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A NOVEL WAY OF STRENGTHING CONCRETE WITH HIGH VOLUME FLY ASH CONCRETE

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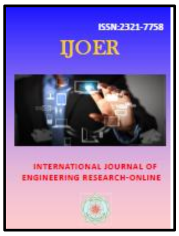

ABSTRACT

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.

Concrete has several advantages like high compressive strength, stiffness and low thermal and electrical conductivity, low combustibility and toxicity. It possesses remarkable qualities of resilience, flexibility and ability to redistribute the stress. But it has some serious deficiencies like poor Tensile Strength, poor impact strength and brittleness etc., and makes it unsuitable for certain applications. 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 an 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 affect the properties of the concrete by improving workability, reducing segregation, bleeding and lowering heat of hydration. High Volume Fly ash Concrete (HVFC) consists more than 50% of Fly ash by weight in the Cement. This is an approach to maximize the Fly ash input in the concrete .The fall of strength belated rheology on account of Fly ash are counteracted through efficient control of water-cement ratio and effective role of super plasticizers. The HVFC so developed has all the attributes of high performance concrete .Viz, excellent mechanical properties, Low permeability and superior durability because of high input of Fly ash, the autogenous temperature is very much under control. In the present work an attempt has been made to study the behaviour of high volume Fly ash concrete in compression and flexure. In the investigations, M20 and M30 Grade concrete mixes are designed at different percentages of Fly ash (0%, 20%, 40%, 60%, 80%) and tests are conducted for Compressive and Flexural Strengths at 7 and 28 days. Then the results are compared with normal concrete. The study reveals that use of HVFC has a beneficial effect on the workability, the cost economy of concrete and Durability of the structure. 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.

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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 are currently consuming natural aggregates at the rate of approximately eight billion tones. The world consumption of Portland cement has risen from less than two billion of 1880 to 1.3 billion tones in 1996.Besides other raw materials each ton of Portland cement requires approximately 1.5 tons of limestone and considerable amounts of fossil fuel and electrical energy. This is also accompanied by the release of approximately 1 ton of Co2 for the production of each ton of Portland cement clinker. So, Co2 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. The analysis on Fly ash production from coal based thermal power stations indicates that 82 power stations produce about 100 million tons of Fly ash per year and this production may increase every year. 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. India with dependence on high ash coal for about 65% of its total power generation capacity has been a very large generation of Fly ash, exceeding 100 million tones. Hence the disposal of the Fly ash should be eco-friendly and disposal has been a major issue before Indian industry. Fly ash utilization program has been made mandatory. Fly ash is most widely used as a pozzolanic material all over the world. Fly ash is first used in large scale in the construction of *HUNGRY HORSE DAM* IN America (1948) in the approximate amount of 30% by weight of cement. Later on, it is used in Canyon, Ferry Dams etc. In India, Fly ash is used in Rihand dam construction replacing cement up to about 15%. Over a period of time and more particularly, the last decade, there has been an increasing appreciation of Fly ash being a resource rather than waste. This has given impetus to Fly ash activities across the board, irrespective of level and nature of technology and its area of applications.

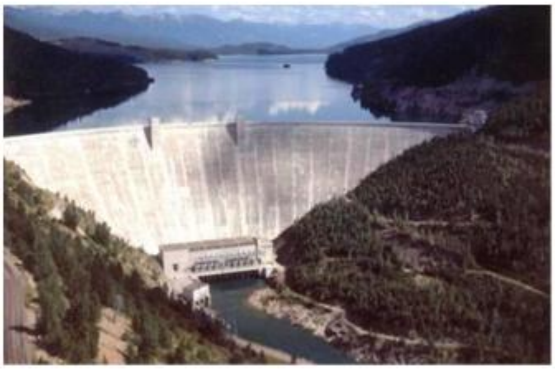


Fig: 1 HUNGRY HORSE DAM

1.4 Characteristics of Fly ash: The Indian Fly ash can be divided into two classes depending on the combustion parameters of the boilers and the behavioral effect of the resultant Fly ash on the end product. Low temperature Fly ash produced at combustion temperature of 8000C-8500C. These ashes are more reactive at early ages and hence are preferred for precasting building materials such as brick and block works. High temperature Fly ash produced at combustion temperature of 10000 c-14000 c. The pozzolanic reaction is slow in these ashes and they kept accelerated with age. These types of ashes are more suitable for cement and concrete industries.

1.5 High Volume Fly ash Concrete : 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.

Malhotra has achieved the distinction of developing HVFC technology consisting of about 55% Fly ash by weight in the cementitious system at Canada Center for Mineral and Energy Technology (CANMET), Canada. HVFC is an approach to maximize the Fly ash input in concrete. The first batch of HVFC was developed in 1986. From theoretical considerations and practical experience Malhotra and Mehta have determined that with 50% or more cement replacement by Fly ash, it is possible to produce sustainable, high-performance concrete mixtures that show high workability, high ultimate strength, and high durability .The fall of strength and belated rheology on account of Fly ash are counteracted through efficient control of water-cement ratio and effective role of superplasticizers. The HVFC so developed has all the attributes of high performance concrete viz., excellent mechanical properties, low permeability and superior durability. Because of high input of Fly ash the autogenous temperature is very much controlled in one of the field level studies it was recorded the temperature raise for HVFC was 350 C against 650C for control of concrete. This is an indirect measure to indicate higher durability for HVFC in comparison to control concrete, because the rise in temperature has a direct manifestation on shrinkage and tensile stresses and in turn, on the soundness of the concrete. The study on HVFC indicates that the Fly ash is added to OPC without commensurate input of gypsum to the former. The strengths are derived by controlling the water/cement ratio through the help of chemical admixtures. However, it is reported that HVFC yields to surface erosion with rampant exposure to de-icing chemicals. It is desirable that HVFC be manufactured with additional gypsum input in order to engage the alumina phase of Fly ash into strength rendering mineralogy. This would not only increase strength but also may improve surface hardness.

In India early 1980 Ambuja cements used HVFA concrete for laying roads at Ropar in Punjab. This has shown good results and now many organizations are using HVFA technology which is economical and eco friendly.

Fig 2: TYPICAL CONSTRUCTION OF ROAD USING HVFA CONCRETE

2. Scope of the Work

In this work, extensive experimental investigations are carried out on Fly ash concretes of different mixes (M20, M30) with different cement replacement percentages of Fly ash by weight (0%, 20%, 40%, 60%, 80%) and at different ages (7days, 28days). The tests are conducted for flexural strengths and The response of Fly ash concretes of various grades to Flexural loading. In addition to this, the compressive strengths for 7 days and 28 days with different percentages of Fly ash (0%, 20%, 40%, 60%, and 80%) for both M20 and M30 mixes are studied. Results are compared with normal concrete and for different percentages of Fly ash concretes.

3. Mix 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.

The first object is to achieve the stipulated minimum strength and durability. The Second object is to make the concrete the most economical manner.

3.1 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.

3.1.1 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. The method is based on extensive experimental investigations on concretes with Flyash from over twenty five generating stations. The mixes designed covered the normal strength range of structural concrete. The cementing efficiency method proposed by smith gives the required values of strength and placeability to the Flyash concrete mixes. In particular the strength of Flyash concrete is shown to depend only on the relative proportions of ash, cement land water. The method can be applied equally well to those concretes in which Flyash was considered as replacing sand as in those where it replaced cement.

3.1.2 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 Flyash in all classes of Concrete for over a decade. However, the method is intended only for proportioning Cement and Flyash and does not deal with the proportioning aggregates or the determination of basic water requirements. The method assumes that the quantity and gradation of the coarse aggregate is the same in comparable mixes and that the difference yield due to the large volume of cementations materials in the Flyash mix is balanced by a reduction of the sand content.

3.1.3 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

3.1.4 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

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

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

4. EXPERIMENTAL INVESTIGATIONS

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.

4.1 Materials used

1) Cement
2) Fly ash
3) Fine aggregate
4) Coarse aggregate

4.2 CEMENT

4.2.1 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.

Fineness percent =8.5 gms.

4.2.2 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. The final setting time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient fineness to resist certain pressure. Once the concrete is placed in final position, compacted and finished it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. 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.

Initial setting time for the sample is 38 min

Final setting time for the sample is 425 min

4.2.3 Strength Test: The compressive strength of hardened cement is one of the important of all the properties. Strength of cement is indirectly found on cement sand matter in specific proportions. The standard sand, confirming to IS 650 – 1991, is used for finding the strength of cemnt.555 grams of standard sand (innore sand) and 185 grams of cement (i.e., ratio of cement to sand is 1:3) are taken in a non-porous enamel tray and mixed with a trowel for one minute. Water of quantity 1/4 +3.0% of compiled weight of cement and sand is added and the three are mixed thoroughly until the mixture is of uniform color. The time of mixing should not be less than 3 minutes and not more than 4 minutes. Immediately after mixing, the mortar is compacted on a table vibrator for 2 Minutes. The compacted angle in the mould is kept at a temperature 27^0 c $\pm$ 2^0 c and at least 90% relative humidity is to be maintained for 24 hours. After 24 hours the cubes are removed from moulds and immersed fresh water 28 days and then tested.

Comp. Strength of cube = 55 N/mm^2

4.2.4 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.

Specific Gravity of cement= 3.04.

4.3 FLY ASH

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

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

4.4 Fine Aggregate

4.4.1 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.

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 I.

4.4.2 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 =2.65

4.5 COARSE AGGREGATE

4.5.1 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.

Specific gravity = 2.67.

5.MIX PROPORTION

Table 1 Mix Proportions

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	0.57	160.6	0	282	904.4	1008
	0.2	0.55	159.35	48.26	240.74	898.65	1008
	0.4	0.53	160.4	84.1	211	898.5	1008
	0.6	0.49	153.22	117.3	195.4	881.08	1008
	0.8	0.47	157.67	148	185.35	851.98	1008
M30	0	0.45	162.84	0	361.87	822.29	1008
	0.2	0.44	167.44	63.55	317	779.01	1008
	0.4	0.42	163.85	110.15	276.35	776.65	1008
	0.6	0.39	166.1	159.3	265.5	736.1	1008
	0.8	0.37	189.26	223.26	284.14	630.34	1008

6. TESTS AND RESULTS

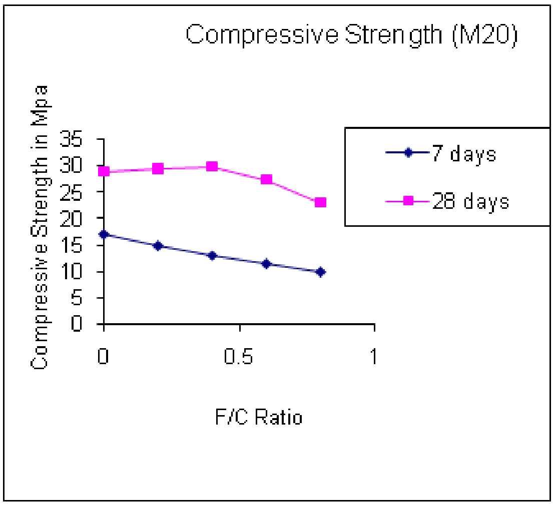
6.1 COMPRESSION TEST

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.

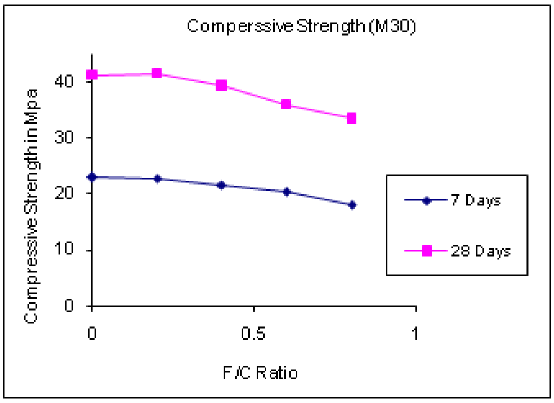
FIg: 3 TYPICAL FRACTURE PATTERN OF CUBE SPECIMENS DUE TO COMPRESSION LOAD

Table 2 Values of compressive strength of concrete with different percentages of Fly ash at different ages.

Grade	F/C RATIO	Compressive Cube Strength (N/mm^2) at Ages (days)	
		7 days	28 days
M20	0	16.9	28.8
	0.2	14.7	29.3
	0.4	13.1	29.8
	0.6	11.3	27.3
	0.8	9.8	22.9
M30	0	22.9	41.23
	0.2	22.7	41.5
	0.4	21.5	39.2
	0.6	20.4	35.8
	0.8	18.1	33.35



Graph 1: **Compressive strength for M20 concrete**



Graph 2 **:Compressive strength for M30 concrete**

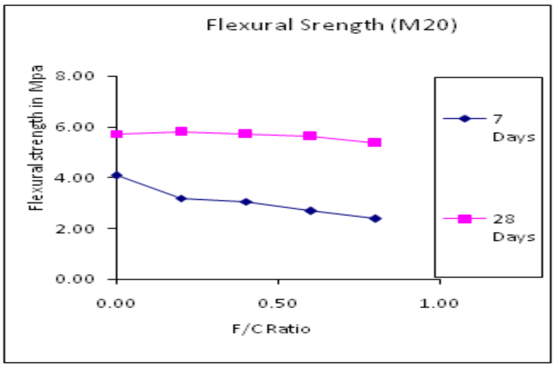
6.2THE FLEXURAL STRENGTH TEST

***Fig:4 TYPICAL FRACTURE PATTERN OF BEAM SPECIMENS DUE TO FLEXURAL LOAD*(M30, 0% Fly ash)**

Fig: 5 **TYPICAL FRACTURE PATTERN OF BEAM SPECIMENS DUE TO FLEXURAL LOAD (M20, 0% Fly ash)**

Grade	F/C Ratio	Flexural Strength (N/mm^2) at Ages (days)	
		7 days	28 days
M20	0	4.1	5.73
	0.2	3.2	5.8
	0.4	3.06	5.7
	0.6	2.7	5.63
	0.8	2.4	5.36
M30	0	4.7	6.43
	0.2	4.3	6.5
	0.4	3.5	6.36
	0.6	3.1	6.33
	0.8	2.8	6.1

Table 3 **Values of Flexural strength of concrete with different percentages of Fly ash at different ages**



***Graph 3*:flexural strength for M20 concrete**

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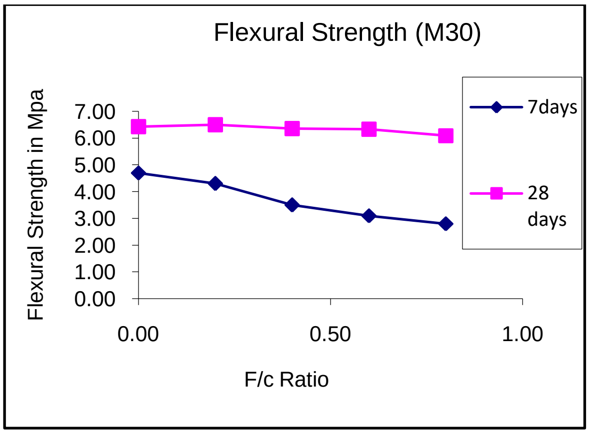

Graph 4:**Flexural strength for M30 concrete**

7. 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.
- Strength increases with the increase in age of Fly ash concrete.

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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