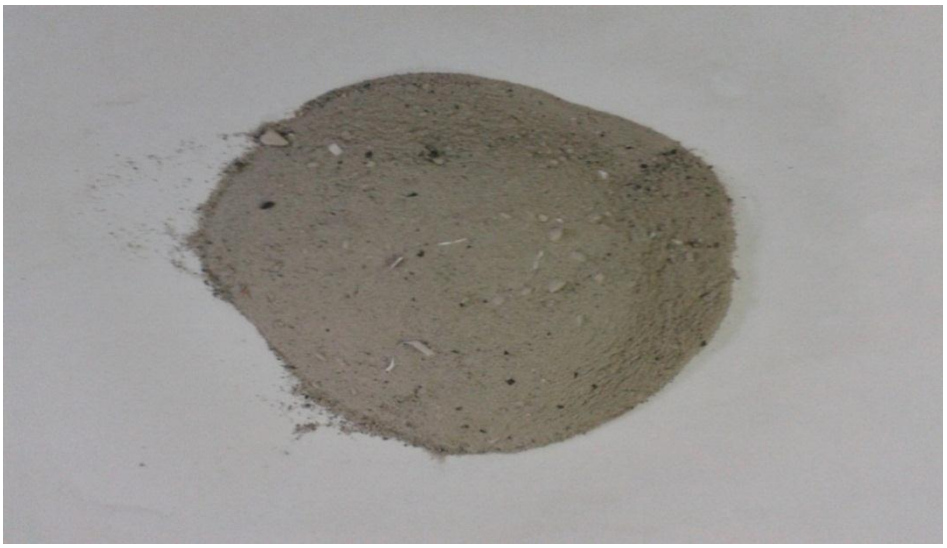


Fig 7: FLY ASH

- The fly ash for this study was provided by PETRA BUILDCARE at BHAVNAGAR
- Class C Fly ash is used in this experiment.
- The physical properties of fly ash are available in Table 4.

7.1.5 WATER:-

- Water is the least expensive but most important ingredient of the concrete. The water, which was used for making concrete was clean and free from harmful impurities like oil, alkalis, acids etc. in general, the water which is fit for drinking should be used for making concrete.

Fig 8: Water.

Table 1: Physical Properties of OPC 53 Grades

PARAMETERS	RANGE
Specific gravity	3.1
Mean grain size (μm)	22.5
Specific area cm^2/gm	3250
Colour	Ivory to Cream
Silicon dioxide (SiO2)	20.25
Aluminium oxide (Al2O3)	5.04
Iron oxide (Fe2O3)	3.16
Calcium oxide(CaO)	63.61
Magnesium oxide (MgO)	4.56
Sodium oxide (Na2O)	0.08
Potassium oxide (K2O)	0.51
Loss on ignition	3.12

Table 2: Physical Properties of FLY ASH

PARAMETERS	RANGE
Specific Gravity	1.90 – 2.55
Plasticity	Non plastic
Maximum dry density (gm/cc)	0.9 – 1.6
Optimum moisture content (%)	38.0 – 18.0
Cohesion (kN/m^2)	Negligible
Angle of internal friction (j)	$30^0 – 40^0$
Coefficient of consolidation Cv (cm /sec^2)	$1.75 \times 10^{-5} – 2.01 \times 10^{-3}$
Compression index Cc	0.05 – 0.4
Permeability (cm/sec)	$8 \times 10^{-6} – 7 \times 10^{-4}$
Coefficient of uniformity	3.1 – 10.7

7.2 MIX DESIGN:-

- The mix design was according to the weight method. The mix proportion was to be assumed as **1 : 1 : 2 (Cement / sand / aggregate).**

- Their mix proportion is shown in table no.4 for various proportion of FLY ASH replacement with cement.

- There were 12 numbers of cubes in which 3 cubes for 0 % FLY ASH, 3 cubes for 10 % FLY ASH, 3 cubes for 20 % FLY ASH and 3 cubes for 30 % FLY ASH for one stage of testing 28 days.

- The coarse aggregate content per cubic meter was 1800 kg/m^3 and sand has specific gravity about 2.65.

- Specific gravity used was 3.15, 2.40 and 2.790 for cement, fly ash and coarse aggregate.

Table 3: Mix design by weight method.

COMPOSITION BY WEIGHT FOR PROPORTION (1:1:2)						
% of FLY ASH	NUMBER OF CUBES	CEMENT (Kg)	FLY ASH (kg)	SAND (kg)	COARSE AGGREGATE (kg)	WATER (kg)
0 %	3	5.490	0.000	6.5407	13.851	2.196
10 %	3	4.941	0.549	6.5407	13.851	1.9764
20 %	3	4.392	1.098	6.5407	13.851	1.7568
30 %	3	3.843	1.647	6.5407	13.851	1.5372
SPECIFIC GRAVITY		3.15	2.40	2.65	2.709	1.00

7.3 MIXING, CASTING AND COMPACTION PROCESS:-

7.3.1Mixing and casting:-

The mixing of concrete was done in a laboratory DRUM mixer available in the concrete laboratory. The following procedure is followed for mixing of ingredients. First sand were added to the mixer. FLY ASH was first mixed with cement until a uniform mix is obtained and then fed into the drum mixer. After that aggregate, sand, cement and fly ash were mixed until uniform mixture is obtained. Then approximately 75 % of water was added in the drum and mixed uniformly. Lastly the remaining water was added and mixed for 3 minutes. After 1 minutes rest, concrete was mixed for another 2 minutes to get a homogenous mix.

Fig: 9 casting of mould.

7.3.2 Compaction:-

The compaction of concrete was made using a table vibrator. To eliminate the effect of possible defects, the cube moulds were initially half filled, the mix was vibrated and then the remaining half was filled and the vibration was continued for one minute. No signs of segregation or air bubbles were observed during mixing or compaction.

7.3.3 Concrete specimen:-

Fig: 10 concrete specimen

The specimens were de-moulded after 24 hours and cured by immersing them in water for 28 days

For each mix 12 cube specimens of size 150 x 150 x 150 mm were cast in C.I. moulds . 12 cubes were tested at 28 days curing of various proportions of fly ash wise 0 %, 10 %, 20 %, and 30 %.

7.4 APPARATUS:-

1. Concrete Compression test :-

Fig: 11 Compression testing machine

7.5 TESTING OF CUBES FOR COMPRESSIVE STRENGTH :-

Fig: 12 testing of cubes

After 28 days of curing the cubes were removed from the curing tank and tested for compressive strength.

The testing was done with the cast face parallel to the axis of loading at the rate of 140Kg/cm2/minute as per IS: 516-1959114.

8. EXPERIMENTAL RESULTS :-

- At a w/c ratio of 0.40 all mixes show superior strength to the control sample; higher replacement levels of fly ash result in better early and ultimate strengths according to the w/c ratio.

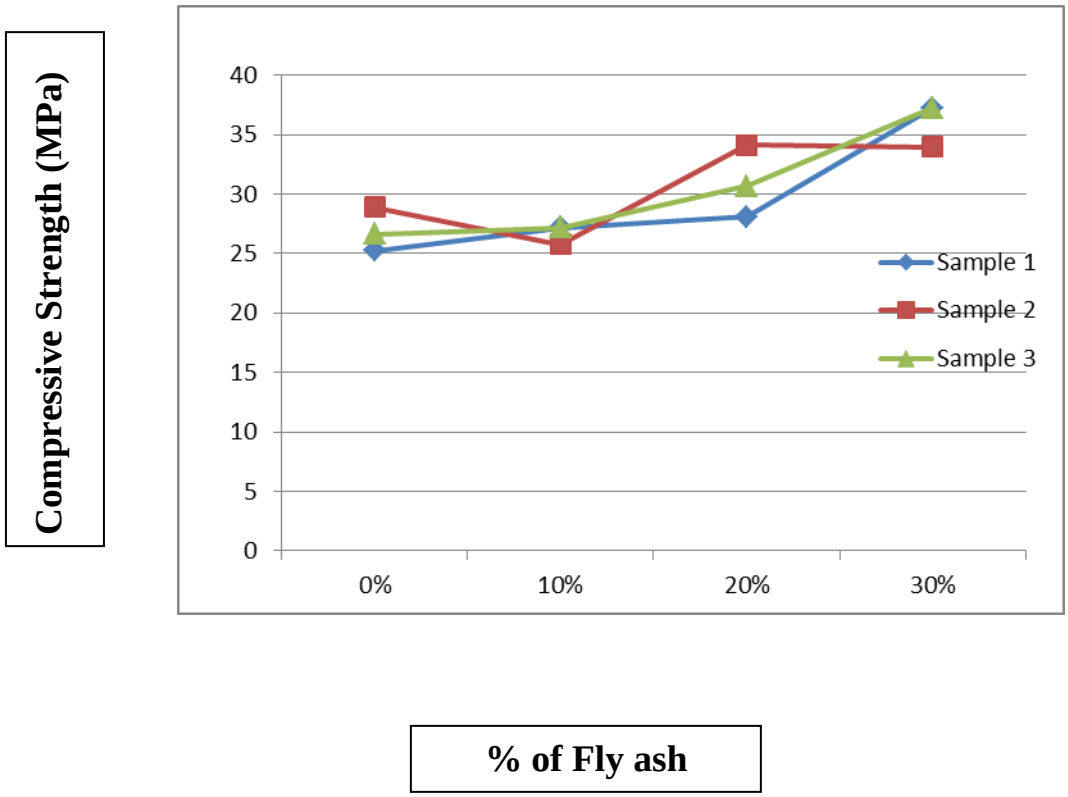
- 30% fly ash mixes show identical performance during the duration of the testing with a maximum strength of 37.24 N/mm^2 at 28 days.

- 10% fly ash mixes shows lower early strengths compared to 30%fly ash and 20%fly ash concrete after 28 day.

- 30% fly ash mixes shows highest compressive Strength after 28 days of 37.24 N/ mm^2.

TABLE 4:

Mix. FLY ASH%	No of specimen	w/c ratio	Compressive Strength (MPa)	Avg. Comp. Strength
0 %	1	0.40	25.24	25.62
	2	0.40	28.88	
	3	0.40	26.62	
10 %	1	0.40	27.20	26.72
	2	0.40	25.77	
	3	0.40	27.20	
20 %	1	0.40	28.08	30.95
	2	0.40	34.13	
	3	0.40	30.66	
30 %	1	0.40	37.24	36.14
	2	0.40	33.95	
	3	0.40	37.24	



Sample -1 = 10% Fly ash replace

Sample-2 = 20% Fly ash replace

Sample-3 = 30% Fly ash replace

9. CONCLUSION:-

- **Compression test confirm that at the same w/c ratio, compressive strength of concrete according to the replacement level of cement with FLY ASH.**
- **Experimental results show that 10%FLY ASH has lower strength after 28 days than 20%and 30%, 30% FLY ASH gain higher compressive strength then other.**
- **As in table, we can clearly see that by replacing cement with 30% of FLY ASH, compressive strength is increased about 10.52 %.**

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IS CODE:

IS: 10262-1982 RECOMMENDED GUIDELINES FOR CONCRETE MIX DESIGN

IS: 3812(Part 1):2003 PULVERISED FUEL ASH—SPECIFICATION. (For use as pozzolana in cement, cement mortar and Concrete).

IS:3812(Part 2):2003 PULVERISED FUEL ASH—SPECIFICATION.(for use As admixture in cement mortar and concrete).