PERFORMANCE EVALUATION OF HIGH VOLUME FLY ASH CONCRETE

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Abstract*:The utilization of fly-ash in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvement in the long term durability of concrete combined with ecological benefits. Technological improvements in thermal power plant operations and fly-ash collection systems have resulted in improving the consistency of fly-ash.The present study was carried out to determine the effect of high volume fly ash on concrete mechanical properties and durability properties. Three types of concrete mixes were prepared that consist of 50%, 60% and 70% of class F fly ash by weight of cement. Normal concrete was also prepared as reference mortar. Compressive strength, split tensile strength, modulus of rupture were conducted on the high volume fly ash concrete at 7, 28, 56, and 90 days. Whereas compressive strength and Acid Attack were evaluated to determine the durability properties of high volume fly ash concrete.Comparative studies were carried out for compressive strength, split tensile strength, modulus of rupture and acid attack for conventional concrete and high volume fly ash concrete.Based on the trial mixes compressive strength v/s W/C curves are plotted so that concrete mix of grades (M 30 and M 40) with different percentages of fly ash can be directly designed.

I.INTRODUCTION

FLY ASH generated by the burning of coal in coal fired power plants was considered till a few years back as mere waste material. This was considered as a material of very low value, useful only for land fill. But its usefulness as pozzolonic additive to cement is an important discovery. Continuous research studies by various engineering research laboratories revealed its varied usefulness as an additive for enhancing the various qualities of concrete including its workability, strength and durability if handled and cared properly. Partial replacement of cement with fly ash in concrete save much of the energy required for production of OPC and also facilitates the economical disposal of millions of tons of fly ash.

At present most of the fly ash blended cements commercially produced in India has 18 to 25% fly ash by weight and addition of fly ash to this extent has a beneficial effect on the workability and economy of concrete. It has been found that in order to improve the other qualities of concrete like resistance of sulfate attack and thermal cracking, larger percentage of fly ash is to be used in concrete. Fly ash content greater than 35% can be considered as high volume replacement or high blending. The seven storey structure of 10780m2 office space in Canada was constructed with HVFAC having compressive strength 30-50N/mm2.

II.RELATED WORK

The past studies on HVFAC reveals that the replacement of cement by fly ash in concrete made great changes in properties such as reduction in cost, significant reduction of steel corrosion, minimization of potential alkali aggregate reaction, reduction in heat of hydration, improvement in durability of concrete etc. [1,2,3,4,5] In addition, it improves the environment by contributing towards reduction of greenhouse gases [6].

The objective of this investigation is

1)To study the effect of partial replacement of cement with fly ash.

2)Evaluation of the mechanical and durability properties of high volume fly ash concrete.

3)To find out the optimum percentage of replacement of fly ash.

III.EXPERIMENTAL STUDY

The experimental program was designed to study the effect of partial replacement of cement with fly ash. For this following parameters considered for M30 and M40 grades of concrete. They are:

1. Plain concrete.
2. 50% replacement of cement by fly ash.
3. 60% replacement of cement by fly ash.
4. 70% replacement of cement by fly ash.

Based on the trial mixes compressive strength v/s W/C curves are plotted so that concrete mix of grades (M30 and M40) with different percentages of fly ash can be directly designed.

Material used

Different materials used in this investigation are

- 53 Grade Ordinary Portland cement
- Fine Aggregate
- Coarse Aggregate
- Water
- Mineral admixtures (Fly ash)
- Chemical admixtures like super plasticizer

Tests on high volume fly ash concrete

1. Compressive strength
2. Split tensile strength
3. Modulus of rupture
4. Acid attack

Compressive Strength Test

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc. Test for compressive strength is carried out either on cube or cylinder. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method for compressive strength of concrete.

Split Tensile Strength

It is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be performed in accordance with IS:5816-1970. A standard test cylinder of concrete specimen (300 mm X 150mm diameter) is placed horizontally between the loading surfaces of Compression Testing Machine with wooden supports.

Modulus of rupture

Flexural strength test is done as per IS: 516-1959. Prisms are tested for flexure in Universal testing machine of capacity 200 kN. The bearing surfaces of the supporting and loading rollers are wiped clean before loading. The prisms are placed in the machine in such a manner that the load is applied to the uppermost surface along the two lines spaced 13.3 cm apart. The axis of the specimen is aligned with the axis of the loading device. The load is applied at a rate of 180 kg/min without shock. The specimen is loaded till it fails and the maximum load (P) applied to the specimen during test is noted. After fracture the distance (a) between the crack and nearest support is measured. The flexural strength of the specimen is expressed as the modulus of rupture.

Acid attack test

The chemical resistance of the concrete was studied through chemical attack by immersing them in an acid solution. After 28days curing period of the specimens of each batch were taken and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial mass, body diagonal dimensions value were measured. 2specimens of each batch of concrete were immersed in 5% HCl.

Preparation of 5% HCl:

Volume of HCl = 100 ml
Mass of HCl (36.5% purity) = 100 x 1.18=118 grams
Actual mass of HCl = 36.5/100 x 118= 42.07 grams
5% HCl= actual mass HCl / (mass HCl + mass water)
5/100 = 42.07/(118+x)
X =731 ml of water.
i.e., for 100ml of 36.5% HCl, 731ml volume of water is added to make 5% HCl solution.

IV.RESULTS AND DISCUSIONS

Concrete mix proportioning

The details of the trial mix proportions used in the investigation are tabulated in the tables. These trial mixes were casted for varying w/b ratios as shown in the respective tables. The 28 days strengths of these trial concrete mixes for varying w/b ratios were then obtained by testing these trial specimens. Then these trial strengths were plotted against the w/b ratios as shown. Then from each of these plots corresponding to 30 and 40 Mpa respective target mean strengths, the w/b ratios were plotted as shown in these figures. These are the respective w/b ratios for final design mixes to be taken which are shown. Water content were taken same in all of the final design mixes. The percentage of sand content were reduced from plain concretes 70% fly ash concrete.

Trial mix of plain cement concrete mix:

w/c ratio	0.3	0.4	0.5	0.6
Water content (kg/m3)	160	160	160	160
Percentage of sand	32	35	38	41
Percentage of super plasticizer	0.5%	0.4%	0.4%	0.3%
Average 28 days strength (Mpa)	64	45	36	27

Trial mix of 50% fly ash concrete mix:

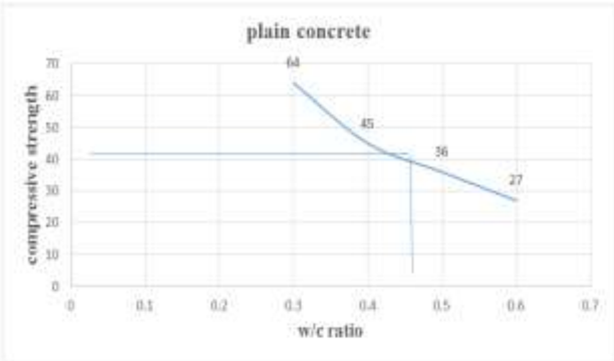
w/c ratio	0.3	0.4	0.5
Water content (kg/m3)	160	160	160
Percentage of sand	32	35	38
Percentage of super plasticizer	0.5%	0.4%	0.4%
Average 28 days strength (Mpa)	56.44	36.64	26.77

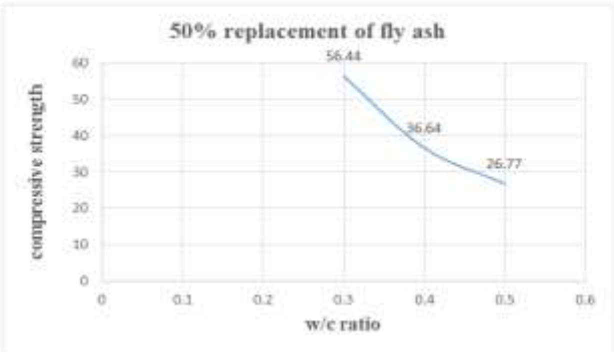
Trial mix of 60% fly ash concrete mix:

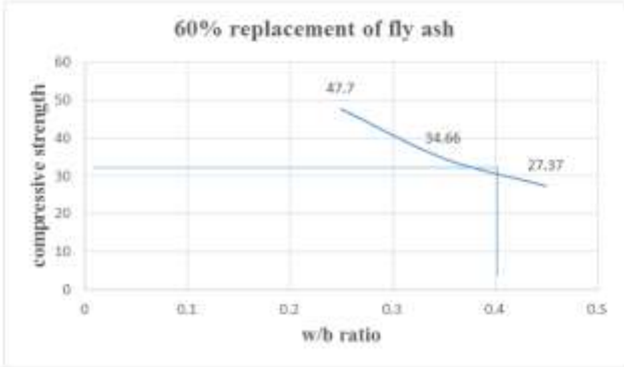
w/c ratio	0.25	0.35	0.45
Water content (kg/m3)	160	160	160
Percentage of sand	24	30	36
Percentage of super plasticizer	0.8%	0.5%	0.5%
Average 28 days strength (Mpa)	47.7	34.66	27.37

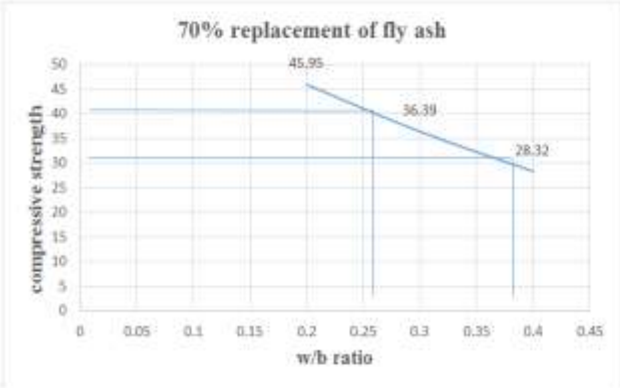
Trial mix of 70% fly ash concrete mix:

w/c ratio	0.20	0.30	0.40
Water content (kg/m3)	160	160	160
Percentage of sand	15	25	35
Percentage of super plasticizer	1%	0.8%	0.6%
Average 28 days strength (Mpa)	44.95	36.39	28.32









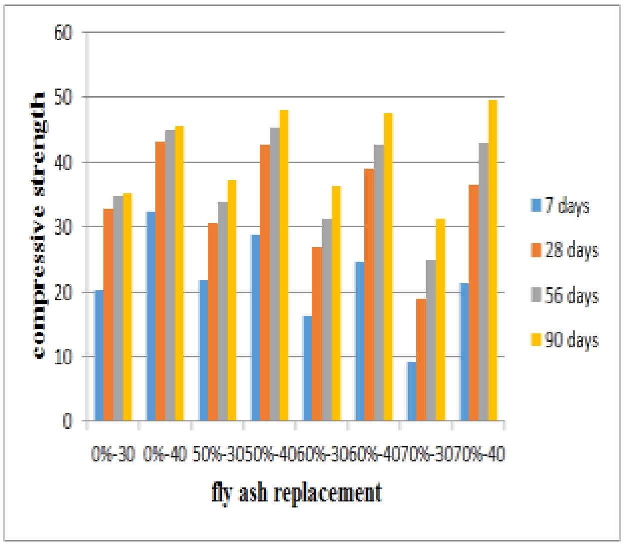
Final mix design used:

Mix	Plain concrete		50% replacement		60% replacement		70% replacement	
	30 Mpa	40 Mpa	30 Mpa	40 Mpa	30 Mpa	40 Mpa	30 Mpa	40 Mpa
w/b ratio	0.58	0.46	0.42	0.35	0.40	0.30	0.38	0.48
% of sand	40	40	36.5	33.5	33	32	35	30
Super plasticizer	0.5	0.6	0.5	0.6	0.6	0.6	0.5	0.5
water content	160	160	160	160	160	160	160	160

Compressive strength:

Percentage of replacement	Target mean strength	7 days	28 days	56 days	90 days
0	30	20.27	32.67	34.72	35.18
	40	32.42	43.21	44.94	45.48
50	30	21.25	30.49	33.92	37.12
	40	28.76	42.71	45.29	47.94
60	30	16.24	26.86	31.26	36.28
	40	24.64	38.86	42.58	47.54
70	30	9.27	19.22	24.90	31.32
	40	21.25	36.54	42.92	49.48

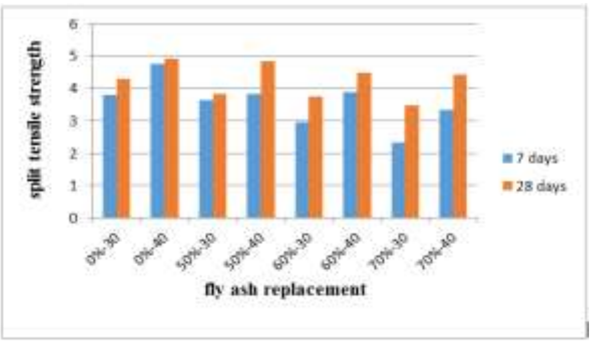
Compressive strength:



The result shows an increase in strength with age in all cases. The targeted strengths achieved in 28 days for plain and 50% concretes; however these are achieved in 56 days for 50% and 60% fly ash concretes. These are achieved in 90 days for 70% fly ash concretes. But the results shows that the beyond 90 days the strengths remarkably improve for fly ash concrete particularly for higher percentages of replacements. 90 days compressive strength test results shows for M30 grade concrete, for 50%, 60%, 70% replacement 5%, 3% more and 11% less when compared with plain concrete. For M40 grade concrete, for 50%, 60%, 70% replacement 5%, 4.5%, 8% more when compared with plain concrete.

Split tensile strength:

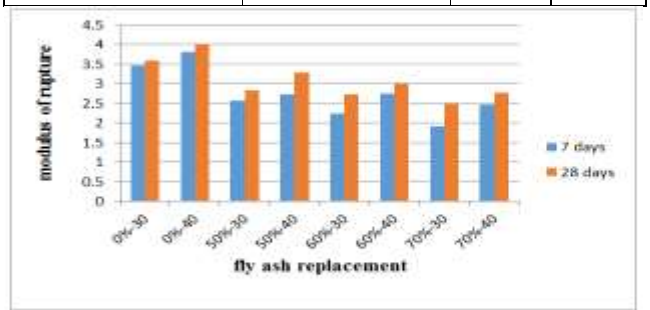
Percentage of replacement	Target mean strength	28 days	56 days
0	30	3.8	4.28
	40	4.75	4.91
50	30	3.64	3.83
	40	3.82	4.84
60	30	2.95	3.75
	40	3.88	4.47
70	30	2.32	3.46
	40	3.35	4.42



The tensile strength increases with age. At early ages of curing the tensile strength decreases with increase in fly ash content in concrete. The 50% replacement of fly ash tensile strength shows almost identical with that of a plain concrete at 56 days. The tensile strengths for M30 grade of concrete for 50%, 60%, 70% replacement of fly ash 4%, 18%, 36%,10.5%, 12%, 19.5% low, when compared with plain concrete at the curing period of 28 days and 56 days. The tensile strengths for M40 grade of concrete for 50%, 60%, 70% replacement of fly ash 19.5%, 18%, 30%, 1.42%, 8.96%, 10% low, when compared with plain concrete at the curing period of 28 days and 56 days. The tensile strengths of 56 days, for M30 grade of concrete for 50% replacement of fly ash 1% increases, for 60% replacement of fly ash 1.3% decreases, for 70% replacement of fly ash 8% decreases when compared with plain concrete at the curing period of 28 days. The tensile strengths of 56 days, for M40 grade of concrete for 50% replacement of fly ash 1.8% increases, for 60% replacement of fly ash 6% decreases, for 70% replacement of fly ash 7% decreases when compared with plain concrete at the curing period of 28 days.

Modulus of rupture:

Percentage of replacement	Target mean strength	28 days	56 days
0	30	3.47	3.58
	40	3.81	4.02
50	30	2.57	2.84
	40	2.72	3.27
60	30	2.24	2.73
	40	2.75	3.02
70	30	1.92	2.48
	40	2.47	2.76



Like compressive strength and split tensile strength the modulus of rupture increases with age. At early ages of curing the modulus of rupture decreases with increase in fly ash content in concrete. The modulus of rupture for M30 grade of concrete for 50%, 60%, 70% replacement of fly ash 26%, 35.4%, 45%,29%, 28%, 35% low, when compared with plain concrete at the curing period of 28 days and 56 days. The modulus of rupture for M40 grade of concrete for 50%, 60%, 70% replacement of fly ash 20.6%, 23.74%, 30.72%, 19%, 25%, 31% low, when compared with plain concrete at the curing period of 28 days and 56 days. The modulus of rupture for 56 days, for M30 grade of concrete for 50% replacement of fly ash 18% decreases, for 60% replacement of fly ash 21.32% decreases, for 70% replacement of fly ash 29% decreases when compared with plain concrete at the curing period of 28 days. The modulus of rupture 56 days, for M40 grade of concrete for 50% replacement of fly ash 14% decreases, for 60% replacement of fly ash 20.7% decreases, for 70% replacement of fly ash 28% decreases when compared with plain concrete at the curing period of 28 days.

Acid attack:

In acid attack studies on high volume fly ash concrete, the effect of 5% HCl acid were studied. The various observations made are explained below.

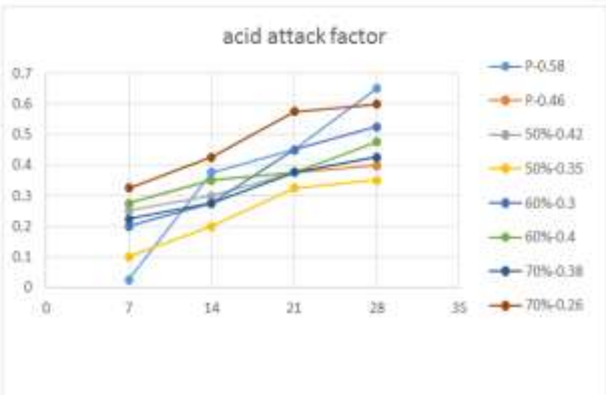
Visual observation

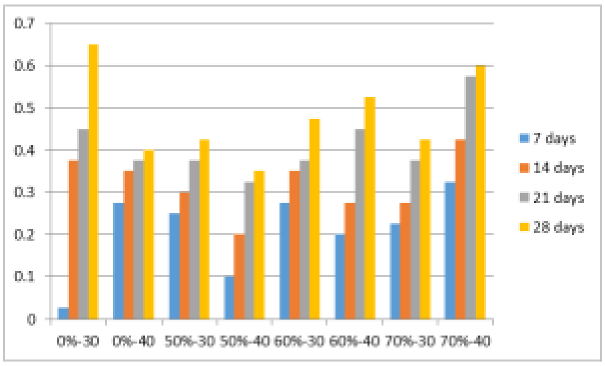
In the first stage of the test the change in the physical state of the specimens after 7, 14, 21, 28 days of immersion is observed. For the specimens immersed in 5% HCl, voids were observed on the surface and edges were lost after 28days.

Acid Attack Factor:

The Acid Attack Factor (AAF) of the specimens were observed and plotted against the number of immersion days in acids as shown in the following.

Percentage of replacement	Target mean strength	7 days	14 days	21 days	28 days
0	30	0.025	0.375	0.45	0.65
	40	0.275	0.35	0.375	0.4
50	30	0.25	0.3	0.375	0.425
	40	0.1	0.2	0.325	0.35
60	30	0.275	0.35	0.375	0.475
	40	0.2	0.275	0.45	0.525
70	30	0.225	0.275	0.375	0.425
	40	0.325	0.425	0.575	0.6

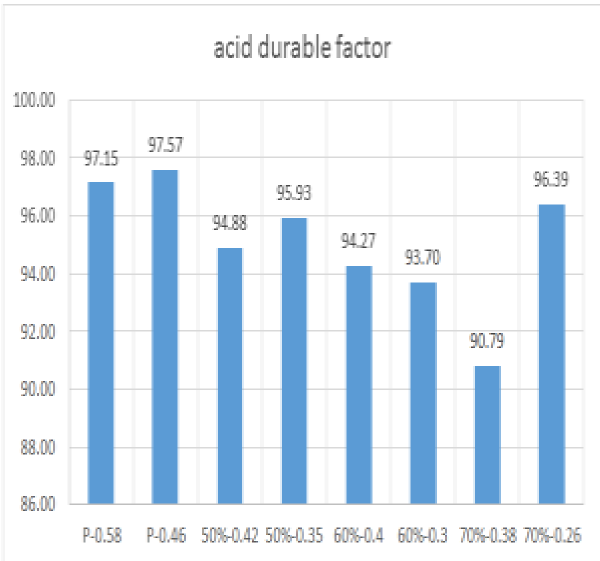




With the addition of fly ash resistance against the acid attack has improved. Acid attack factor is low for specimens with replacement of 50%, but for 7 days plain concrete (M30 grade) shows low acid attack factor.

Acid durable factor:

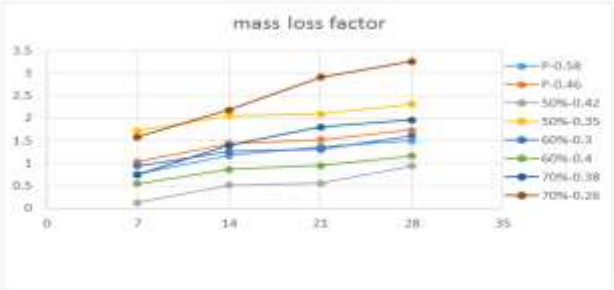
Percentage of replacement	Target mean strength	28 days strength	28 days strength after acid attack
0	30	32.67	31.74
	40	43.21	42.16
50	30	30.49	28.93
	40	42.71	40.97
60	30	26.86	25.32
	40	38.86	36.41
70	30	19.22	17.45
	40	36.54	35.22

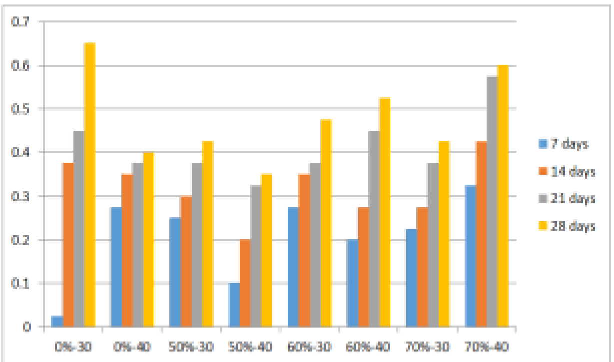


Acid durable factor is more for plain concrete. In fly ash concrete acid durable factor high for 50% replacement. The acid durable actor for M30 grade of concrete for 50%, 60%, 70% replacement of fly ash 11.44, 22.49%, 46%, low, when compared with plain concrete at the curing period of 28 days. The acid durable factor for M40 grade of concrete for 50%, 60%, 70% replacement of fly ash 5.81%, 15.73%, 19%, low, when compared with plain concrete at the curing period of 28 days.

Mass loss factor:

Percentage of replacement	Target mean strength	7 days	14 days	21 days	28 days
0	30	0.7575	1.1655	1.3636	1.4918
	40	1.0416	1.4351	1.5162	1.7361
50	30	0.1191	0.5005	0.5482	0.9296
	40	1.7149	2.0461	2.0934	2.3063
60	30	0.5454	0.8606	0.9454	1.1636
	40	0.9378	1.2543	1.3012	1.6060
70	30	0.7384	1.3907	1.8092	1.9569
	40	1.5757	2.1818	2.9090	3.2727





Diagonal loss is more for specimens with 70% replacement of fly ash. Compare with the plain concrete and among all the percentage replacement, 50% replacement of fly ash shows less mass loss.

CONCLUSION

The experimental exercise has helped to study the various properties of fly ash concrete and to develop the mix design curves for concrete mix proportioning with various percentages of fly ash. Based on the studies conducted following conclusion is drawn on the fly ash concrete.

1. The data show clearly that the compressive strength of control concrete as well as fly ash concrete increases with age.

2. As the fly ash content increases there is reduction in the strength of concrete. This reduction is more at earlier ages as compared to later ages.

3. Compressive strength of concrete decreased with increase in cement replacement with class F fly ash. However, at each replacement level of cement with fly ash, an increase in strength was observed with the increase in age.

4. The tensile strength increases with age. At early ages of curing the tensile strength decreases with increase in fly ash content in concrete. The 50% replacement of fly ash, tensile strength shows almost identical with that of a plain concrete at 56 days.

5. Like compressive strength and split tensile strength the modulus of rupture increases with age. At early ages of curing the modulus of rupture decreases with increase in fly ash content in concrete.

6. Resistance against acid attack is increased with the fly ash replacement when compared with plain concrete.

7.The optimum fly ash content is observed to be 50% of cement, considering all the factors viz., compressive strength, split tensile strength, modulus of rupture, acid attack.

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