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STUDY OF STRENGTH AND DURABILITY PARAMETERS OF CONCRETE MADE USING FLY ASH AGGREGATES

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Abstract:- In this study, the fine and coarse aggregates were completely replaced by fly ash aggregates in fly ash concrete. A mix design was done for M40 grade of concrete by IS method. Ordinary Portland cement of 43 Grade was selected and fly ash aggregates were prepared by mixing fly ash with cement and water. The properties of fly ash fine aggregates and fly ash coarse aggregates were studied. The aggregate crushing value and aggregate impact value of fly ash coarse aggregates were also studied. The fly ash aggregates proportions of 0% , 10%, 20% , 30 % , 40% , 50% by aggregates weight were tried with a suitable water cement ratio 0.45 to get the fly ash aggregates. The concrete cubes, cylinders and beams were cast with the fly ash aggregates obtained from the above six cement fly ash proportions. Then the compressive strength, split tensile strength and flexural strength and durability were tested and compared with control concrete. This paper briefly presents the compressive strength development of fly ash aggregate concrete at different ages. The split tensile strength and flexural strength of all the concrete mix were also investigated at different days of curing.

Keywords: *Fly ash aggregates (FAA), Compressive Strength, Split tensile strength, Flexural strength, etc.*

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I INTRODUCTION

Many researchers have been carried out in the area of fly ash utilization in the past. It mainly concentrated on replacement of cement with fly ash but production of artificial aggregates with fly ash helps in utilizing large volume of fly ash in concrete. In the present scenario the world is much interested in this part recently due to this large scale utilization which also reduces environmental pollution and dwindling of natural resources. The production of concrete requires aggregate as an inert filler to provide bulk volume as well as stiffness to concrete. Crushed aggregates are commonly used in concrete which can be depleting the natural resources and necessitates an alternative building material. This led to the widespread research on using a viable waste material as aggregates.

Fly ash is one promising material which can be used as both supplementary cementitious materials as well as to produce light weight aggregate. This paper mainly focuses on manufacturing process of fly ash light weight aggregates using pelletizer and curing has been done in cold bonded technique.

The properties of these fly ash aggregates have been tested and the results indicated that cold bonded fly ash aggregates can be effectively used as a coarse aggregate replacement material in concrete. Artificial manufactured lightweight aggregates can be produced from industrial by-products such as fly ash, bottom ash, silica fume, blast furnace slag, rice husk, slag or sludge waste or palm oil shell, shale, slate, clay. The use of cost effective construction materials has accelerated in recent times due to the increase in the demand of light weight concrete for mass applications. The present experimental investigation aimed in studying workability, strength properties of M40 concrete made with artificial fly ash aggregates as replacement of coarse aggregates with addition of super plasticizer.

MATERIAL PROPERTIES

Below table shows the chemical composition of Fly Ash (Class F) at Thermal Power Station (Fly ash (Class F) obtained from Ramagundam Thermal Power Station (**Telangana Super Thermal Power Project (TSTPP)** was used in the experimental work.

Comparison of conventional aggregates with fly ash coarse aggregates

PROPERTIES	CONVENTIONAL COARSE	ARTIFICAL COARSE AGGREGATES
Specific Gravity	2.65	1.727
Fineness modulus	7.50	4.2626
Moisture content (in 1 hr)	1.53%	11.84%
Bulk density	partial -1720 kg/m^3 full — 1773.33 kg/m^3	partial -793.854 kg/m^3 full — 924.816 kg/m^3

METHODS OF PREPARING FLY ASH AGGREGATES

1. PELLETIZATION PROCESS

The desired grain size distribution of an artificial fly-ash aggregate is either crushed or by means of agglomeration process. The pelletization process is used to manufacture of lightweight coarse aggregate; some of the important parameters need to be considered for the efficiency of the production of pellet such as speed of revolution of pelletizer disc, moisture content, and angle of pelletizer disc and duration of pelletization.

Fig: Pelletization Process; Disc Pelletizer

2. COLD BONDING METHOD

In laboratory scale, fly ash and binder are uniformly mixed. This proportion is thoroughly dry mixed in a mixture. After dry mixing, water is sprinkled in a pelletizer and the contents were thoroughly mixed in pelletizer until the formation of fly ash aggregate.

This method of formation of aggregates is called pelletization A specially fabricated disc pelletizer as shown in **Figure2** was used in this study which has a disc diameter 500 mm and depth 250 mm. The angle of the disc can be adjusted between 450 to 500 and speed 55 rpm.

In **cold bonding** process the aggregates were allowed for curing for 1, 3 and 7 days in order to achieve green strength.

Figure 2: Disc pelletizer.

3. AUTOCLAVING METHOD

This method involves green pellets are then cured in pressurized saturated steam at a temperature of 140°C for 30 minutes. After that they are collected and allowed for dry in 24 hours. This process helps in reducing bonding material in pellet formation and curing time. It seems that the strength property and durability properties of AFA and CFA are very close to each other**.**

4. SINTERING METHOD

Once the aggregate is formed in disc pelletizer, it is collected in tray allowed to dry for a day. Finally the aggregates are allowed for sinter -ing for a temperature of 1150°C for half-an-hour duration in order to gain good strength. Sintering of fly ash aggregate was done by down draft sintering method. Batch type suction grate sinter machine of 300 × 300 mm and cross section area 500 mm height hearth is used for prepare sintered fly ash aggregate from the pelletizer raw machine.

The sintering experiment is being carried out by maintain 400 mm bed height of the granulated particle on a 50 mm thick hearth layer with suction pressure 400 mm WG below the grate to complete the preheating at 1150°C and cooling in 25 to 30mins of time. The process of laboratory produced sintered fly ash aggregates are shown in Figure 3. During the sintering process higher amount of coal is accepted as it helps for sintering. But the high energy requirement makes the process undesirable. The aggregates which are formed in sintering process show better durability and corrosion resistance property (Figures 3-5).

Figure 3: Downdraft sintering machine.

The laboratory prepared different types fly ash aggregates procedure in various methods is shown in Figures 4 and 5.

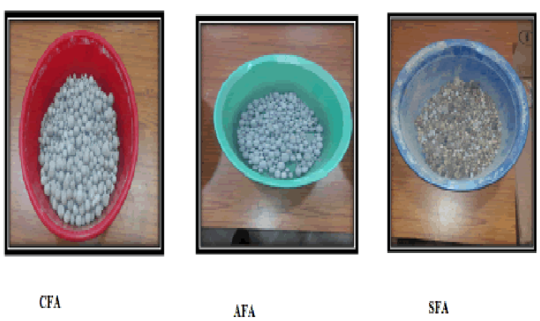

Figure 4: Various types of fly ash aggregates.

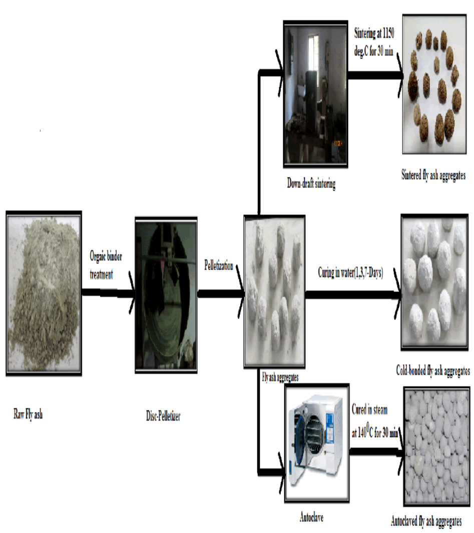

Figure 5: Laboratory methods of preparation of fly ash aggregates.

II LITERATURE REVIEW

N.P.Rajamani and P.S. Ambily el al(2008)

Scientists OF SERC, Chennai carried out the research work on “Selection of mortar for light weight aggregate concrete made with fly ash based aggregate”. They concluded that conversion of fly ash with aggregate is technically feasible and are found to be light weight in nature. They found fly ash aggregate concrete up to 20Mpa can be used for production of concrete blocks for masonry construction in structures. They also suggested to select mortar which can produce fly ash aggregate concrete of strength up to 40Mpa. However concrete strengths more than 40Mpa can also be produced using less content of fly ash aggregates.

Dr.J.B.Behera, Dr.B.D.Nayak, Dr.H.S.Ray and Dr.B.Sarangi et and all,.(1996)

They studied and examined the use of sintered fly ash aggregate in concrete as a partial replacement of granite aggregate. They concluded that in addition to light weight characteristics, the sintered fly ash concrete possesses strength and deformation characteristics similar to concrete with natural granite aggregate.

Gao Li-Xiong, Yaoyan and Wang Ling et all,.(2016)

This paper states that The China building materials Academy, Beijing found light weight aggregate concrete made with sintered fly ash aggregate showed good workability, high compressive strength and low absorption of water.

Mehnet Gesoglu, Turan Ozturan and Erhan Gunegisi et all,.(2014)

They studied and found the compressive strength of concrete ranging from 20 to 50Mpa was practically produced by using light weight fly ash aggregates. They also found the increase in splitting tensile strength of concrete due to increase in aggregate crushing strength of fly ash aggregates.

Haydar Arsian and Gokhan Baykal et and all,.(2009)

They investigated the fly ash aggregates produced from fly ash and cement mixing by pelletization method and evaluated Engineering properties such as crushing strength, specific gravity, water absorption, particle size distribution, surface characteristics and shear strength properties of the manufactured aggregates experimentally. The experimental investigation showed

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that these aggregates are a good alternative for wide range of civil Engineering applications.

III EXPERIMENTAL PROGRAM

The details of number of blocks to be tested while the experimentation process is given in the below table:

Sl.No	% Replacement of fly ash aggregates	Compressive strength of concrete				Split tensile strength of concrete		Flexural strength of concrete	
		7days	14days	28days	56days	7days	28days	7days	28days
1	0.00%	3	3	3	3	3	3	3	3
2	10.00%	3	3	3	3	3	3	3	3
3	20.00%	3	3	3	3	3	3	3	3
4	30.00%	3	3	3	3	3	3	3	3
5	40.00%	3	3	3	3	3	3	3	3
6	50.00%	3	3	3	3	3	3	3	3
Total		72				36		36	

MATERIALS:

1. CEMENT:

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete-which is a combination of cement and an aggregate to form a strong building material.

Ordinary Portland cement 53 grade

The ordinary Portland cement of 53 Grade is used in accordance with IS: 12269-1987.

Properties of this cement were tested and listed here.

1. Fineness of cement = 5%
2. Specific gravity if cement = 3.02
3. Standard Consistency of cement = 33%
4. Initial setting time = 50 minutes
5. Final setting time = Not more than 10 hours.

2 AGGREGATES:

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. Aggregates are the most mined materials in the world.

i. COARSE AGGREGATE:

Crushed stone aggregate of 20mm size is brought from nearby quarry. Aggregates of size more than 20mm size are separated by sieving. Tests are carried in order to find out the

- Specific gravity = 2.98
- Fineness modulus = 7.5

Coarse aggregate

ii. FINE AGGREGATE:

Locally available fresh sand, free from organic matter is used. The result of sieve analysis confirms it to Zone-II (according to IS: 383-1970).The tests conducted and results plotted below.

- Specific gravity = 2.3
- Fineness modulus = 3.06

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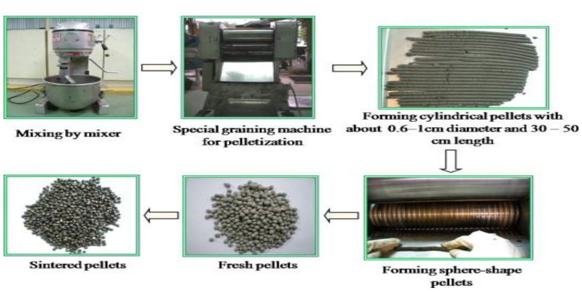
Fine aggregate

FLY ASH AGGREGATES

PELLETIZING PROCESS

The desired grain size distribution of an artificial lightweight aggregate is either crushed or by means of agglomeration process. The pelletization process is used to manufacture lightweight coarse aggregate; some of the parameters need to be considered for the efficiency of the production of pellet such as speed of revolution of pelletizer disc, moisture content and angle of pelletizer disc and duration of pelletization (Harikrishnan and Ramamurthy, 2006). The different types of pelletizer machine were used to make the pellet such as disc or pan type, drum type, cone type and mixer type.

With disc type pelletizer the pellet size distribution is easier to control than drum type pelletizer. With mixer type pelletizer, the small grains are formed initially and are subsequently increased in particle size by disc type pelletization (Bijen, 1986). The disc pelletizer size is 570 mm diameter and side depth of the disc as 250 mm, it is fixed in a flexible frame with adjusting the angle of the disc as 35 to 55° and to control for the rotate disc in vertically manner should varying speed as 35 to 55 rpm (Manikandan and Ramamurthy, 2007)



WATER:

Generally potable water should be used. This is to ensure that the water is reasonable free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc

MIX DESIGN

Final trial mix for M30 grade concrete is 1:1.64:2.55 at w/c of 0.45

TEST TO BE CONDUCTED ON THE SPECIMENS:

Compressive strength

- 7 days specimens age
- 14 days specimens age
- 28 days specimens age
- 56 days specimens age

Split tensile strength of specimens

- 7 days specimens age
- 28 days specimens age

Flexural strength of specimens

- 7 days specimens age
- 28 days specimens age

Durability

- 56 days specimens age

IV RESULTS AND ANALYSIS

1. Material Properties

a. Cement

Sl.no	Test	Results	IS code used	Acceptable limit
1	Specific gravity of cement	3.160	IS:2386:1963	3 to 3.2
2	Standard consistency of cement	6mm at 34% w/c	IS:4031:1996	w/c ratio 28%-35%
3	Initial and final setting time	45 mins and 10 hours	IS:4031:1988	Minimum 30mins and should not more than 10 hours
4	Fineness of cement	3.00%	IS:4031:1988	<10%

b. Coarse aggregates

Sl.no	Test	Results	Is code used	Acceptable limit
1	Fineness modulus	6.5	IS:2386:1963	6.0 to 8.0mm
2	Specific gravity	2.90	IS:2386:1963	2 to 3.1mm
3	Porosity	46.83%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.8855	IS:2386:1963	Any value
5	Bulk density	1.50g/cc	IS:2386:1963	-
6	Aggregate impact value	37.5	IS:2386:1963	Less than 45%
7	Aggregate crushing value	26.6%	IS:2386:1963	Less than 45%

c. Fine aggregates

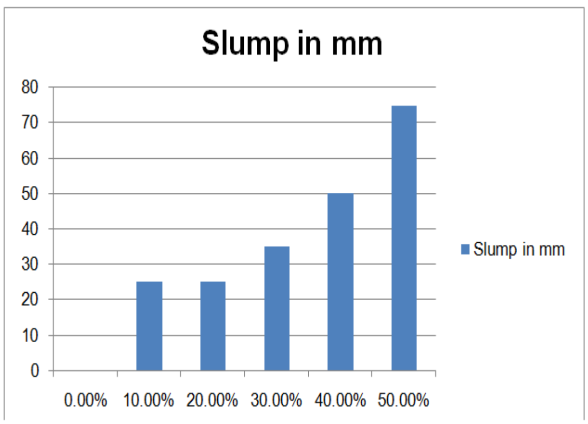
Sl.no	Test	Result	Is code used	Acceptable limits
1	Fineness modulus	4.305	IS:2386:1963	Not more than 3.2 mm
2	Specific gravity	2.43	IS:2386:1963	2.0 to 3.1
3	Porosity	36.6%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.577	IS:2386:1963	Any value
5	Bulk density	1.5424	IS:2386:1963	-
6	Bulking of sand	3.0%	IS:2386:1963	Less than 10%

2. Concrete tests

I. Tests on fresh concrete

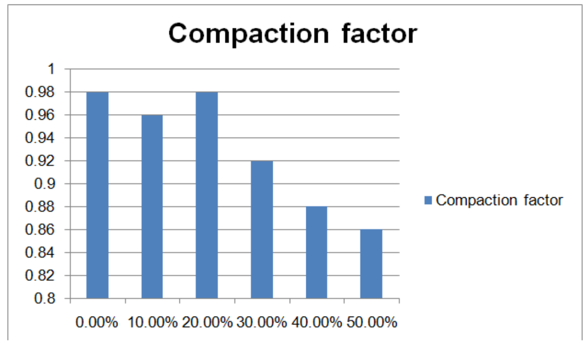
a. Slump cone test

S.no	%Replacement of fly ash aggregates	Slump in mm
1	0.00%	0
2	10.00%	25
3	20.00%	25
4	30.00%	35
5	40.00%	50
6	50.00%	75



b. Compaction factor test

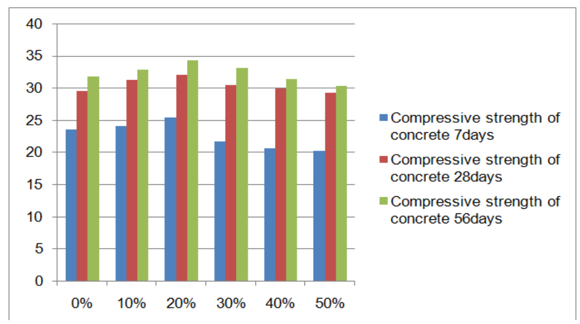
S.no	%Replacement of fly ash aggregates	Compaction factor
1	00.00%	0.98
2	10.00%	0.96
3	20.00%	0.98
4	30.00%	0.92
5	40.00%	0.88
6	50.00%	0.86



II. Tests on hardened concrete

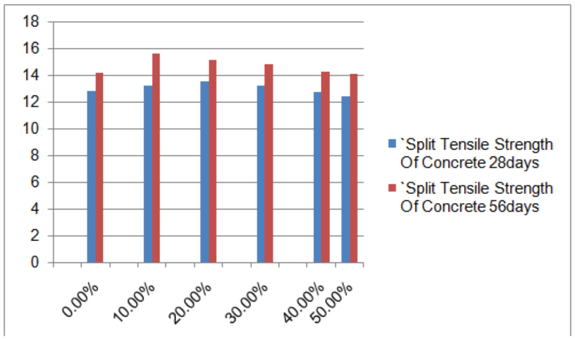
a. Compressive strength of concrete

S.no	% Replacement of fly ash aggregates	Compressive strength of concrete		
		7days	28days	56days
1	00.00	23.49	29.55	31.73
2	10.00	24.01	31.19	32.84
3	20.00	25.34	32.016	34.31
4	30.00	21.72	30.47	33.12
5	40.00	20.66	29.84	31.31
6	50.00	20.16	29.20	30.24



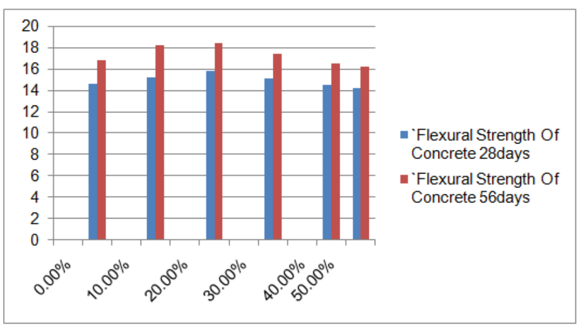
b. Split tensile strength of concrete

S.no	% Replacement Of fly ash aggregates	`Split Tensile Strength Of Concrete	
		28days	56days
1	00.00%	12.82	14.20
2	10.00%	13.21	15.62
3	20.00%	13.53	15.12
4	30.00%	13.23	14.82
5	40.00%	12.68	14.27
6	50.00%	12.42	14.12



c. Flexural strength of concrete

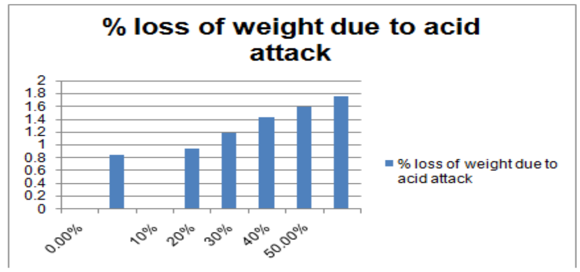
S.no	% Replacement Of fly ash aggregates	`Flexural Strength Of Concrete	
		28days	56days
1	00.00%	14.62	16.84
2	10.00%	15.24	18.20
3	20.00%	15.84	18.40
4	30.00%	15.10	17.40
5	40.00%	14.52	16.48
6	50.00%	14.24	16.20

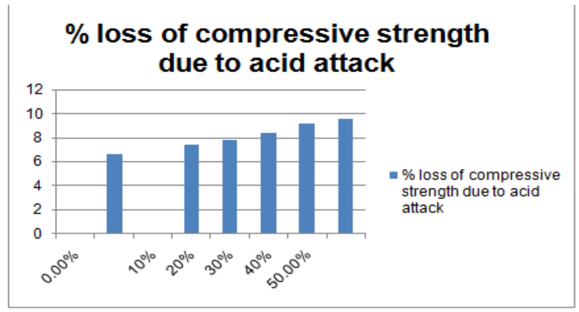


3. Durability

a. Acid attack

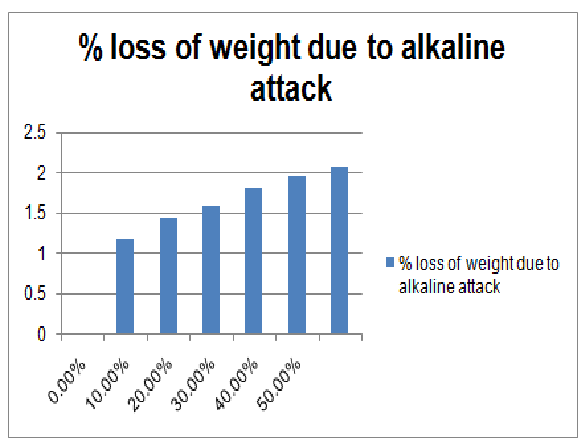
Sl.no	% replacement Of fly ash aggregates	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to acid attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to acid attack
1	0.00%	2261	2242	**0.840**	29.55	27.60	**6.60**
2	10 %	2340	2318	**0.940**	31.19	28.88	**7.40**
3	20%	2351	2323	**1.190**	32.016	29.52	**7.80**
4	30%	2234	2202	**1.433**	30.47	27.91	**8.40**
5	40%	2394	2356	**1.587**	29.84	27.10	**9.20**
6	50.00%	2286	2246	**1.749**	29.20	26.40	**9.60**

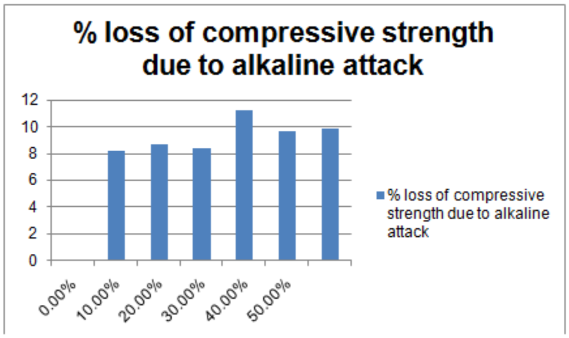




b. Alkaline attack

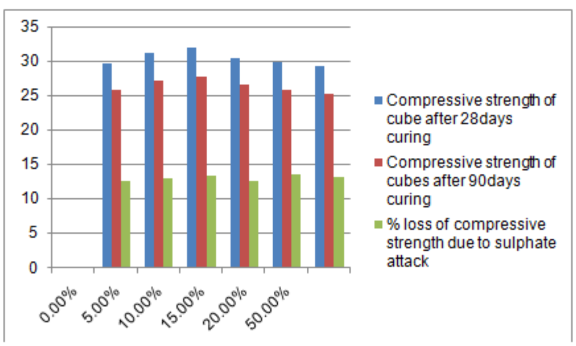
Sl. No	% replacement fly ash aggregates	Initial weight of cube after 28days curing in grams	Final weight of cubes after 90days curing in grams	% loss of weight due to alkaline attack	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to alkaline attack
1	0.00%	2286	2259	1.181	29.55	27.12	8.223
2	10.00%	2340	2306	1.452	31.19	28.48	8.688
3	20.00%	2280	2244	1.578	32.016	29.32	8.42
4	30.00%	2310	2268	1.818	30.47	27.06	11.191
5	40.00%	2296	2251	1.959	29.84	26.97	9.617
6	50.00%	2324	2276	2.065	29.2	26.32	9.86





c. **Sulphate attack**

Sl.no	% replacement fly ash aggregates	Compressive strength of cube after 28days curing	Compressive strength of cubes after 90days curing	% loss of compressive strength due to sulphate attack
1	0.00%	29.55	25.80	12.66
2	5.00%	31.19	27.14	12.98
3	10.00%	32.016	27.73	13.4
4	15.00%	30.47	26.63	12.6
5	20.00%	29.84	25.78	13.6
6	50.00%	29.20	25.34	13.20



V CONCLUSIONS

From the above experimental program the following conclusions were made

1. The material properties of the cement, fine aggregates and coarse aggregates are within the acceptable limits as per IS code recommendations so we will use the materials for research.
2. Slump cone value for the fly ash aggregate concrete increases with increasing in the percentage of fly ash aggregate so the concrete was not workable.
3. Compaction factor value of fly ash aggregate concrete decreases with increase in the percentage of fly ash aggregate and the maximum values of compaction factor was observed at 20% of fly ash aggregate.
3. The compressive strength of concrete is maximum at 20% of fly ash aggregate and is the optimum value for 7days curing, 28days curing, 56days curing,
4. Split tensile strength for the cylindrical specimens is maximum at 20% of fly ash aggregate for 28days curing, 56days curing,
5. The flexural strength of fly ash aggregate concrete is also maximum at 20% of fly ash aggregate for 28days curing, 56days curing,
6. The percentage loss of weight and percentage loss of compressive strength is increases with in increasing the percentages in all cases in durability studies in fly ash aggregate concrete. So, the fly ash aggregate concrete is durable up to 20% replacement.

So the replacement of 20% of fly ash aggregate is generally useful for better strength values in M40 grade of concrete.

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