Experimental Investigation on Ductility of Fly Ash Aggregate Concrete

Kali Doss S[1], B. Venkatarama Prabhu[2], A. Sasi kumar[3]
[1, 2, 3] Dept of Civil Engineering
[1, 2, 3] NSN College of Engineering and Technology, Karur - 639003, Tamilnadu, India.

Abstract- *Aggregate in concrete is structural filler, which occupies the most of the volume of the concrete. It is the cement paste coats and binds together. The composition, shape and size of the aggregate have significant impact on the workability, durability, strength, weight and shrinkage of the concrete. In recent period some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste. Aggregate occupy 60-80% of the volume of concrete is considerable.*

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. Three grades of ordinary Portland cement (OPC) are 33,43 and 53 as classified by Bureau of Indian Standard (BIS) are commonly used in construction industry. The main variable investigated in this study is variation of fly ash dosage in 10%, 20%, 30% and 40%. The compressive strength, durability and shrinkage of concrete were mainly studied.

In the investigation, fly ash aggregates will be used in concrete and its effect on strength of concrete will be studied. The fly ash is collected in Mettur Thermal Power Plant. Then the cement and fly ash proportions of 12.5:87.5, 15:85 and 17.5:82.5 will be adopted to get fly ash aggregates. The particle size distribution, specific gravity, bulk density, impact test on aggregate will be conducted.

The M20 grade of concrete will be considered. The fresh concrete tests Slump testand Compacting factor test will be conducted. For the plain concrete and fly ash aggregate concrete of beams (Plain concrete and RCC beams), cubes and cylinders will be cast. All the specimens will be cured in a curingtank.The Ductility test and compressive strength test will be conducted on these plain and fly ashaggregate concrete specimens.

I. INTRODUCTION

Fly ash is generated as by-product from coal based thermal power plants. In India every year nearly 200 million ton fly ash is generated from major thermal plants. It is likely to increase to 400 million ton per year within next decade as more than 70% power generation in India is through coal based power plants.

The disposal of such large quantity of fly ash not only involves huge expenditure but also creates numerous ecological and environmental problems. In the interest of economy, environment and sustainability, it is essential that this large quantity of fly ash is gainfully used.

Fly ash is an extremely fine powder consisting of spherical particles less than 50 microns in size. Fly ash is one of the construction industry's most commonly used pozzolans. Pozzolans are siliceous or siliceous/alumino materials possessing the ability to form cementitious compounds when mixed with lime (calcium hydroxide, or Ca(OH)2,) and water. When portland cement is mixed with water, most of the cement forms insoluble cementitious compounds; Ca(OH)2 is formed as part of this reaction. When fly ash is introduced into concrete, it reacts with the Ca(OH)2 to form additional cementitious compounds. In a properly proportioned mix, fly ash can improve many of the properties of concrete, including workability and consolidation, flexural and compressive strengths, pumpability, and decreased permeability.

Fly ash provides a significant contribution to sustainable construction. Its use in concrete production consumes less energy and offers improved efficiency and building performance. Fly ash can be used to help achieve LEED (Leadership in Energy and Environmental Design) points.

It is used as a substitute material of the Portland cement content concrete. Fly ash, a supplementary cementitious material, when used in combination with Portland cement contributes to the properties of the hardened concrete through pozzolanic and/or hydraulic activity.

Fly ash is a residual product produced in combustion of coal and comprises of fine particles. The most important use of fly ash in found in Portland cement. It is used as a substitute material of the Portland cement content concrete.

Fly ash, a supplementary cementitious material, when used in combination with Portland cement contributes to the properties of the hardened concrete through pozzolanic and/or hydraulic activity.

Fly ash has been used as a supplementary cementitious material in concrete since the last century, but its use became widespread in the mid-1900s. Historically, the use of fly ash in concrete ranged between the levels of 15% to 25% by mass. However, the actual quantity used depends on the properties of the fly ash, its application, specification limits and the location and climate of the site. In the last few decades, the content of fly ash in concrete has raised up to 40% to 60% producing concrete with higher durability and good mechanical properties.

Two types of fly ash are commonly used in concrete: Class C and Class F. Class C are often high-calcium fly ashes with carbon content less than 2%; whereas, Class F are generally low-calcium fly ashes with carbon contents less than 5% but sometimes as high as 10%. In general, Class C ashes are produced from burning sub-bituminous or lignite coals and Class F ashes bituminous or anthracite coals.

Performance properties between Class C and F ashes vary depending on the chemical and physical properties of the ash and how the ash interacts with cement in the concrete. Many Class C ashes when exposed to water will react and become hard just like cement, but not Class F ashes. Most, if not all, Class F ashes will only react with the by-products formed when cement reacts with water. Class C and F fly ashes were used in this research project.

In any situation, there is an optimum amount of fly ash that can be used in concrete so that the technical, environmental and economic benefits can be maximized without reducing the rate of concrete or compromising the long term performance of the finished product. The optimum quantity of fly ash is based on a wide array of factors and is determined on case-by-case basis

The advantages of using fly ash far outweigh the disadvantages. The most important benefit is reduced permeability to water and aggressive chemicals. Properly cured concrete made with fly ash creates a denser product because the size of the pores is reduced. This increases strength and reduces permeability.

II. IDENTIFY,RESEARCHANDCOLLECT IDEA

Fly ash was collected from Mettur thermal power plant at Mettur near Salem. Fly ash has been collected using electrostatic precipitator in the plant was taken directly from hopper in dry state. It has been categorised as class F fly ash. It usually produced by burning anthracite or bituminous coal. In the sum of the percentage of three principle constitutes i.e. Sio2, Al2o3, is equal to greater than 70%, so the fly ash is termed as class F. Cement and fly ash were mixed in concrete mixer with 12.5:87.5, 15:85 and 17.5:82.5, ratios with w/c of 0.3 and is mixed until the pellets are formed.

III. RESULTS AND DISCUSSIONS

FINENESS TEST ON CEMENT

Procedure

- Air set lumps if any in the cement sample are removed with fingers.
- About 100g of cement is weighed (W1) accurately.
- This is sieved in I.S.Sieve no:90, continuously for 15 minutes in a sieve shaker. After every 5 minutes of sieving, the underside of sieve is lightly brushed with a bristle brush.
- The residue left after 15 minutes of sieving, is weighed (W2).
- The experiment is repeated thrice for the same sample of cement and the average percentage weight of residue is calculated.

Observation and calculation

Table 5.1 Fineness test

Types of cement	Cement sample	Weight of sample (W1) g	Weight of residue (W2) g	Percentage weight of residue W2/W1x100	Average percentage of residue
OPC 43 Grade	1	100	5	5	6.67
	2	100	8	8	
	3	100	7	7	

Result

Average fineness of cement= 6.67%

INITIAL SETTING TIME OF CEMENT

Procedure

- The sample of 400g cement is kept on the nonporous plate.
- The needle is released quickly allowing it to penetrate into the plate.
- When the needle comes to rest, the reading on the index scale is noted.
- The moving rod is raised clear off the cement paste and is wiped clean. The procedure of releasing the needle is repeated at every 30 seconds until the reading on the index scale shows 5± 0.5 mm from the bottom of the mould.
- Then releasing the needle is continued at every 2 minutes till the needle makes an impression on the test block, while the attachment fails to do so.
- Then the time is noted down. The time that elapsed between the moment when water is first added to the cement and the moment at which the needle only makes an impression on the test block, while the attachment fails to do so is the final setting time for the cement under the test.

Observation and calculation

Table 5.2 Initial setting time

Trial	Initial setting time(min)	Initial reading
1	15min	1.5mm
2	17 min	2mm
3	21 min	3.3mm
4	27 min	4.3mm
5	32 min	5.3mm

Result

Initial setting time of cement=32min

SPECIFIC GRAVITY OF CEMENT

Procedure

- Weigh the clean dry pyconometer with its cap.
- Fill the pyconometer one third of cement and determine its weight after screwing the cap.
- Add kerosene to pyconometer after removing the cap, until the pyconometer is half full and stir it with a glass rod, occasionally rolling the pyconometer to assist the removal of air and screw the brass cap.
- Add the kerosene till the pyconometer is full.
- Remove remaining air by shaking after closing the screw top with one finger clean the outer surface. So pyconometer and then determine its weight.
- Empty the contents. So pyconometer and thoroughly wash it.
- Fill the pyconometer with kerosene till the surface. So kerosene is flush with the hold in the screw cap. Then weigh the pyconometer.

Observation and calculation

Weight of pyconometer (W1 g) =660 g
Weight of pyconometer + sample (W2 g) =1470 g
Weight of pyconometer + sample + kerosene (W3 g) =1770 g
Weight of pyconometer + kerosene (W4 g) =1210 g
Weight of sample in the pyconometer (W2 – W1) =810 g
Weight of equal volume of water (W4 – W1)-(W3 – W2) =250 g

Specific gravity of cement $= \frac{\text{Dryweightofsample}}{\text{weight of equalvolume ofwater}}$

= (W2 – W1)/(W4 – W1) -(W3 – W2)
= 810/250
= 3.24

Result

Specific gravity of cement = 3.24.

TESTS ON FINE AGGREGATE

- The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. The aggregate used for the making concrete normally of the maximum size of 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 600micron, 300micron and 150micron.
- The aggregate fraction for 40mm to 4.75mm is treated as coarse aggregate and the fraction for 4.75mm to 150mm micron are termed as fine aggregate.

- Fineness modulus is an empirical factor obtained by adding cumulative percentage of aggregate retained on the standard sieves ranging from 40mm to 150micron and dividing this by arbitrary No.100.

The following limits of fineness modulus may be taken guidance.

Fine sand = 2.2 to 2.6
Medium sand = 2.6 to 2.9
Coarse sand =2.9 to 3.2

DETERMINATION OF PARTICLE SIZE DISTRIBUTION

Table 5.3 Particle size distribution of fine aggregate

Weight of sample taken = 500gm

Sieve size	Weight of particle retained	Percentage retained	Cumulative percentage retained	Percentage passing
4.75mm	20	4	4	96
2.36mm	31	6.2	10.2	89.8
1.18mm	63	12.6	22.8	77.2
600 micron	197	39.4	62.2	37.8
300 micron	113	22.6	84.8	15.2
150 micron	69	13.8	98.6	1.4
Retaining	7	1.4	100	-

Fineness modulus =2.82

DETERMINATION OF SPECIFIC GRAVITY

The pyconometer is cleaned for presence of dust or moisture inside and its empty weight is taken. A small quantity of dry sand is put inside the pyconometer and its weight with sand is taken. The pyconometer shall be topped up with distilled water to remove any forth from the dried on the outside and weighted. The pyconometer is filled with distilled water to the same level as before, dried on the outside and weighed.

Modal calculation
Weight of empty pyconometer (W1)=0.02 kg
Weight of pyconometer and dry sand (W2) =0.074 kg
Weight of pyconometer, sand and water (W3) =0.103 kg
Weight of pyconometer and water (W4) =0.0169 kg

Specific gravity =(W2 – W1)⁄W2 – W1) -(W3 – W4)
= (0.076-0.02)/((0.074-0.02)-(0.103-0.0169))
= 2.7

TESTS ON COARSE AGGREGATES

DETERMINATION OF PARTICLE SIZE DISTRIBUTION

Weight of sample taken = 500 gm

Table 5.4 Particle size distribution of conventional coarse aggregate

Sieve size	Weight of particles retained	Percentage retained	Cumulative percentage retained	Percentage passing
80mm	-	-	-	100
40mm	-	-	-	400
37.5mm	500	10	10	90
20mm	3050	61	71	29
12.5mm	920	18.4	89.4	10.6
10mm	530	10.6	100	-
retaining	-	-	100	-

Fineness modulus = 2.57

DETERMINATION OF SPECIFIC GRAVITY

- The pyconometer is cleaned for presence of dust or moisture inside and its empty weight is taken (W1)
- A small quantity of dry aggregate is put inside pyconometer with aggregate is taken (W2).
- The pyconometer is then filled completely with distilled water. Any entrapped air shall be eliminated by rotating the pyconometer on its side. The pyconometer shall be topped up with distilled water to remove any forth from the surface dried on the outside and weighted (W3).
- The pyconometer is filled with distilled water to the same level as before dried on the outside and weighted (W4).

Model calculation

(W1) = 0.652 kg
(W2) = 1.395 kg
(W3) = 2.005 kg
(W4) = 1.550 kg

Specific gravity = (W2 – W1)/[(W2 – W1) -(W3 – W4)]
=[1.395-0.652]/[(1.395-0.652)-(2.005-1.550)]
= 2.58

PREPARATION OF TEST SPECIMENS

COMPRESSIVE STRENGTH TEST

The concrete cubes(control specimen 6 nos each) of size 150mm x 150mm x 150mm will be cast using conventional fine aggregate (CFA) and conventional coarse aggregate (CCA). For FAAC (6 nos for each of the three ratios), the specimens are cast with fly ash fine aggregate (FAFA) and fly ash coarse aggregate (FACA) obtained from the above three cement fly ash proportions. The specimens are demoulded after 1 day and immersed in water for curing and will be tested for Compressive Strength.

5.4.2 FLEXURAL STRENGTH TEST

The concrete beams (control specimen 3 nos each) of size 200mm x 150mm x 1000mm will be cast using conventional fine aggregate (CFA) and conventional coarse aggregate (CCA). For FAAC (3 nos for each of the three ratios), the specimens are cast with fly ash fine aggregate (FAFA) and fly ash coarse aggregate (FACA) obtained from the above three cement fly ash proportions. The specimens are demoulded after 1 day and immersed in water for curing and will be tested for flexural Strength.

SPLIT TENSILE STRENGTH TEST

The concrete cylinders (control specimen 6 nos each) of size 150mm x 300mm will be cast using conventional fine aggregate (CFA) and conventional coarse aggregate (CCA). For FAAC (6 nos for each of the three ratios), the specimens are cast with fly ash fine aggregate (FAFA) and fly ash coarse aggregate (FACA) obtained from the above three cement fly ash proportions. The specimens are demoulded after 1 day and immersed in water for curing and will be tested for Split Tensile Strength.

TEST PROCEDURE

COMPRESSIVE STRENGTH TEST

The concrete cubes of size 150mm x 150mm x 150mm will be tested as per IS 456-2000. The load will be applied on the specimens on Universal Testing Machine. The load will be applied without shock until the failure occurs.

FLEXURAL STRENGTH TEST

The Plain concrete and RCC beams of size 200mm x 150mm x 1000mm were tested as per IS 516-1959. The load will be applied through two similar rollers mount over the beam for the two span continuous beam specimens. The load will be applied without shock until the failure occurs.

SPLIT TENSILE STRENGTH TEST

The concrete cylinders of size 150mm x 300mm will be tested as per IS 456-2000. The load will be applied on the specimens on Universal Testing Machine. The load will be applied without shock until the failure occurs.

TEST RESULTS

COMPRESSIVE STRENGTH TEST

Compressive strength of fly ash aggregate concrete and control concrete with different Age of Testing

Age of Testing	Cement : Fly ash	Compressive Strength in N/mm2
7 days	12.5:87.5	12.56
	15:85	15.13
	17.5:82.5	12.95
	Control concrete	14.02
14 days	12.5:87.5	14.92
	15:85	19.85
	17.5:82.5	16.52
	Control concrete	16.73
28 days	12.5:87.5	16.23
	15:85	22.56

	17.5:82.5	17.35
	Control concrete	19.74
56 days	12.5:87.5	18.13
	15:85	26.01
	17.5:82.5	20.57
	Control concrete	22.14
90 days	12.5:87.5	18.68
	15:85	28.14
	17.5:82.5	21.41
	Control concrete	25.22

FLEXURAL STRENGTH TEST

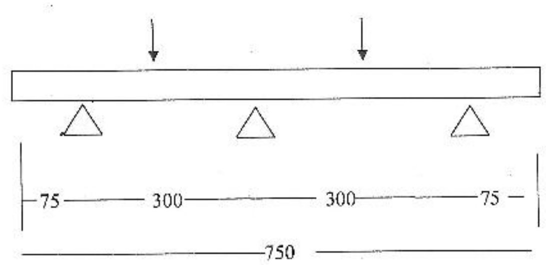
Flexural strength of fly ash aggregate concrete and control concrete with different Age of testing.

Age of testing	Cement : Fly ash	Flexural strength in N/mm2
7 days	12.5:87.5	4.15
	15:85	5.68
	17.5:82.5	3.12
	Control concrete	4.23
14 days	12.5:87.5	4.08
	15:85	5.73
	17.5:82.5	3.41
	Control concrete	4.55
28 days	12.5:87.5	3.85
	15:85	6.75
	17.5:82.5	4.56
	Control concrete	5.75

Ductility Test

The concrete beams of size 20cm x 15cm x 75cm were tested as per IS 516 1959. The load was applied through two similar rollers mounted over the beam for the two span continuous beam specimen as shown in figure 3.7.1. The load was applied without shock until the failure occurs.

Loading Arrangement for Ductility Test

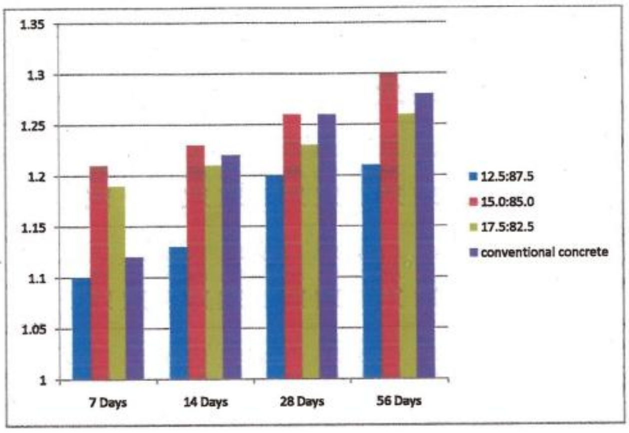


Test Results

Ductility Test

Ductility of Fly Ash Aggregate Concrete and Conventional Concrete with Conventional reinforcement

Age of testing	Proportion Cement: Fly ash	Ultimate load, Pu	Yield point load, Py	Ductility Pu /Py
7 days	12.5:87.5	77.25	70.00	1.1
	15:85	86.5	71.25	1.21
	17.5:82.5	82.25	69.00	1.19
	Conventional concrete	84.45	70.75	1.2
14 days	12.5:87.5	153.50	135.50	1.13
	15:85	172.00	139.75	1.23
	17.5:82.5	163.50	135.00	1.21
	Conventional concrete	168.50	138.00	1.22
28 days	12.5:87.5	202.50	169.00	1.20
	15:85	217.75	173.00	1.26
	17.5:82.5	211.25	171.75	1.23
	Conventional concrete	215.50	171.00	1.26
56 days	12.5:87.5	208.55	172.50	1.21
	15:85	227.50	176.50	. 1.30
	17.5:82.5	217.50	173.00	1.26
	Conventional concrete	221.75	172.00	1.3



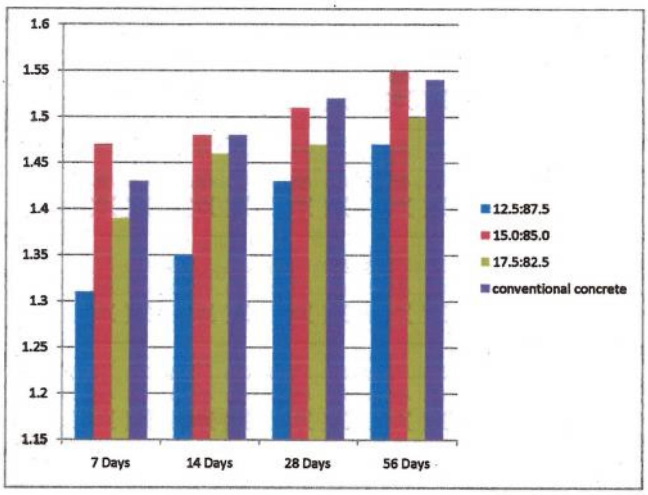
Ductility of Fly Ash Aggregate Concrete and Conventional Concrete with Conventional reinforcement

Discussion

At the initial days of curing, FAAC with cement and fly ash proportions 15:85 has shown Ductility greater than that of conventional concrete. At 28 and 56 days of curing, both FAAC and conventional concrete has shown the similar values of ductility.

Ductility of Fly Ash Aggregate Concrete Conventional Concrete with Steel Fibre

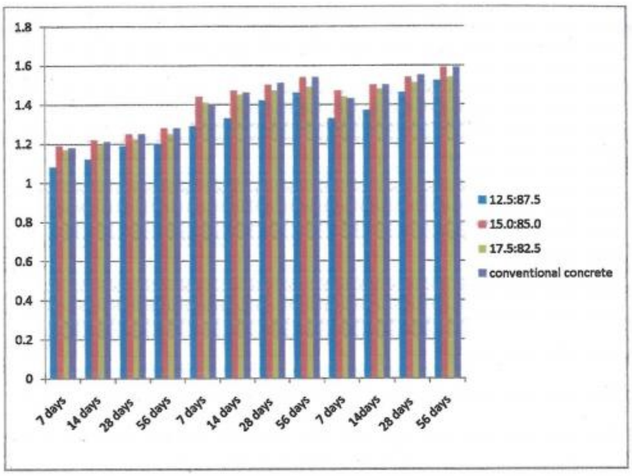
Age of testing	Proportion Cement: Fly ash	Ultimate load, Pu	Yield point load, Py	Ductility Pu /Py
7 days	12.5:87.5	116.75	88.5	1.31
	15:85	129.0	88	1.47
	17.5:82.5	122.75	88.5	1.39
	Conventional concrete	127.75	89.5	1.43
14 days	12.5:87.5	228.75	169.5	1.35
	15:85	258	174.25	1.48
	17.5:82.5	246	168	1.46
	Conventional concrete	253.75	171.75	1.48
28 days	12.5:87.5	301.75	210.5	1.43
	15:85	325.75	215.5	1.51
	17.5:82.5	316.75	213.75	1.47
	Conventional concrete	324	213	1.52
56 days	12.5:87.5	316.75	215	1.47
	15:85	341.25	220.25	1.55
	17.5:82.5	325.75	216.75	1.5
	Conventional concrete	332.25	214.25	1.55



Comparison of Ductility of FAAC and Conventional Concrete with SteelFibre

Discussion:

At the initial days of curing, FAAC with cement and fly ash proportions 15:85 and 17.5:82.5 has shown Ductility greater than that of conventional concrete. But the ductility of conventional concrete has shown a progressive increase upon increase in age of concrete and finally at 56 days of curing both CC and FAAC 15:85 has shown the same ratio of ductility.



Comparison of Ductility

Discussion:

At all the periods of curing, the fly ash aggregate concrete obtained from cement fly ash proportion 15:85 has consistency shown a ductility very much similar to the conventional concrete specimen

IV. CONCLUSION

The basic properties of Cement and Fly ash are studied.

- The Fly ash aggregates are formed under the three ratios of cement and fly ash proportions are 12.5:87.5, 15:85 and 17.5:82.5.
- The Specific gravity test and sieve analysis test were conducted on the both conventional and fly ash fine and coarse aggregate.
- The cube compressive strength of conventional concrete and fly ash aggregate concrete will be tested for 7 days, 14 days, 28 days, 56 days and 90 days of curing.
- Fly ash aggregate concrete cube with fly ash aggregates prepared from cement fly ash proportions 15:85 showed 11%, 15%, 14%, 13% and 8% increase in Compressive strength at the ages of 7days, 14days, 28days, 56days and 90days respectively over the control concrete.
- Fly ash aggregate concrete cube with fly ash aggregates prepared from other cement fly ash proportions 12.5:87.5 and 17.5:82.5, showed reduction in compressive strength at the ages of 7days, 14days, 28days, 56days and 90days respectively over control concrete.
- The beam flexural strength of conventional concrete and fly ash aggregate concrete will be tested for 7 days, 14 days and 28 days of curing.
- The fly ash aggregate concrete beam containing fly ash aggregate made from cement fly ash proportion 15:85 showed increase in flexural strength of 11%, 13% and 16% respectively at the ages of curing in 7days, 14 days and 28days than the control concrete beam.
- The cement fly ash proportions 12.5:87.5 and 17.5:82.5 showed reduction in flexural strength of 9% and 11% respectively at the age of curing in 7days and 11% and14% respectively at the age of curing in 28days than control concrete beam.
- The fly ash aggregate concrete cylinders with fly ash aggregate made from cement fly ash proportion 15:85 showed an increase in split tensile strength of 12%, 13% and 15% respectively at the ages of 7days, 14 days and 28days compared with control concrete specimens.
- The cement fly ash proportions of 12.5:87.5 and 17.5:82.5, showed reduction in split tensile strength of16% and 22% respectively at the age of curing in 7days and 15% and19% respectively at the age of curing in 28 days than control concrete specimen.
- Considering the depletion of natural sources and the effect on environment, the disposal problems involved in disposing fly ash, light weight characteristics of fly ash aggregates with good mechanical properties(Compression strength, Split Tension strength and Flexural strength) as seen in the above investigation, a particular attention may be focused on the usage of fly ash aggregates in concrete.

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