Flexural Behaviour of RC Beam With Pond Fly Ash And ESP Fly Ash

Manikandan P[1], A.Sasi Kumar[2]
[1, 2] Dept of Civil Engineering
[1, 2] NSN College of Engineering and Technology, Kaur - 639003, Tamilnadu, India.

Abstract- *The use of Supplementary Cementitious Materials (SCM) such as Fly ash, Granulated Slag and Silica fume as a replacement for Portland cement in concrete presents one viable solution with multiple benefits for the sustainable development of the construction industry. Out of various supplementary materials, Fly ash is the most widely used material worldwide. Fly ash has excellent structural and durability characteristics. The pore filling effect and pozzolanic properties of Flyash improves the properties of fresh and hardened concrete. In addition to the cost saving by the replacement amount of cement; it reduces co2 emission during the manufacture of Portland cement.*

In the present investigation, a controlled beam and six number of ESP flyash and Pond flyash beams of size 200 x 100 x 1700 mm were cast. This paper deals with the investigation on the flexural behaviour of beam with pond flyash and ESP (Electro static precipitated) flyash at various cement replacement levels of 4%, 6%, and 8% and the results are compared with controlled beam. The flexural test was conducted to determine the ultimate load carrying capacity of the beams and their corresponding mid span deflection, load point deflection, crack pattern, Stress vs strain are measured.

The flexural strength of ESP flyash is increased 24.76% for 8% replacement level and pond flyash is increased 10.97 % for 6% replacement level than controlled beam respectively. This study revealed that the replacement of cement by flyash concrete provides higher compressive strength & flexural strength compared with controlled concrete.

I. INTRODUCTION

We are constantly faced with ever-large economical problems associated with the emission of CO2 in to the atmosphere. The increasing scarcity of raw materials and an urgent need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power station and is creating unmanageable disposal problems due to its potential to pollute the environment. The utilization of by-products as the partial replacement of cement has important economic, environmental and technical benefits such as the reduced amount of waste materials, cleaner environment, reduced energy requirement, durable service performance during service life and cost-effective structures. It is well known that blending cement with fly-ash improves the rheological properties of hardened concrete. These improvements are generally attributed to both the physical and chemical effects.

The flyash production amounts to approximately 60-100 million tons per year at present in the country and this is likely to exceed 175 million tons by the end of 2009 and therefore, will become a serious problem as far as availability of land and pollution hazards are concerned. In India only 2% of the produced flyash is currently being utilized and there is vast scope for its effective utilization. At present there are more than 72 thermal power stations in India. Safe environment-friendly disposal of these ashes is of major concern. Hence attempts should be made to utilize ash rather than dumping the same thereby losing thousands of hectares of land. Conventionally about 15-30% of cement is being replaced in the concrete with flyash. But investigations have tried even with higher percentages (up to 70%) and achieved good results particularly in pavement and marine structures and roller compacted concretes.

ESPFlyash

According to ACI 116R, Flyash is a finely divided residue resulting from the combustion of ground or pulverised coal, which is transported from the fire box through the boiler by flue gases. The air borne particles are removed by mechanical collectors, electrostatic precipitators, or wet scrubbers. Nearly using electrostatic precipitator collects 99% of flyash.

Flyash looks very similar to cement in appearance. However, when magnified, flyash will appear as spherical particles, similar to ball bearings, whereas cement appears angular, more like crushed rock. Flyash has cementiticeous qualities and therefore, can be used as a replacement of a portion of the cement in a concrete mix. Chemically flyash is amorphous, Ferro – alumna silicate mineral with major matrix elements like Si, Al, Fe together with significant amount of ca, k, Na, and Ti.

The use of blended cement is associated with a number of advantages, which could be divided in to the following two main categories: ecology and energy saving benefits and improvements in properties of concrete.

POND FLYASH

In order to avoid the environmental pollution, at the plant itself the flyash is mixed with water in 1: 20 proportion and discharged into pond. The pond occupies so many hectares of land and having number of sluices at different levels. When storing the slurry in the pond, the water drained away through the sluices for Irrigation purpose. After that the ash gets dried and it can be utilized by cement factories, filling works etc. This type of flyash is known as POND FLYASH.

Current ASTM standards allow the use of 25% maximum by weight of pond fly ash to be induced in the amount of cementitious materials used in construction work.

BENEFITS OF USE OF FLY ASH-To Environment

The use of Flyash decreases landfill disposal. Coal – Fired Power plants are the No-1 source of electricity in this country and will likely continue to be the No -1 because coal is America's most abundant energy resource. Currently only about one-third of the Flyash produced in this country is recycled. The balance (roughly 42 million tons) is disposed of in landfills, which is roughly equivalent to 80% of volume of all cement produced in this country.

The use of Flyash decreases CO_2 emissions. The cumulative impact of producing on ton of cement is the release of one ton of CO_2 into the atmosphere. Replacing cement in concrete applications with flyash has the potential of reducing, or at the least capping, the CO_2 released into the atmosphere through cement production.

To produce Ready-Mix concrete

A ready mix producer has several reasons for using Flyash in Concrete
Flyash can compensate for fines not found in some sands and thereby enhance pump ability and concrete finishing.
Flyash will result in a more predictable and consistent finished product that will ensure customer acceptance.
Flyash improves the flow ability of the concrete, which translates into less wear and tear on all the producer's equipment from batching facilities to trucks.

Scope and objectives of the Present Investigation

The production of every tone of Portland cement contributes about one ton of CO_2in the atmosphere. Minor amounts of $NO_2$and CH_4 are also released into the atmosphere. The process of producing ordinary Portland cement releases large amount of carbon dioxide (CO_2) cement plants and processes have been modernized to cut down on CO_2emission.

The other avenue is to reduce cement demand by substituting supplementary cementitious materials like flyash, silica fume, slag etc. for part of the cement in concrete mixes for Eco-smart concrete project, a locally spearheaded national program to reduce greenhouse gas emissions associated construction.

Cementitious materials, which can replace some of the cement, include industrial by-products such as Flyash, Blast furnace slag, Rice hush ash, Metakaolin, Silica fume etc. to ordinary Portland cement. This technology is well established globally and it produces blended cements with ensured quality standard consistently. These supplementary cementitious materials posses properties which impact certain desirable characteristics to the concrete mix which can enhance the strength and durability of concrete. Of course, a number of tests and a lot of processing of these materials have to be carried out before they can be suitably blended with cement.

Most of the studies are focused on the improvement of physical and mechanical properties of flyash in concrete.

Objectives of the Present Investigation

The objectives of the present investigation are
To study the physical properties of pond fly ash, ESP fly ash and cement.
To study the mechanical properties of pond fly ash and ESP fly ash under various percentage of replacement levels
To study the behavior of fly ash reinforced concrete beam in flexure for load –deflection behavior, patterns of cracks, moment of resistance and load at first crack.
To determine the flexural behaviour of RC beam with pond fly ash and ESP fly ash as cement replacement

Experimental Investigation

In this investigation, studies are carried out to compare the performance of pond flyash and ESP flyash added concrete and conventional concrete in terms of flexural strength. Grades of concrete play an important role in assessing the durability factor. For this reason M20 grade of concrete is used in this investigation

Test Method

1. Physical properties
2. Strength properties
3. Flexural Strength

II. RESULTS AND DISCUSSIONS

The results of the tests that were performed to evaluate the strength and serviceability criteria of ESP fly ash and pond fly ash reinforced concrete beam specimen reported in this chapter. The influence of fly ash in concrete is investigated and the final results are tabulated, sets of charts are also presented to get a comparative study between the controlled RCC and fly ash blended reinforced concrete under normal condition.

Properties of Materials

CEMENT ESP FLY ASH AND POND FLY ASH

Dalmia 43 grade cement and ESP fly ash and Pond fly ash from Neyveli Thermal power station is used throughout this investigation**.** The tests conducted on cement and ESP flyash and pond flyash were specific gravity, surface area and their values are given in the following tables.

Specific gravity of cement ESP flyash and pond flyash

Table: 5.1

Sl.No	Material	Specific Gravity
1	Cement	3.13
2	ESP fly ash	2.27
3	Pond fly ash	2.15

Physical Properties of Cement and ESP Fly Ash and Pond Fly ash

Table: 5.2

Sl. No.	Material	Specific Surface in cm^2/gm
1.	Ordinary Portland Cement	3976
2.	ESP fly ash	4015
3	Pond fly ash	5688

The Specific Surface of the Fly ash is higher than the Ordinary Portland cement, which indicates the fineness of Fly ash is more than the OPC. From the above table(5.2) the specific surface area of ESP flyash and pond flyash is more as compared with opc.

The development of earlier strength is mainly due to this specific surface area. So we can get the maximum earlier strength by using ESP flyash and pond flyash with cement.

CHEMICAL PROPERTIES OF ESP FLY ASH

Table 5.3 shows the chemical properties of flyash, in which the silica content is more where as the other constituent Iron, Alumina, Cao, Mgo, sodium, Potassium and sulphate found comparatively low. The presence of silica content reacts with the calcium hydroxide results from hydration process of Portland cements and form gel. These gel formations increase the strength of matrix.

Table:5.4

Sl. no	Ingredients	cement	Pond flyash	ESP flyash
1.	Loss on ignition	3.12	6.0	1.81
2.	Silica Dioxide (SiO2)	20.25	43.78	61.75
3.	Ferrous oxide (Fe2O3)	3.16	14.83	5.05
4.	Aluminium oxide (AL2O3)	5.04	15.21	17.63
5.	Calcium oxide (CaO)	65.61	12.97	9.16
6.	Magnisium oxide (MgO)	4.56	4.03	2.34
7.	Sulphite (SO3)	0.79	2.70	1.96
8.	Sodium oxide (Na2O)	0.08	0.39	0.28
9.	Potassium oxide (K2O)	0.51	0.09	0.02

FINE AGGREGATE

The fine aggregate used in this investigation was clean river sand passing through 4.75mm sieve fine fineness modulus of 2.25 and specific gravity of 2.67.the particle size distribution is given in the table: 5.5

Test particulars	Result obtained
Specific gravity	2.67
Fineness modulus	2.25
Size	Passing through 4.75mm sieve

Coarse Aggregate

For the high strength concrete, the maximum size aggregate should be less. So size of crushed angular aggregate used in this experiment was between 12.5mm and 4.75mm with the specific gravity of 2.6 and fineness modulus of 5.96. The particle size distribution of coarse Aggregate was given in the table5.6

Test particulars	Result obtained
Specific gravity	2.6
Fineness modulus	5.96
Size	Passing through 20mm sieve and retained in 10mm sieve

Water

Potable water generally considered satisfactory for concreting purpose. Since the present investigation involves comparison of performance of concrete in normal environments.

Locally available potable water obtained from source of college pore well was used for mixing and curing for normal concrete.

MIX PROPORTION AND MIX DESIGNATION

In this study, Indian Standard method was used to design the concrete mix of grade M20. The mix was designed for good degree of control. The details of mix design are given in the appendix II. The mix proportion is presented in table 5.5

Cement kg/m^3	Coarse aggregate kg/m^3	Fine aggregate kg/m^3	w/c lit/m^3
383	546.7	1187	191.6

Mix proportion1:1.42:3.09 w/c = 0.50

Table: 5.6

Replacement level	Cement kg/m^3	ESP flyash and pond flyash replacement
control	383	-
4 % replacement	367.68	15.62
6% replacement	360.02	22.98
8% replacement	352.36	30.64

EFFECT OF ESP FLY ASH ON THE STRENGTH PROPERTIES OF POND FLYASH AND ESP FLYASH WITH REINFORCED CONCRETE

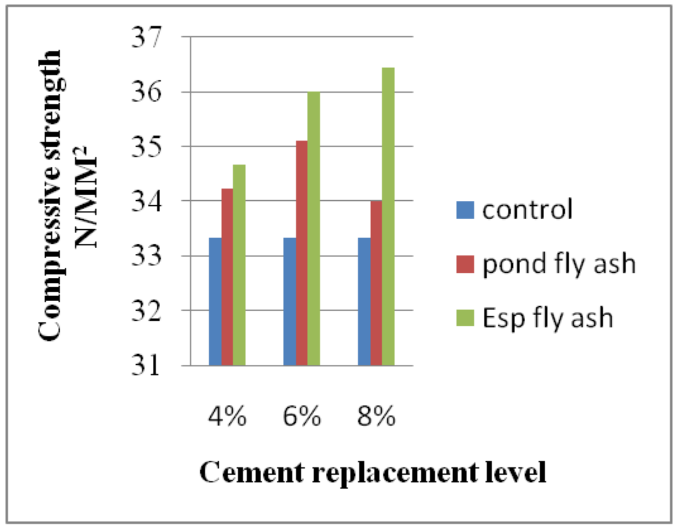
Compressive Strength Test-Table-5.6

Sl.No	% of Replacement	Pond fly ash @ 28 days(N/MM^2)	ESP fly ash @ 28 days(N/MM^2)
1	4%	34.22	34.67
2	6%	35.11	36
3	8%	33.78	36.89

Compressive strength for control M20 grade cube is $33.33N/mm^2$

From the strength data obtained, it was observed that the critical level is 6% for Pond fly ash. Beyond 6% replacement level reduction in compressive strength was observed. The free lime present in cement reacts with silica in flyash it will form a strong component called calcium hydro silicate (CHS)

For 4 % replacement of ESP shows 4.02% increasing when compared with controlled concrete as compared with 4 % replacement of pond flyash shows 2.67 % increasing when compared with controlled concrete. ESP flyash shows 1.315% increasing when compared with pond flyash.



FLEXURAL STRENGTH TEST

The ESP flyash and pond flyash beams with various replacement levels were cast. The Flexural test for the beams will be conducted, after the curing period 28 days.

Table: 5.7

Sl.No	Load in KN	Deflection at mid span in mm	Deflection at load points in mm	Remarks
1	0	0	0	
2	5	0.5	0.35	
3	10	1.25	1.1	
4	15	1.92	1.75	
5	20	2.75	2.39	First crack
6	25	3.12	2.77	
7	30	3.45	3.2	Second crack
8	35	4.05	3.75	
9	40	4.56	4.25	
10	45	5.6	4.58	
11	50	7.38	6.42	
12	55	8.5	7.35	
13	60	11.2	9.4	
14	63.8	14.9	13.92	Ultimate load

Total load carrying capacity = 63.8 KN

Comparative results of beams

Specimens	Ultimate load (KN)
Control	63.8
ESP flyash @4%	69.5
ESP flyash @6%	74
ESP flyash @8%	79.6
Pond flyash @4%	68.4
Pond flyash @6%	70.8
Pond flyash @8%	64.5

While considering the ESP flyash for all replacement level, the first and second crack were found at 20 KN and 30 KN respectively. But the ultimate load varied with various percentage of replacement level. The maximum load carrying capacity was obtained at 8% replacement level is 79.6 KN which is 24.76 % greater than controlled concrete.

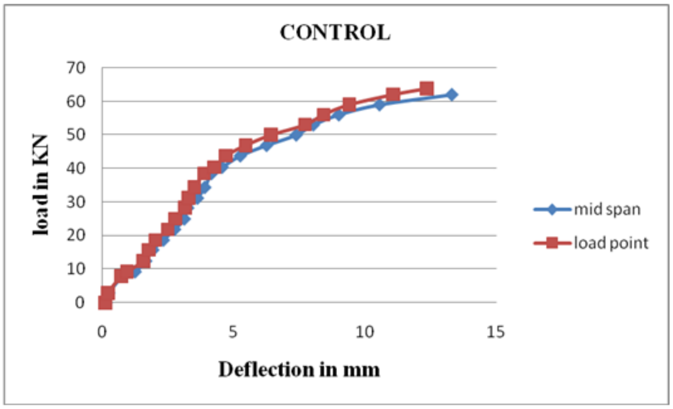
While considering the pond flyash for all replacement level, the first and second crack were found at 20 KN and 25 KN respectively. But the ultimate load varied with various percentage of replacement level. The maximum load carrying capacity was obtained at 6% replacement level is 70.8 KN which is 10.97 % greater than controlled concrete.

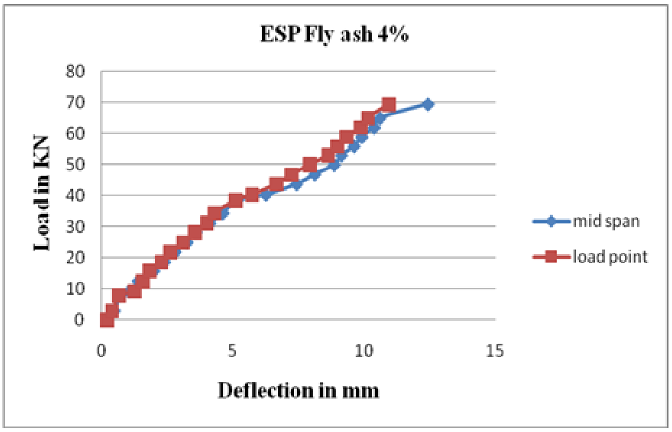
While considering the ESP flyash and pond flyash for all replacement level the ultimate load varied with various percentage of replacement level. The maximum load carrying capacity was obtained for ESP flyash at 8% replacement level is 79.6 KN and The maximum load carrying capacity was obtained for pond flyash 6% replacement level is 70.8 KN which is 12.42 % greater than ESP flyash concrete.

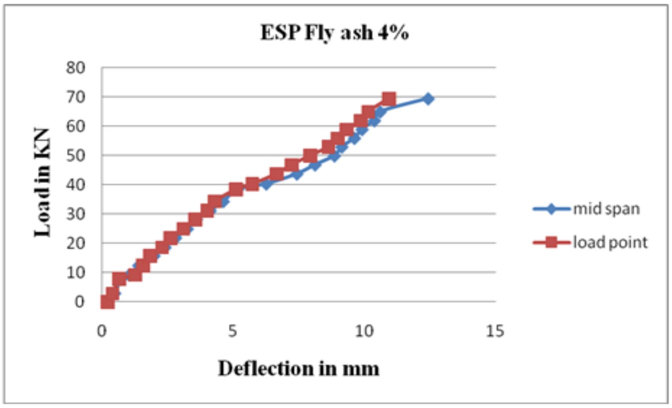
From the results obtained it may be concluded that the 4%, 6%, 8% ESP fly-ash replacement of cement shows a higher value in all appreciable characteristics than the controlled specimens.ESP fly ash increasing 8.93%, 15.98%, 24.76 for 4%, 6%, 8% ESP fly-ash replacement, Pond flyash increasing up to 6% replacement.

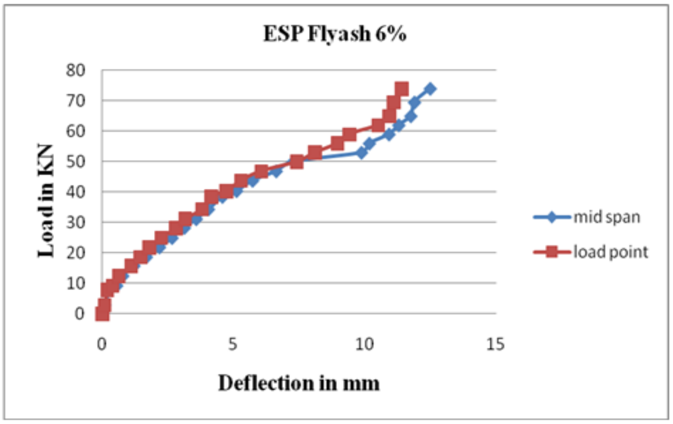
LOAD DEFLECTION CURVE

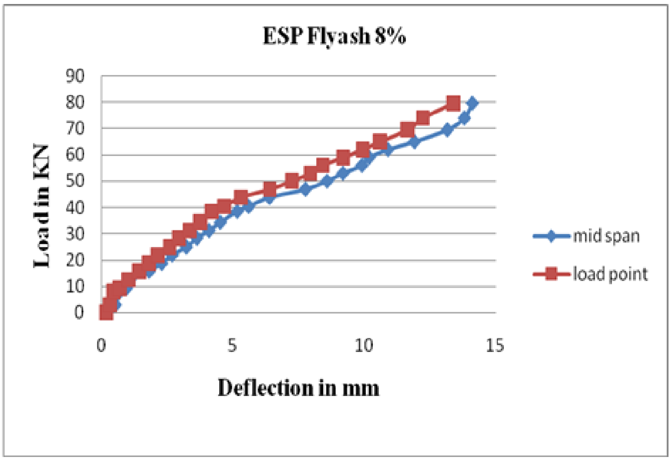
The control beam, presented on approximately linear load deflection behaviour until the yield point of reinforcing steel with ultimate failure load is 63.8 KN large and deep cracks in the constant bending moment. The beams ESP flyash and pond flyash@4%, 6%, 8% exhibited almost linear load deflection behaviour. From the table it is observed that the load increases as the deflection increases

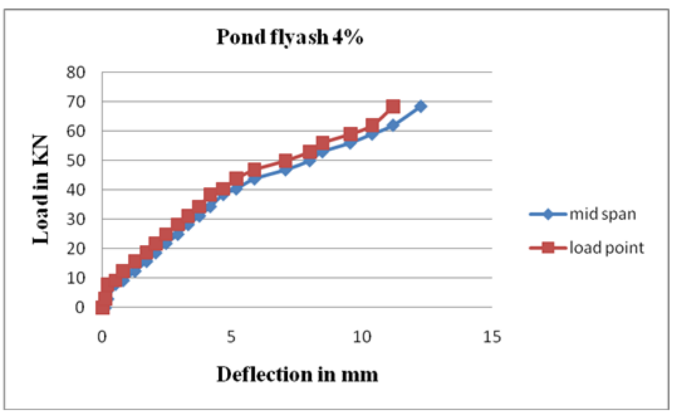


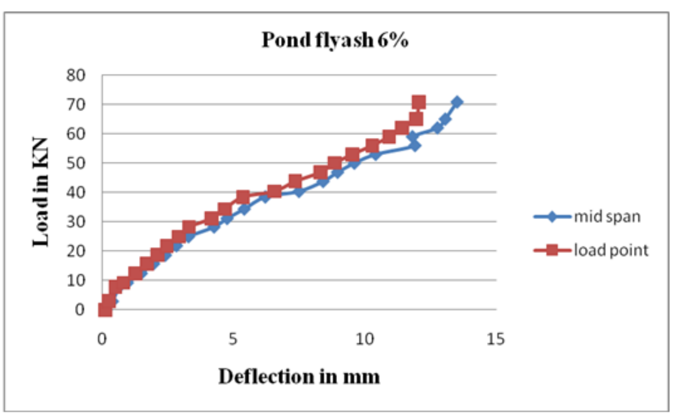


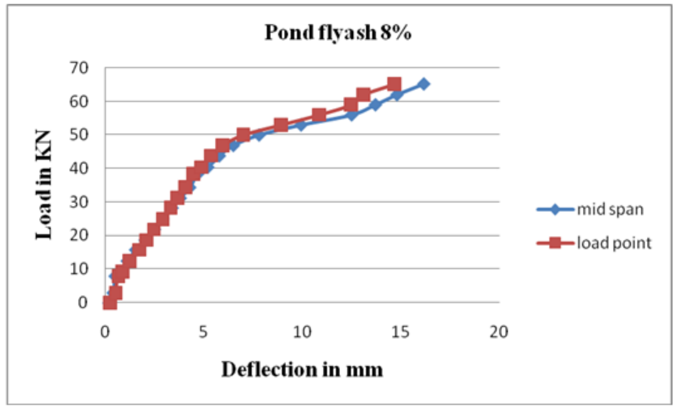


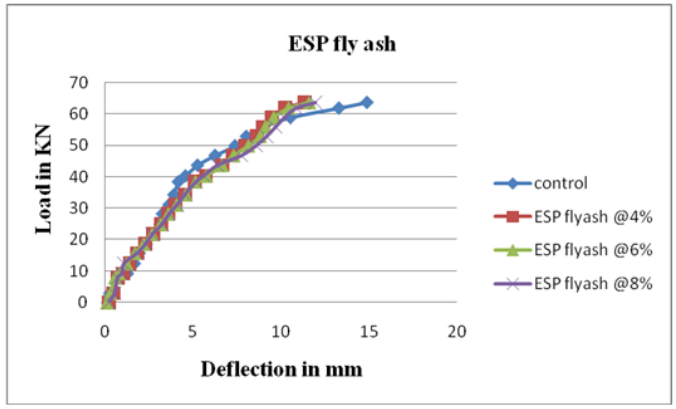


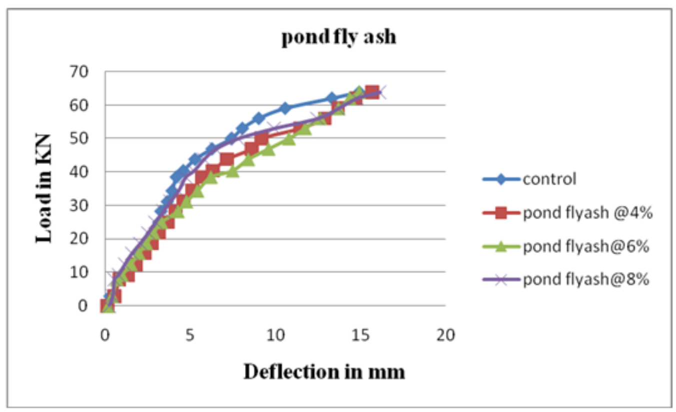












From the load vs deflection curve the controlled beam ulitmate failure load is 63.8 KN for ESP flyash is 79.6 KN and 70.8 KN for pond flyash. Deflection for ESP flyash and Pond flyash is less than controlled concrete.

Behavior of crack

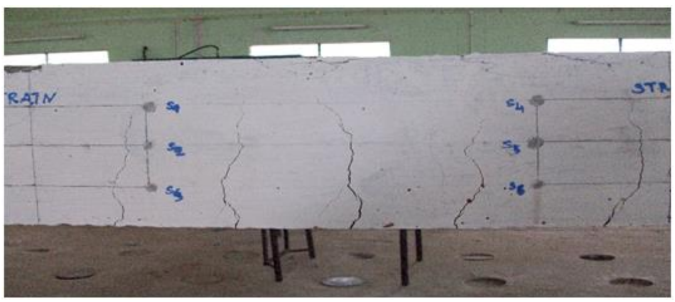
The controlled beam shows large and deep cracks in the constant bending moment zone. The beam continued to deflect under fairly constant load.

The beams ESP flyash and pond flyash@4%, 6% and 8% replacement shows the flexural behaviour of the flyash reinforced concrete beam may be described as follows.

During the first crack loading of reinforced concrete on the specimen when the applied load reached first crack load, further increases of loading, resulted in formation of additional cracks. The cracks were initiated at the tension side of beam and propagated towards the compression side of the beam. On further application of load, the cracks in flexural zone were get widened and finally the beam failed by flexure. Different types of cracks occurred in the beam are.

FLEXURAL CRACK

The failure is characterized by an excessive elongation of steel followed by the crushing of concrete. As bending loads are increased, excessive elongation of the steel raises the neutral axis closer to the compression face at the critical section. Large deflection and wide cracks are the characteristic features of flexural crack.



SHEAR CRACK

Shear at a section of a beam is the algebraic sum of all the external loads and reactions on any side of it; Maximum shear occurs near the supports. Tensile and compressive stress which are set up due to bending are greatest in the flanges or extreme edges of the beam and decreases to zero at neutral axis, and are normal to the section.

III. CONCLUSIONS

- From the specific surface area results the ashes (ESP flyash and pond flyash) having more specific area than the cement this will leads to form strong gel while adding water. The formation of this gel leads to reduce the segregation of aggregate.
- The cube compressive strength of ESP flyash replaced concrete is higher than the controlled concrete and pond flyash replaced concrete is higher than the control concrete up to 6% replacement.
- The water demand of concrete containing fly-ash increases with increasing amount of fly ash. The increase is primarily due to the high surface area of the fly ash..
- The ultimate load resisting capacity of Pond fly ash replaced R.C beams are higher than the controlled R.C beams up to 6% replacement is 10.97% and ESP flyash replaced R.C beams are higher than the controlled R.C beam is 24.76%
- Hence from this study it can be recommended the cement may be replacement by pond flyash is increasing 7.21% and 10.97 % for 4%, 6% replacement level respectively and ESP fly ash increasing 8.93%, 15.98%, 24.76 for 4%, 6%, 8% ESP fly-ash replacement.
- From the results obtained it may be concluded that the ESP fly-ash Pond flyash replacement of cement shows a higher value in all appreciable characteristics than the controlled specimens.

IV. SCOPE FOR THE FUTURE WORK

- The present study can be extended for future research with consideration to the following points.
- Shear behaviour can be studied by casting more number of beam specimens by varying the percentage of reinforcement.
- Different percentage in reinforcement can be tested for flexural behaviour.
- Corrosion resistance test can be studied for long term durations.
- Durability studies can be extended for long term studies for much better results.
- Analytical models can be developed and compared with experimental program.

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