Experimental Investigation on Ductility in Fly Ash Aggregate Concrete

S.Judith Carmal
PG Research Scholar, Department of Civil Engineering
Sengunthar Engineering College (Autonomous),
Tiruchengode, TamilNadu, INDIA
s.judithcarmal@gmail.com
K.Mohan
Faculty of Civil Engineering, Department of Civil Engineering,
Sengunthar Engineering College (Autonomous),
Tiruchengode, TamilNadu, INDIA

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Abstract: Aggregate in concrete is structural filler, which occupies the most of the volume of the concrete 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. 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. 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 curing tank. The Ductility test and compressive strength test will be conducted on these plain and fly ash aggregate concrete specimens.
Keywords: Fly Ash, Compressive strength, Ductility, Shrinkage of concrete.

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 port land 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..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. 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.

2. LITERATURE REVIEW:

P.Aggarwal, Y. Aggrawal, S.M. Gupta: This paper presents the experimental investigation carried out to study the effect of use of bottom ash (the coarser material), which falls into furnace bottom in the modern large thermal power plants and constitute about 20% of total ash content of the coal fed in the boiler as a replacement of fine aggregates. The various strength properties studied consist of compressive strength, flexural strength and split tensile strength. The strength development for various percentages (0-50%) replacement of fine aggregates with bottom ash can easily is equated to the strength development of normal concrete as various ages

Gao li-xiong Research on a sintered fly ash aggregate is presented. The aggregate was manufactured through material orthogonal test and quick chilled firing schedule test. It displayed high strength (7.8 MPa) and low water absorption (4.2%). Light weight concrete aggregate made with this aggregate reached compressive strength more than CL60,slump over 20cm, 60minutes slump loss then 2cm, and expansibility higher then 50cm. such properties meet the high strength and pump-ability. This new technology has important economic and social impacts on the use of industrial waste residue and on the environmental protection.

Priyadharshini.P, Mohan Ganesh.G, Santhi.A.S. This paper mainly focuses on manufacturing process of light weight aggregates using curing has been done in cold bound technique. The properties of these fly ash aggregates have been tested and compared with natural gravel and the study shows that cold bounded fly ash aggregates can be used as aggregate replacement material in concrete. The strength property and density of concrete made with artificial fly ash aggregates and natural gravel were also studied which conforms that introduction of fly ash in concrete reduces the compressive strength but the required strength to be used as a structural material.

Anurag Misra. The experiments were conducted using a mix proportion of cement (1): sand (1.57): 10mm aggregates (1.35): 20mm aggregates (2.03) with four water to cementitious material(Cement + Fly Ash)ratios (w/cm) (0.55, 0.475, 0.40 and 0.340).the cement replacement by fly ash was varied between 0 to 50%. Compressive strength and water absorption tests were conducted on each of the twenty-four mixes. The sorptivity of concrete was compared with that of the control concrete. The results indicated that higher volume of cement replacement and lower w/cm ratios have lower values of cumulative water absorption and sorptivity. There was a small reduction in 28 days compressive strength of concrete within increase in fly ash content. However, it was found to be almost the same or marginally higher than that of control mix at 90 days.

T Seshadri Sekhar. Whereas concrete containing fly ash as partial replacement of cement poses problems of delayed early strength development, concrete containing fly ash as partial replacement of fine aggregate will have no delayed early strength development, but rather will enhance its strength on long-termbasis. In this investigation fly ash is used as sand replacement material.The material mix of proportion 1:1:45:2:46:0.5. Each category comprises of various percentages of sand replacement material in increasing order i.e. 46%, 47%, 48%, 49%, 50%, 51%, 52%, 53%, 54% and 55%. The workability is maintained constant for all mixes. Strength characteristics such as compressive strength, flexural strength, split tensile strength of concrete mixes are found out for 7 and 28 days curing period and results are analysed.

Pofale AD Deo This paper presents an approach to increase the utilization of fly ash and conserve scarcely available natural sand for sustainable development. The control cement mortar mixes indicated 50% to 100% increase in the compressive strength of mortar at 91 days. Replacement of 50% sand with fly ash can save about 0.4m^3sand.Comparison of cost per N/mm^2 compressive strength has shown about 40% to 60% saving in cost. Sand was replaced with 10% to 50% of fly ash by weight and cost at 0.5, 0.55, 0.6 and 0.65 W/C ratios was used. Flow test performed for mortar revealed that as the percentage replacement of sand with the fly ash increased the flow of the mortar decreased. It was also observed that wet and dry densities were more than the control mortar for 10% and 20% replacement of sand with fly ash but for higher replacement percentage density reduced marginally.

P.Kumar Mehta. For a variety of reasons, the concrete construction industry is not sustainable. First, it consumes huge quantities of virgin materials. Second, the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in global warming and climate change. Third, many concrete structures suffer from lack of durability which has an adverse effect on the resource productivity of the industry. Because the High-volume fly ash concrete system addresses all three sustainability issues, its adoption will enable the concrete construction industry to become more

- Reduced expansion due to ASR
- Improved hot weather handling characteristics
- Reduced corrosion damage

Sushantupadhyaya, G Goulias, Karthikobla.

Objective of this study was to demonstrate using maturity based techniques that the beneficial effects of high in place temperature may be able to compensate for the slower rate of strength gain in HVFA concrete. Furthermore, different methods (match cured cylinders, pull out testing) estimating the early-age in-place strength of HVFA concrete were examined so as to confirm the maturity predicted strengths. The results have shown that the use of standard and field cured cylinders actually penalized estimates of concrete strength in the field. Higher in place due to the mass characteristics of structural element clearly led to increased early age strengths.

3. MATERIAL AND METHODS:

Cement 43 grade ordinary Portland cement is used for the study program and the specific gravity of cement was found to be 2.85. The test of physical, chemical and strength properties of cement was conducted.

Fly ash 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. Sio_2, Al_2o_3, is equal to greater than 70%, so 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.

Fine aggregate For ordinary Concrete River sand was used in preparing the concrete as it is locally available in sand quarry. The specific gravity was found to be 2.7. The natural fine aggregate was compared with fly ash aggregates prepared from various cement fly ash proportion.

Coarse aggregate For ordinary concrete 20mm normal size grades aggregate was used. The specific gravity was found to be 2.58. The natural coarse aggregate was compared with fly ash aggregate prepared from various cement fly ash proportion.

Water Ordinary tap water of MPNMJ Engineering College was used in the preparation of concrete.

Constituents for fly ash aggregates

Cement and fly ash are constituents for preparation of the aggregate; also water is the binder where it is added to increase the workability. Three different proportions are taken and subjected to pelletisation process.

Proportions of cement fly ash

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.

Pelletisation

It is a process of agglomeration of moisturised fines in a rotating drum or disc, to produce 'fresh pellets' having enough for further handling. Formation of pellets is based on the mechanisms involved in balling phenomenon of powdery materials. When a fine-grained material is moisturized, a thin liquid film develops on the surface of each grain and bridges are formed at points where the moisturized particles contact each other. The particle rotated into balls bonding forces develop gradually. The initial bonding between particles is due to a water bridge or meniscus. When more liquid is added, the liquid film on the particle surface began to coalesce, but closed and air-filled cavities remain between the grains. The ball grows as more moisturized particles are coated into the nucleus. Mechanical forces, produced by the balls bumping against each other and against the walls of rotating device, expel the air enveloped in the balls. At this capillary stage, the liquid fills the free space between the particles. The filled capillary forces affect the particle coherence throughout the whole ball. The concave membrane on the surface of the liquid seals surface pores. Under uneven or excessive moisturizing, particle clusters are enveloped in the droplets that tend to produce large, irregular entities. Grain size distribution and surface texture of material influence the efficiency of pelletisation process. In the present study green pellets were produced from a mixture of fly ash, ordinary Portland cement and water as binder in the concrete mixer, which performed as a pelletiser.

Figure 3.1 Fly ash aggregates

Processing and curing of fly ash aggregates

The prepared green pellets are allowed to dry for a day. Fly ash aggregates are than placed under water for 7 days curing.

Segregation of fly ash aggregates

The cured aggregates are allowed to dry completely for 24 hours and segregated as fine and coarse aggregates based on particle size. Sieving is adopted for the separation of aggregates.

The aggregates passing through 20mm sieve and retained on 4.75mm sieve are taken as coarse aggregate and the aggregates passing through 4.75mm sieve and retained on 2micron sieve are taken as fine aggregates.

Figure 3.2. Segregation of fly ash aggregates.

4. MIX DESIGN

By weight
Cement=416 kg
Sand=636.95 kg
Coarse aggregate=1112.97 kg
Water=208 kg
Mix proportion=1:1.53:2.68:0.5

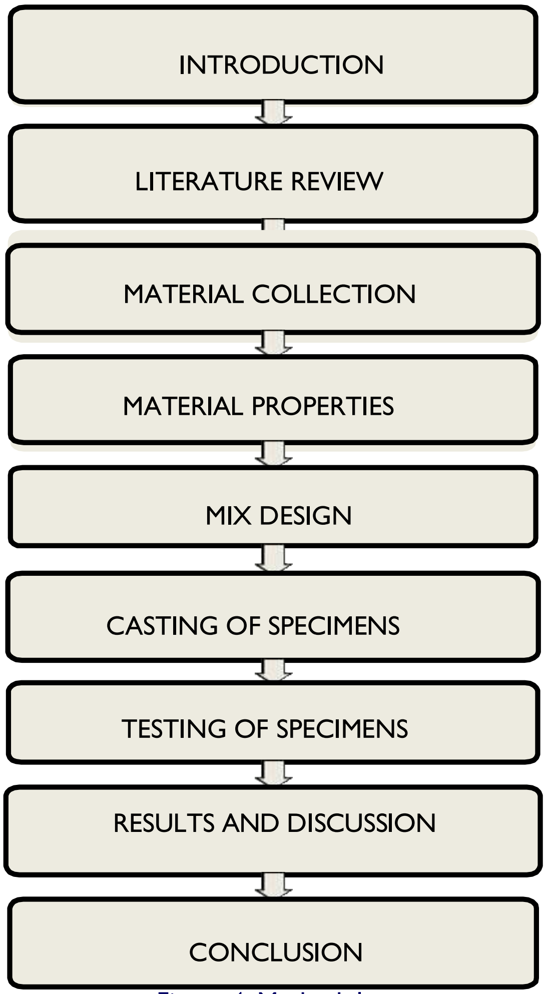

Figure 4: Methodology

By volume
Cement=1440kg/m^3
Sand=1498 kg/m^3
Coarse aggregate=1453 kg/m^3
Water=1000 kg/m^3

$C=416/1440=0.289m^3$
$S=636.95/1498=0.425m^3$
$Ca=1112.97/1453=0.766m^3$
$W=208/1000=0.208m^3$
Mix proportion=1:1.47:2.65:0.50
Materials per bag of cement
C=50kg
S=50/416x636.95=76.55 kg
Ca=50/416x1112.97=133.77 kg
W=50/416x208=25 kg
Yield of concrete per bag of cem. 50/416=0.126 m^3
Yield of concrete per bag of cement=0.12 m^3

TEST RESULTS AND DISCUSSION

Table 5.1 Fineness test

Types of cement	Cement sample	Weight of sample W_1)g	Weight of residue (W_2)g	Percentage weight of residue W_2/W_1x100	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%

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
Weight of sample taken = 500gm
Fineness modulus =2.82

Table 5.3 Particle size distribution of fine aggregate

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	-

Table 5.4 Particle size distribution of conventional coarse aggregate

Sieve size	Weight of particles retained	% retained	Cumulative % 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

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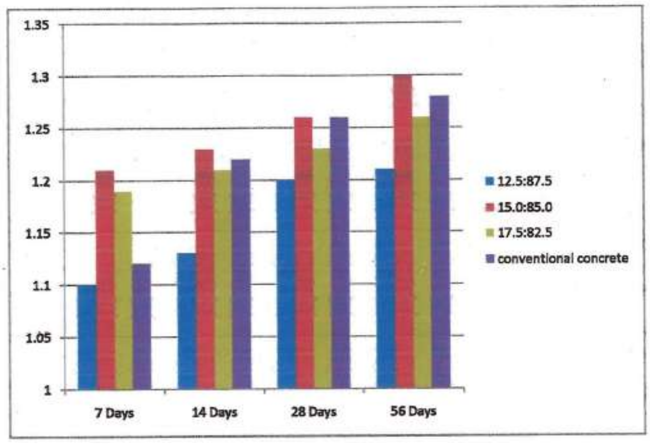


Table 5.5. Compressive strength of fly ash aggregate concrete and control concrete with different Age of Testing

Age of Testing	Cement : Fly ash	Copressive 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

Table 5.6 Ductility of Fly Ash Aggregate Concrete and Conventional Concrete with Conventional reinforcement

Age of testing	Proportion Cement: Fly ash	Ultimate load, P_u	Yield point load	Ductility P_u /P_y
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

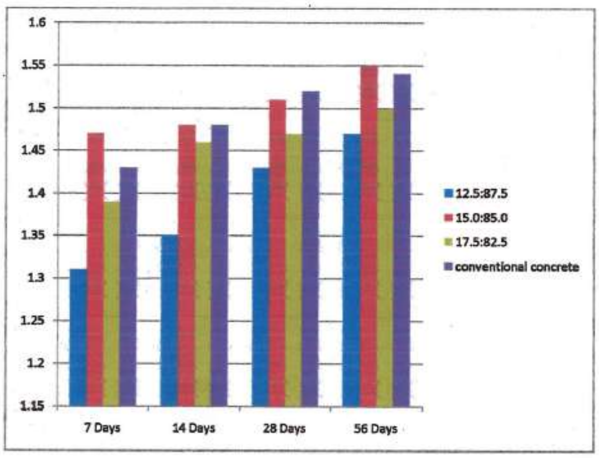
Discussion At the initial days of curing, FAAC with cement and fly ash proportions 15:85 has shown Ductility greater than that of conventional concrete. At 28 and 56 days of curing, both FAAC and conventional concrete has shown the similar values of ductility.

Table 5.7 Ductility of Fly Ash Aggregate Concrete Conventional Concrete with Steel Fibre

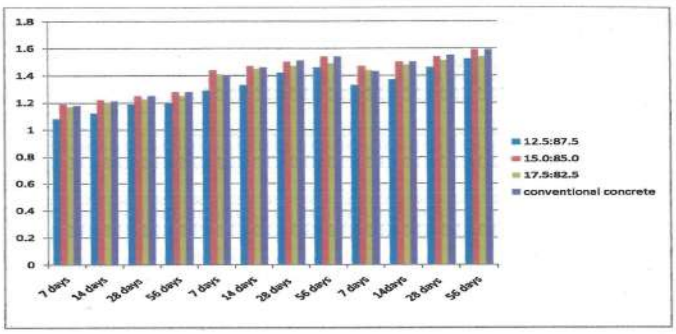
Age of testing	Proportion Cement: Fly ash	Ultimate load, P_u	Yield point load, P_y	Ductility P_u/P_y
7 days	12.5:87.5	116.75	88.5	1.31
	15:85	129.0	88	1.47
	17.5:82.5	122.75	88.5	1.39
	Conventional concrete	127.75	89.5	1.43
14 days	12.5:87.5	228.75	169.5	1.35
	15:85	258	174.25	1.48
	17.5:82.5	246	168	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

6. 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.

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