International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 12 | Dec-2017 www.irjet.net p-ISSN: 2395-0072

DURABILITY AND STRENGTH CHARACTERSTICS OF BOTTOM ASH CONCRETE

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Abstract - *Concrete is a widely used man made construction material in all Civil Engineering structures ever since its acceptance as a construction material. Researchers are trying to improve its quality, strength and durability against adverse conditions.*

Fly ash is the by-product of the combustion of coal in thermal plants. Fly ash was identified as a 'pozzolan'and this has lead to the use of Fly ash in production of concrete which improves many qualities of concrete. Fly ash can be used as a admixture or as replacement of cement. The use of Fly ash makes the concrete less permeable. The improvement of the strength of Concrete is not only the consequence of its pozzalonic properties but also of the ability of the very small Fly ash particles to fit in between the cement particles. Fly ash also affects the properties of the concrete by improving workability, reducing segregation, bleeding and lowering heat of hydration.

***Key Words*: High Volume Fly ash Concrete (HVFC), Pozzolon, Super Plasticizers, Smith's method and Canon's method.**

1. INTRODUCTION

1.1. General.

The enormous growth in human population of the world is being sustained by agricultural revolution and rapid industrialization. As a result, it reveals us that there is an abundant need of low cost materials such as Portland cement concrete which are being globally satisfying the infrastructure need of Hi-tech environment. Very soon India will be one country, which adopts concrete for a wide verity of structures including buildings, long span structures such as cooling towers and chimneys.

Today the concrete industry plays a vital role and is the huge consumers of natural resources like water, sand and gravel. The ten billion concrete industries is currently consuming natural aggregates at the rate of approximately eight billion tonnes. The world consumption of Portland cement has raised from less than two billions of 1880 to 1.3 billion tonnes in 1996.Besides other raw materials each ton of Portland cement requires approximately 1.5 tonnes of limestone and considerable amounts of fossil fuel and electrical energy. This is also accompanied by the release of approximately 1 ton of Co_2 for the production of each ton of Portland cement clinker. So, Co_2 is the main environmental pollutant from cement industry.

1.2 Fly ash Production.

India has recorded over 50-fold increase in the generation of electricity during the last five decades .The Hydro-Thermal mix was 60:40 in the seventies and it is now 18:79, which means that more coal based thermal power stations have been installed. Coal is the primary source of fuel and its combustion results in a residue known as ash. The quantum of ash generated directly linked with the quantity and quality of coal fired and percentage of ash it contains. The following Flow Chart Shows Typical Production of Fly ash.

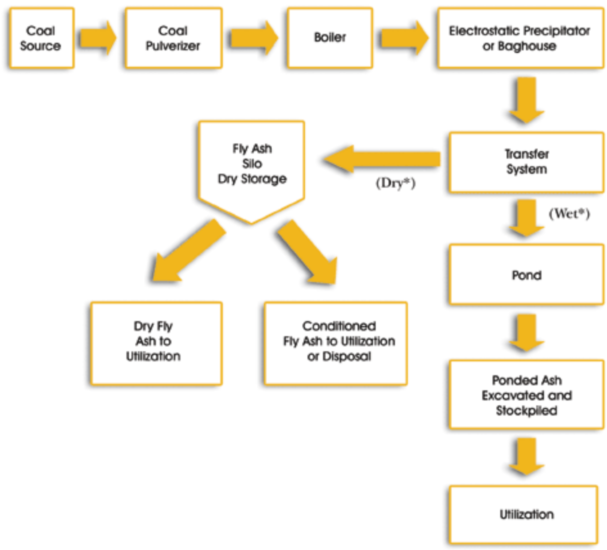

Fig.1 A Flow Chart of Fly ash Production

Indian coal contains high ash content as much as 45.36% in the coal mined from Singareni coalfields. Due to high ash content in coal, the ash produced in Indian thermal power stations is also high. It is estimated that typical 200MW power station produce 50-60 MT of ash per hour. While it is only 7-8 MT of ash produced in developed countries.

1.3 Fly ash Utilization.

The problem of Fly ash utilization is not confined to India alone but is being experienced all over the world, however this problem is particularly acute in countries like in India where utilization of Fly ash is not received much attention. The degree of its utilization varies among different countries. In India, the present rate of utilization is only about 9 -10 percent, which is about world average of about 16 percent.

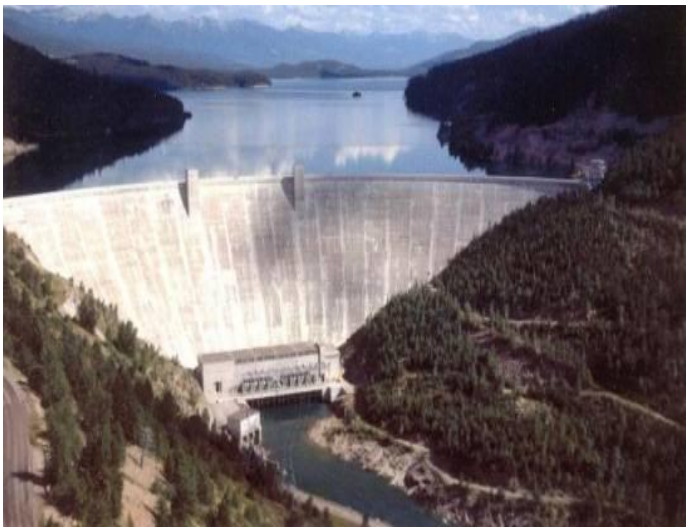

Fig 2 HUNGRY HORSE DAM

1.4 Benefits of using Fly ash:

A research investigation over the last three decades has indicated three major benefits utilizing Fly ash.

1.4.1 Economical Benefits:

Cement production requires large quantities of energy replacement of cement results in energy savings since Fly ash does not need additional energy input before use. Larger the quantity of Fly ash replacement, the energy saved is proportionately more. Thermodynamic computations indicate that one-ton of cement replacement saves at least 6000 MG of energy, which is equivalent to a barrel of oil or 0.25 tonnes of coal.

1.5 High Volume Fly ash Concrete(HVFC):

In commercial practice, the dosage of Fly ash is limited to 15-20% by mass of the total cementitious material. Usually, this amount has a beneficial effect on the workability and cost economy of concrete but it may not be enough to sufficiently improve the durability to sulphate attack, alkali-silica expansion, and thermal cracking. For this purpose, larger amounts of Fly ash are being used.

Fig 3 TYPICAL CONSTRUCTION OF ROAD USING HVFA CONCRETE

Advantages of HVFC:

- Low permeability and high durability.
- Prevents thermal cracking. Reduction in shrinkage cracking.
- High long term compressive and Flexural Strength.
- High Resistance to Sulphate Attack.
- High resistance to Alkali Aggregate reaction.

2. FLY ASH –AN INGREDIENT OF CONCRETE

Fly ash is a by-product of pulverized coal in thermal power plants. The electrostatic precipitators remove the combustion gases before they are discharged into the atmosphere.

2.2 Features of Fly ash

- Spherical shape: Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures.
- Ball bearing effect: The "ball-bearing" effect of Fly ash particles creates a lubricating action when concrete is in its plastic state.
- Higher Strength: Fly ash continues to combine with free lime, increasing structural strength over time.
- Decreased Permeability: Increased density and long-term pozzolanic action of Fly ash, which ties

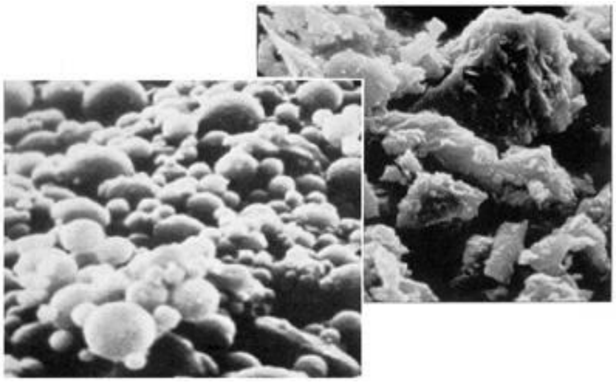

Fig 4 Typical Micro structures of Fly ash and Cement

2.3 Factors Affecting Pozzolanic Reactivity Of Fly ashes

The reactivity of Fly ash and other pozzolanes with lime or cement is affected by inherent characteristics of the Fly ash such as chemical and mineralogical composition, morphology, fineness and the amount of glass phase. External factors, such as thermal treatments and the addition of admixtures also affect pozzolanic reactivity.

2.4Mix Design:

Mix Design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible.

2.5 Methods of designing Fly ash concrete Mixes:

Experimental Investigations by Smith, Cannon, Dhir et al and Ghosh clearly indicate that it is Possible to design Flyash Concrete mixes of comparable strength to Portland Cement Concrete covering a strength range up to 50N/mm^2 at 28 days.

2.5.1. Brief Description Of Smith's Method:

A rational method of mix design by which trial mixes of Flyash concretes could be produced with an accuracy equivalent to that obtained when applying to the design of orthodox concretes, has been formulated by smith.

2.5.2. Brief Description Of Cannon's Method:

The procedure for proportioning Fly ash concrete mixes has been evolved from extensive investigations by the Tennesse Valley Authority; as a result of using Fly ash in all classes of Concrete for over a decade. However, the method is intended only for proportioning Cement and Fly ash and does not deal with the proportioning aggregates or the determination of basic water requirements.

2.5.3. Brief Description of Dhir's Method:

Dhir's method of mix design is useful for Fly ashes which are of finer variety with percentage retained on 45 micron sieve not greater than 35 percent

2.5.4. Brief Description Of Ram.S.Ghosh Method:

The method is described for portioning Fly ash concrete to produce similar compressive strengths as a normal Portland cement concrete at 3, 7,28 and 90 days. The method is primarily based on the Abrams law relating compressive strength and water cement ratio. Curves are also present at, for estimating the most economical Fly ash to the cement ratio for a particular strength and cost of Fly ash. Two mixtures namely M20 and M30 are designed for normal concrete (0% Fly ash) and Fly ash concrete (20%, 40%, 60%and 80%). The mix design is done based on "proportioning of concrete mixtures incorporating Fly ash by RAM S GHOSH.

Abram established that the strength of a fully compacted concrete is inversely proportional to the water cement ratio. The relation is given

$$f_c' = k_1/k_2^{\,(w/c)} \qquad \text{-----------(1)}$$

where,

f'_c is the compressive strength of concrete

W/c is the water-cement ratio,

k_1& k_2 are empirical constants.

In case of Fly ash concrete, the water cement ratio (w/c) becomes the ratio of the weight of water to the weight of the cementing material (cement and Fly ash mixture) w/(c+f). Eq. (1) becomes

$$f_c' = k_1/k_2^{\,(w/(c+f))} \qquad \text{-----------(2)}$$

Where k_1& k_2 are empirical constants

For the case of calculation, these two power function can be combined into an arithmetic function and the following relationship between w/c and w/(c+f) can be established.

$$W/(c+f) = M + N\,(w/c) \qquad \text{-----------(3)}$$

Using the test results, values for k_1& k_2 and subsequently M&N, were calculated for different Fly ash cement ratio (f/c) at selected ages.

3. EXPERIMENTAL INVESTIGATIONS

General: The experiments have been conducted with Fly ash from Vijayawada thermal power station, Cement of 53 Grade Fine Aggregate as river sand and Crushed aggregates maximum size of 20mm as coarse aggregates are used.

The tests Conducted on each are as given below: -

1) Cement
   - Fineness by sieving

- Initial and final setting times by Vicat apparatus
- Specific gravity

2) Fly ash
- Specific gravity

3) Fine aggregate
- Sieve analysis and grading
- Specific gravity

4) Course aggregate
- Specific gravity

3.1 CEMENT -

3.1.1 Fineness

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers greater surface area for hydration and hence the faster and greater the development of strength. Increase in fineness of cement is also found to increase the drying shrinkage of concrete. Fineness of cement is tested either by sieving or by determination of specific surface by Air-Permeability apparatus.

100gms of weight cement is placed on standard 90micron IS sieve. Any air set bumps in the cement sample is broken by fingers. The sample is continuously sieved in vertical and circular motions for a period of 15 minutes. The residue left on the sieve is weighed. As per IS codes (IS:269-1989 and IS:4031-1988) the percentage residue should not exceed 10% weight taken on the 90 micron sieve is 100gms. Weight retained on 90 micron after sieving = 8.5 gms (<10%).

Fineness percent = (weight of residue in gms/100)*100
Fineness percent =8.5 gms.

3.1.2 Initial & Final setting time

(IS 269-1989, IS: 112-1989,IS: 12269-1989IS: 4031-1988 part 5)

In actual construction dealing with cement mortar or concrete, certain time is required for mixing, transporting and placing. During this time cement paste, mortar or concrete should be on plastic condition. The time elapsed between the moments the water is added to the cement to the time the paste starts losing its plasticity. This time should not be more than 10 hours, which is referred to as final setting time. Initial setting time should not be less than 30 minutes.

Procedure –

A neat cement paste is prepared by gauging 300 grams of cement material (a mixture of Fly ash and cement) in proportion with 0.85 time times the water required to give a paste of standard consistency. (It is defined as the c consistency which will permit the vicat plunger to penetrate to a point 5 to 7 mm from the bottom of the vicat mould). Potable water is used in preparing the paste. A stopwatch is started at the instance when water is added to the cement paste in the mould placed on a nonporous plate. The mould is filled completely and surface of the paste is made level by striking off. The cement block thus prepared in the mould is the test block. The needle of Vicat apparatus is replaced by an annular attachment. The period elapsed between the time when water is added to the cement and the time at which the needle makes an impression on the surface of test block while the attachment fails to do so shall be the final setting time

Initial setting time for the sample is 38 min

Final setting time for the sample is 425 min

3.1.3. Specific Gravity

Specific Gravity is defined as the ratio between weight of a given volume of material and weight of an equal volume of material and weight of an equal volume of water. To determine the specific gravity of cement, kerosene is used which doesn't react with cement.

A clean, dry specific gravity bottle with stopper (W1), The specific gravity bottle with cement sample at least half of the bottle is filled and weighed with stoppers (W5). The specific gravity bottle is filled with cement and kerosene and weighed placing the stoppers (W4). After weighing the bottle, the bottle is cleaned and dried. Then the bottle is filled with fresh kerosene and weighed with stopper (W3) kerosene is removed and filled with water and weighed with stopper (W2).

Specific Gravity of cement $S_c = \frac{W5\ (W3-W1)}{(W3+W5-W4)(W2-W1)}$

$= 3.04$

3.2 Fly ash –

3.2.1 Specific Gravity

Specific gravity of Fly ash is done in the same way as that of cement Its Value is equal to 1.970.

3.2.2 Fineness

Fineness of Fly ash is found out in the same way as that of cement. Its value is equal to 2.2%.

3.3 Fine Aggregate -

3.3.1 Sieve Analysis

Fineness modulus is only a numerical index of fineness, giving some idea about the main size of the particles in the entire body of concrete. Determination of fineness modulus is considered a method of standardization of grading of aggregates i.e. the main object of finding Fineness modulus is to grade the given aggregate for the most economical mix and workability with minimum quality of cement. It is obtained by sieving known weight of given aggregate in a set of standard sieves and by adding the percent weight of material retained on all sieves and dividing by the total percent of hundred.1 Kg of sand is taken and sieved in sieves of No's 480,240,120,30and 15 keeping 480 at top and 15 at bottom. The set is fixed in the sieve-shaking machine with the pen at the bottom and cover at the top and sieved for not less than ten minutes the weight retained on each sieve is weighed The fineness modulus of fine aggregate is 2.71. Based on the table for a grading limit of fine aggregate IS-383-1970, the fine aggregate is under zone one.

3.3.2 Specific Gravity of Fine Aggregate

The specific gravity of fine aggregate can be determined in the following way.

The weight of empty specific gravity measuring jar is found to be W1 .The weight of jar and 150 ml sand is noted W2. The container of 150 ml sand and 100 ml of water is weighed W3. The mix of sand and water is removed and filled with water up to the top surface of the jar W4.

The specific gravity of fine aggregate = Weigh of solids / volume of solids = 2.65

3.4 coarse Aggregate -

3.4.1 Specific gravity

The specific gravity of an aggregate is generally required for a calculation in connection with cement concrete design work for determination of moisture content and for calculation of volume of concrete. The specific gravity also gives information of the quality and properties of aggregates. Specific gravity is the weight of aggregate relative to the weight of equal volume of water.

The weight of empty cylinder W1 is taken porous aggregate is taken nearly to half of the container and weighed W2.Water is filled in the container up to the level of porous aggregate so that all void space in the aggregate is filled with water. The total weight is W3.

The container is filled with W4 after removing from the porous aggregate and the water is filled up to the mark after which the porous aggregate is filled.

Specific gravity = (W2-W1)/((W4-W1)-(W3-W2)) = 2.67.

3.5. Mix Design Procedure –

The method is described for portioning Fly ash concrete to produce similar compressive strengths as a normal Portland cement concrete at 3, 7,28 and 90 days. The method is primarily based on the Abrams law relating compressive strength and water cement ratio. Curves are also present at, for estimating the most economical Fly ash to the cement ratio for a particular strength and cost of Fly ash.

Two mixtures namely M20 and M30 are designed for normal concrete (0% Fly ash) and Fly ash concrete (20%, 40%, 60%and 80%). The mix design is done based on "proportioning of concrete mixtures incorporating Fly ash by RAM S GHOSH.

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where

f'_c is the compressive strength of concrete

w/c is the water-cement ratio,

k_1& k_2 are empirical constants.

In case of Fly ash concrete, the water cement ratio (w/c) becomes the ratio of the weight of water to the weight of the cementing material (cement and Fly ash mixture) w/(c+f). Eq. (1) becomes

$f_c' = k_1 / k_2^{(w/(c+f))}$ -----------(2)

Where

k_1& k_2 are empirical constants

For the case of calculation, these two power function can be combined into an arithmetic function and the following relationship between w/c and w/(c+f) can be established.

W/(c+f)=M+N (w/c) -----------(3)

Using the test results, values for k^1 & k^2 and subsequently M&N, were calculated for different Fly ash cement ratio (f/c) at selected ages.

Example: calculation for determining the proportions of the ingredients in Fly ash concrete.

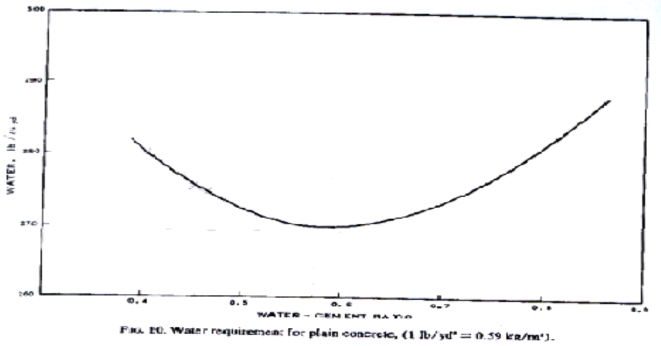


Fig .5 Water Requirement for plain concrete (1lb/yd^3 = 0.59Kg/m^3)

The target mean strength

$f'_c = f_c + t \times s$

$= 20+1.65 \times 4.6$

$= 27.6\ N/mm^2$

= 4000 psi.

The water cement ratio for 4000 Psi (27.6 Mpa) plain concrete at 28 days can be determine by substituting the constants from table 1 into Eq. 1 as follows.

Age-Days

F/C	K1	K2	K1	K2	K1	K2	K1	K2
0.00	13614	21	14292	15	16608	12	18315	10
0.20	14047	28	14689	20	17112	14	19584	10
0.40	13152	35	13814	23	18034	17	20850	13
0.60	11904	43	14047	35	18205	22	17255	11
0.80	11153	54	13360	42	16600	20	16244	10
1.00	13317	112	15343	78	21602	44	18802	16

Table .1 Values of K_1 and K_2

$f_c' = k_1/k_2^{(W/C)}$

W/c = 0.57

At a w/c ratio of 0.57, the water requirement from fig 5 is $271 lb/yd^3$ ($160.6 kg/m^3$)

Therefore cement content of this mix is = 160.6/0.57

= $282 kg/m^3$

Maximum size of aggregate	Bulk volume of oven-dry rodded coarse aggregate per unit volume of concrete for fineness modulus of fine aggregate			
	2.40	2.60	2.80.	3.00
10.00	0.50	0.48	0.46	0.44
12.50	0.59	0.57	0.55	0.53
20.00	0.66	0.64	0.62	0.60
25.00	0.71	0.69	0.67	0.65
40.00	0.75	0.73	0.71	0.70
50.00	0.78	0.76	0.74	0.72
70.00	0.82	0.80	0.78	0.75
150.00	0.87	0.85	0.83	0.81

Table2. Bulk volume of dry rodded coarse aggregate per unit volume of concrete as given by ACI

From Table 2, for 20mm coarse aggregate, for fineness modulus of 2.71, the dry rodded bulk volume of coarse is 0.63/unit volume of concrete.

Therefore the weight of coarse aggregate =0.63 X 1600

$=1008 kg/m^3$

From Table 3, the first estimate of density of fresh concrete for 20mm max size aggregate and for non entrained concrete = $2355 kg/m^3$

Maximum size of Aggregate in mm	First estimate of density (unit weight) of fresh concrete kg/m^3	
	Non-Air-entrained	Air-entrained
10	2285	2192
12.5	2315	2235
20	2355	2280
25	2375	2315
40	2420	2355
50	2445	2375
70	2465	2400
150	2505	2435

Table.3, First estimate of density (unit weight) of fresh concrete as

Given by ACI 211.1-91

Hence the weight of water = $160.6 lt/m^3$

Weight of Cement = $282 kg/m^3$

Weight of Coarse aggregate = $1008 kg/m^3$

Weight of Fine Aggregate = 2355-(160.6+282+1008)

= $904.4 kg/m^3$

M20 with Fly ash content (P = 0.2)

P = F/C =Weight of Fly ash / weight of cement

Percentage of Fly ash = (F/C)/ (1+F/C) X 100

0.2(F/C) = 0.2 / (1+0.2)

= 16.7 % of Fly ash.

$f_c' = K_1/ K_2^{(W/C+F)}$

$4000 = 17112 / 14^{(W/C+F)}$ (Values of K_1 and K_2 are from table)

Therefore, (W/C+F) = 0.55

But (W/C+F) = M+N (W/C) (M and N values from table)

= 0.0113 + (0.9416 X0.57)

=0.548 = 0.55

Age-Days

F/C	3 M	3 N	7 M	7 N	28 M	28 N	90 M	90 N
0.2	0.0094	0.913	0.0091	0.904	0.0113	0.941	0.0291	1.000
0.4	-0.009	0.856	-0.010	0.863	0.0291	0.877	0.0505	0.897
0.6	-0.035	0.809	-0.005	0.761	0.0297	0.803	-0.025	0.960
0.8	-0.050	0.763	-0.018	0.724	-0.0002	0.829	-0.052	1.000
1.0	-0.004	0.645	0.0163	0.621	0.0695	0.656	0.009	0.830

Table: 4 values of M and N

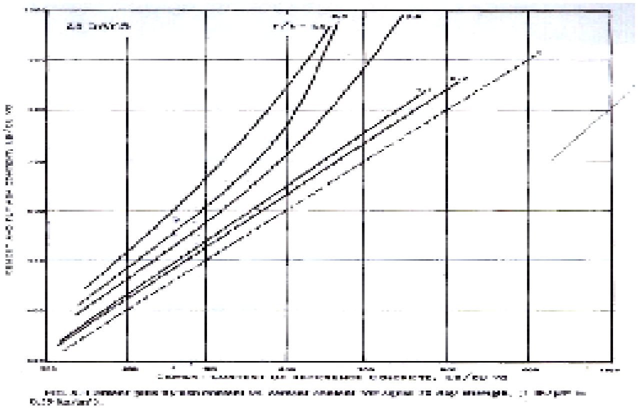


Fig.6 **Cement plus Fly ash content Vs Cement content for equal 28 Days Strength,(1 lb/yd^3 = 0.59 Kg/m^3).**

From fig.6, For F/ C = 0.2 and corresponding to 478 lb of cement , Cement and Fly ash content is 490 lb / yd ^{3} (289 Kg / m^3)

The water required for Fly ash concrete =490 (w/(c+f))
=490 x 0.55
=270 lb / yd ^{3}
=159.35 Kg / m^3

As percentage of Fly ash = 16.7%
Weight of Fly ash =289 x0.167
=48.26 Kg / m^3
Cement content = 289 – 48.26
=240.74 Kg / m^3
Weight of coarse aggregate =0.63 x1600
= 1008 Kg / m^3

Therefore,
Weight of water =159.35 lt/m^3
Weight of cement =240.74 Kg / m^3
Weight of Fly ash =48.26 Kg / m^3
Weight of coarse aggregate =1008 Kg / m^3
Weight of fine aggregate =2355-(48.26+240.74+159.35+1008)
=898.65 Kg

In the similar manner, p=0.4, 0.6, 0.8 is calculated. For another mix M30 and for p=0,0.2,0.4,0.6,0.8 the weight of Fly ash, cement, water, fine aggregate, coarse aggregate are calculated in the above mentioned way. Weight of each of the ingredient thus arrived at is tabulated in table.

Grade	F/C Ratio	Water / (C+F) Ratio	Water Content Lts /m^3	Fly ash Kg / m3	Cement Kg / m3	Fine Agg. Kg / m3	Coarse Agg. Kg / m3
M20	0.00	0.57	160.60	0.00	282.00	904.40	1008.00
	0.20	0.55	159.35	48.26	240.74	898.65	1008.00
	0.40	0.53	160.40	84.10	211.00	898.50	1008.00
	0.60	0.49	153.22	117.30	195.40	881.08	1008.00
	0.80	0.47	157.67	148.00	185.35	851.98	1008.00
M30	0.00	0.45	162.84	0.00	361.87	822.29	1008.00
	0.20	0.44	167.44	63.55	317.00	779.01	1008.00
	0.40	0.42	163.85	110.15	276.35	776.65	1008.00
	0.60	0.39	166.10	159.30	265.50	736.10	1008.00
	0.80	0.37	189.26	223.26	284.14	630.34	1008.00

Table 5 Mix Proportions

The moulds are specially made for these experiment investigations. Metal moulds of cast iron, 3mm thick are made in such a manner to facilitate the removal of moulded specimen without damage. The height the mould and distance between the opposite faces are of specified size ± 0.2mm the interior faces of the mould, are plain surface at a permissible variation of 0.03mm.

The base plate is of such dimensions as to support the mould during the filling without linkage and it is preferably attached to the mould by screws.

3.5 Flexural Test

3.5.1 Description of Equipment

The test is currently under consideration for inclusion as an ASTM standard. The Equipment is shown in figure.. A 500mmX100mmX100mm size of specimen made by standard compressive rectangular mould. The mould should be of metal preferably steel or cast iron and the metal should be of sufficient thickness to prevent spreading or wrapping.

The mould should be constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimens without damage.

3.5.2 Procedure for Flexural Test

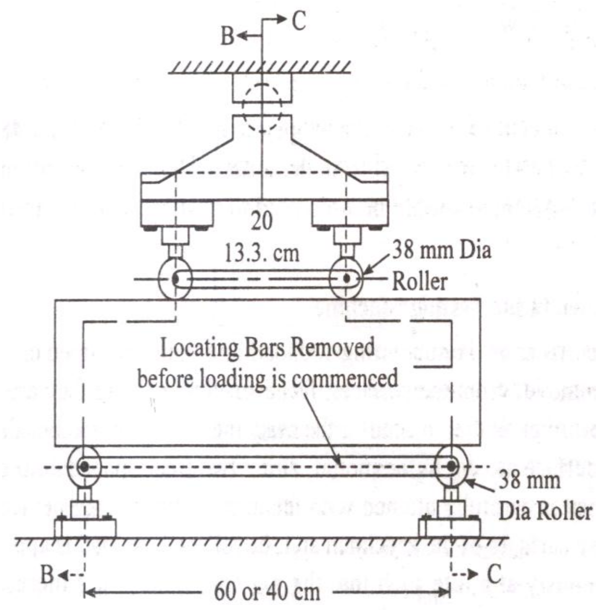


Fig. 7 **Arrangement for Loading of Flexural**

Test Specimen

The bed of the testing Machine should be provide with two steel rollers, 38mm diameter, on which the specimen is to be supported and these rollers should be mounted that the distance from center to center 400mm for 100mm specimens the load is applied through two similar rollers mounted at the third points of the supporting span i.e., space at 133mm distance center to center.

The modulus of rupture is given by

f_b = PL / (bd^2) for a > 133 mm

f_b = 3 Pa / (bd^2) for 133 > a > 110 mm

If a < 110 mm,the results are discarded.

Where,

P=maximum total load on the specimen

L=Length of the specimen

b=Width of the specimen

d=Depth of the specimen

a=Distance of the line of fracture and the nearest support measured on the center line of the tension side.

3.6 Results

The Cube specimens are tested for compressive strength at 7 days and 28 days for two mixes M20 and M30 and the results obtained are tabulated below.

Grade	F/C RATIO	Compressive Cube Strength (N/mm^2) at Ages (days)	
		7 days	28 days
M20	0.00	16.90	28.80
	0.20	14.70	29.30
	0.40	13.10	29.80
	0.60	11.30	27.30
	0.80	9.80	22.90
M30	0.00	22.90	41.23
	0.20	22.70	41.50
	0.40	21.50	39.20
	0.60	20.40	35.80
	0.80	18.10	33.35

Table 6 Values of compressive strength of concrete with different percentages of Fly ash at different ages.

The flexural strength of normal Concrete and Fly ash concrete specimens of two mixes M20 and M30 and at different ages are found and tabulated below.

Grade	F/C Ratio	Flexural Strength (N/mm^2) at Ages (days)	
		7 days	28 days
M20	0.00	4.10	5.73
	0.20	3.20	5.80
	0.40	3.06	5.70
	0.60	2.70	5.63
	0.80	2.40	5.36
M30	0.00	4.70	6.43
	0.20	4.30	6.50
	0.40	3.50	6.36
	0.60	3.10	6.33
	0.80	2.80	6.10

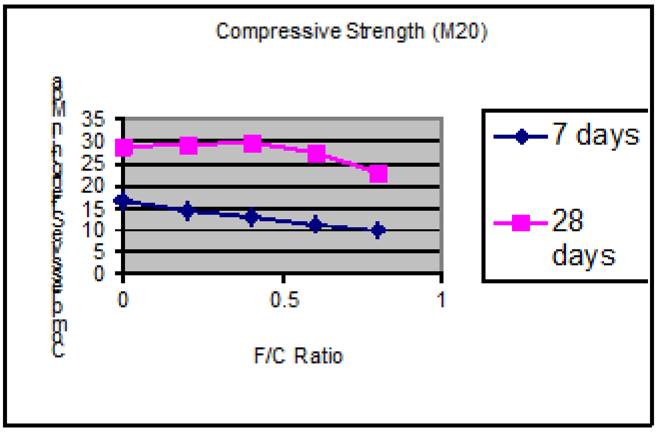
Table 7 Values of Flexural strength of concrete with different percentages of Fly ash at different ages.

3.7 Discussions

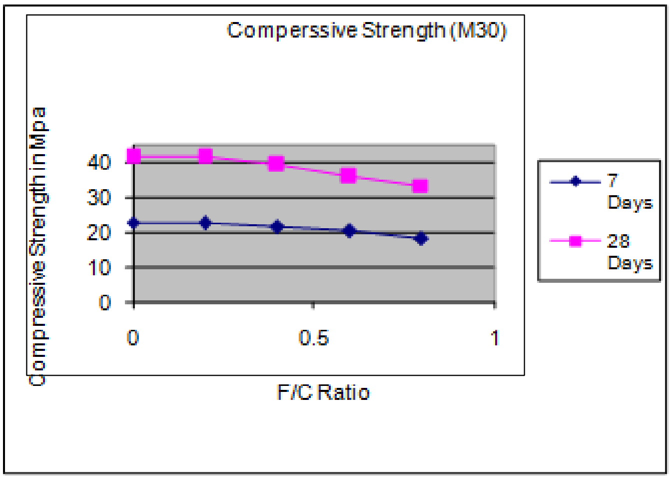
Fig: 8 TYPICAL FRACTURE PATTERN OF CUBE SPECIMENS DUE TO COMPRESSION LOAD

The failure of concrete cube is shown in figure. The failure of Fly ash concrete is as that of normal concrete. The value of compressive strength may be much higher for an aggregate of superior quality.The graphs 3 & 4 are plotted for Flexural strength Vs Age for two grades M20 and M30 and for all percentages of normal and Fly ash concretes.

Graph 1 Indicates the Compressive strength of M20 at 7 days and 28 days with different percentage of Fly ash (0%, 20%, 40%, 60%, 80%). Graph 2 indicates the Compressive strength of M30 at 7 days and 28 days with different percentage of Fly ash (0%, 20%, 40%, 60%, 80%). The compressive strengths of cube specimens of the two grades showed relatively lower value at early ages (7 Days) for Fly ash concretes (20%, 40%, 60%, 80%) than for normal concretes of all mixes.



Graph 1, Compressive strength for M20 concrete



Graph 2, Compressive strength for M30 concrete

Fig: 9 TYPICAL FRACTURE PATTERN OF BEAM SPECIMENS DUE TO FLEXURAL LOAD (M20, 0% Flyash)

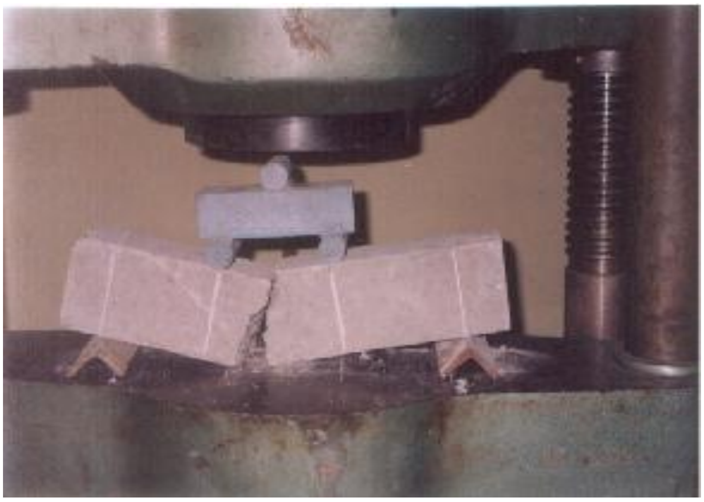


Fig:10 TYPICAL FRACTURE PATTERN OF BEAM SPECIMENS DUE TO FLEXURAL LOAD (M30, 0% Fly ash)

CONCLUSIONS –

Based on the study conducted on M20 and M30 grade concrete with different percentages of Fly ash at different ages the following conclusions are drawn:

- **General Conclusions**
  - At early ages, Fly ash concrete gave lower strength as compared to normal concretes.
  - Using Fly ash is Eco-friendly and Economical in Construction of Structures.
- **Specific Conclusions**
  - The compressive strengths of cube specimens of the two grades showed relatively lower value at early ages (7 Days) for Fly ash concretes (20%, 40%, 60%, 80%) than for normal concretes for all mixes.
  - The 28 Days compressive strength of Fly ash concretes (20%, 40%) are nearly equal to normal concretes. But the Fly ash concretes of (60%, 80%) gives lower value than normal concretes. According to the present investigations, the Mix Design may not give good results for High Volume Fly ash Concretes.
  - The flexural strength of the beam specimen of the two grades showed relatively lower value at early ages (7 days), for Fly ash concrete (20%, 40%, 60%, 80%) than normal concretes for all mixes.
  - The 28 Days flexural strength of Fly ash concretes are nearly equal to that of normal concretes

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