An Experimental Study on Fly Ash Pellets in Concrete Replacing Coarse Aggregate

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Abstract— The quantity of fly ash produced from thermal power plants in India is approximately 80 million tons each year and its percentage utilization is less than 10%. During the last few years, some cement companies have started using fly ash in manufacturing cement, known as Pozzalanic Portland cement. It mainly concentrated on replacement of cement with fly ash but production of artificial aggregate with fly ash helps in utilizing large volume of fly ash in concrete. 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. In this present investigation an attempt is made by partial replacing of coarse aggregate with fly ash pellets. For preparing fly ash pellets a ratio of 15:85 (cement: fly ash) is considered throughout investigation. The main objectives of the present work is focused on preparing light weight aggregates and to find optimum replacement of fly ash pellets and to identify the chemical compounds formed in different replacements (of fly ash pellets in coarse aggregate) by assessing the spatial variations in the chemical compositions which was done by using XRD studies. Based on the above mix ratio, fly ash aggregate are prepared and same aggregates were used for casting the cement concrete cubes, cylinders and same were tested for compressive strength at 3,7,28,60 and 90 days curing period and compared with Controlled concrete. Split tensile strength, Acid attack test also done and compared with the Controlled concrete. The results revealed that the compressive strength properties of concrete is increased significantly up to 20% replacement of fly ash aggregate and later on strength decreased for 30%, 40% replacements of fly ash aggregate.

Key words: Concrete, Fly ash Pellets, Natural Coarse Aggregate, Compressive Strength, Split Tensile, Acid Attack

I. INTRODUCTION

Generally, now a day's solid waste is the major problem in any countries. Solid wastes are materials and masses dumped outside by various human activities. These are the some of the examples of solid waste materials industrial waste, medical waste and domestic waste. In particular construction waste is the output results of removal of external structure, rehabilitation, destruction, construction and installations. This waste consists of stone, sand, gravel, tiles, ceramic, glass, marbles, wood, plastic, paper, plumbing pipes and other materials. In that stones, gravel and sand waste is more when compared to the other material. These are the natural available material especially coarse aggregate is available at queries. These materials we are going to be saving and replacement of coarse aggregate by another material. That material we are going prepare by using fly-ash. The fly ash is a fairly divided residue which results from the combustion of ground or powdered bituminous coal or sub-bituminous coal like lignite and transported by the flue gases of boilers fired by pulverized coal or lignite. It is a by-product of many thermal power stations and other plants using pulverized coal or lignite as a source of heat for boilers. On burning, nearly 75% of which is fine fly-ash and 30% of coal is converted into ash and the rest is coarse bottom ash. The fly-ash flies through the chimneys can be minimized by installing and proper working of fabric filters, mechanical dust collectors and electrostatic precipitators. The fly ash resembles a pozzolana i.e. a substance which although not cementitious itself contains constituents which combine with the lime to form a material having cementing properties. Normally, the fly ash contains some unburnt carbon. It is acidic in nature and its main constituents are silica, aluminium oxide and ferrous oxides. There are more than 70% thermal power plants in our country and to cope with the increasing demand of electricity, more thermal power plants may be set up in near future. It is expected that by the turn of century, the quantity of fly ash available will touch the figure of 1000 million kN per annum. The disposal of such large quantities of fly ash is certainly a gigantic problem and a matter of national concern

II. LITERATURE REVIEW

V. R. Prasath kumar, K. S. Anandh, Midhun kumar. V found out in this project an experimental investigation is done on the partial replacement of coarse aggregate with fly ash aggregate. It mainly concentrated on replacement of cement with fly ash but production of artificial aggregates with fly ash helps in utilizing large volume of ash in concrete. 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. This paper mainly focuses on manufacturing process of light weight aggregates. The production of fly ash aggregate is produced in ratio of 10:90, 15:85 and 20:80.Basedupon the above mix ratio, fly ash aggregates are produced and used for casting the concrete cubes and cylinder for comparing the strength with conventional aggregate concrete at 7 and 28 days curing period.

Priyadharshini. P, Mohan anesh. G, santhi. A .S "Experimental study on Cold Bonded Fly Ash Aggregates", this paper mainly focuses on manufacturing process of 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 compared with natural gravel and the study shows that cold bonded fly ash aggregates can be used as an 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 confirms that introduction of fly ash aggregates in concrete reduces the compressive strength but

meets the required strength to be used as a structural material.

Harilal B. and Job Thomas "concrete made using cold bonded artificial aggregate" found out property of concrete made from cold bonded aggregate from fly ash and quarry dust are studied in this paper. The aggregate are manufactured through polarisation method in different proportion of fly ash and quarry dust with ordinary Portland cement as binder. The tests carried out in concrete are porosity, compaction factor and compressive strength of 28 days for different water cement ratio 0.35, 0.45, 0.55 and 0.65. The results indicate that the usage of above aggregate in concrete is an alternative for natural aggregate in concrete industry and future practice in concrete also reduces the environmental impact.

A. Siva kumar and P. Gomathi, "Pelletized fly ash lightweight aggregate concrete: A promising material", In recent times, the addition of artificial aggregates has shown a reasonable cut down in the construction costs and had gained good attention due to quality on par with conventional aggregates.

S. Lokesh, M. G. Ranjith Kumar, S. Loganathan, "Effective Utilization of High Volume Fly ash with Light Weight Aggregate in Concrete for Construction Industry" carried out fly ash is also used as pozzolanic material for partial replacement of Portland cement in the light weight aggregate concretes. Such light weight aggregate concrete with high volume fly ash cement has all the attributes of high performance concrete i.e. excellent mechanical properties, lower permeability, superior durability and environmental friendly nature. Incorporation of silica fume in small quantities in high volume light weight aggregate concrete is likely to compensate the deficiency occurring in initial days. The results of the investigation reported here in, have shown that the light weight aggregate concrete made with cement mortar in combined use of fly ash with silica fume, has improved the strength development in initial days.

III. Materials

A. Cement

Ordinary Portland Cement is graded according to strength, the other cements too have to gain a particular strength 33, 43 and 53 grade in OPC indicates the compressive strength of cement after 28 days when tested as per IS: 4031-1988. Cement used in the present study is Anjani 53 Grade.

B. Fly Ash

Fly ash is a byproduct of the combustion of pulverized coal in thermal power plants. A dust-collection system removes the fly ash, as a fine particulate residue, from combustion gases before they are discharged into the atmosphere. The types and relative amounts of incombustible matter in the coal used determine the chemical composition of fly ash. More than 85% of most fly ashes is comprised of chemical compounds and glasses formed from the elements silicon, aluminum, iron, calcium, and magnesium. Generally, fly ash from the combustion of sub bituminous coals contains more calcium and less iron than fly ash from bituminous coal; also, fly ash from sub bituminous coals contains very little unburned carbon. Plants that operate only intermittently (peak-load stations) and that burn bituminous coals produce the largest percentage of unburned carbon. Fly-ash particles are typically spherical, ranging in diameter from <1 µm up to 150 µm.

C. Fine Aggregate

The sand used throughout the experimental work ws obtained from Vijayawada, Krishna district, Andhra Pradesh. Sand was thoroughly washed with tap water to remove impurities like decayed vegetable matter, humus, organic matter and deleterious materials like clay, fine silt and fine dust and was oven dried for 24 hours and cooled to room temperature and hence care was taken for the sand used in the investigation.

D. Coarse Aggregate

Coarse aggregates are generally used as crushed stones. The maximum size of the coarse aggregates is used in our work as 20 mm.

E. Water

The locally available potable water is free from concentration of acid and organic substances and it has a neither taste nor odour. This type of water is used for mixing the concrete. In this theses water-cement ratio are taken as 0.5.

IV. Preparation of Fly-Ash Aggregates

Basically there are four steps for preparing fly ash aggregate given below.

- Formation of fly ash aggregate.
- Proportion of fly ash aggregate.
- Preparation of fly ash aggregate.
- Drying and curing of fly ash aggregate.
- Segregation of fly ash aggregate.

There are the main classifications for preparing the fly ash aggregate

A. Formation of Fly Ash Aggregates

The materials like cement, fly ash and water to form the fly ash aggregate. Water is the binding material gives fly ash aggregate with good bonding property and also water is added to the concrete to increase the workability

B. Proportion of Fly Ash Aggregate

We are going to prepare the fly ash aggregate and the proportions of fly ash aggregate in the ratio of cement fly ash ratio is 15:85. And water is going to add that cement fly ash ratio is 0.3.

C. Preparation of Fly Ash Aggregate

The fly ash coarse aggregate was prepared by mixing the cement and fly ash in 15:85 ratio. First the required quantity of fly ash is taken in the mixer machine and then the cement quantity is put in the mixer for 15:85 ratio. Now for mixing take the water cement ratio as 0.3. The water added slowly to the mixer. As the mixer rotates the fly ash combine and form a spherical shaped aggregate formed.

Fig. 1: Fly Ash Aggregate

D. Drying and Curing of Fly Ash Aggregate

After formation of spherical aggregate by using cement fly ash ratio. That aggregate was taken out from mixer and allowed for a day. Then the aggregate were cured in a water tank for 7 days.

E. Segregation of Fly Ash Aggregate

After curing, they were segregated into fine and coarse aggregate based on the size of the pellets as shown in figure. The aggregate having size less than 4.75 mm were sieved as fine aggregate and more than 4.75 mm were sieved as a coarse aggregate. From them 20 mm size coarse aggregate were sieved separately to use them as coarse aggregate. Fly ash aggregate were prepare by using cement fly ash proposition 15:85 and water added to that mix at 0.3. And mixer is rotated until to form aggregate. The contents were thoroughly mixed in the drum until the complete formation of fly ash aggregate is called "pelletisation".

V. EXPERIMENTAL INVESTIGATION

A. Compressive Strength

The compressive strength for fly ash aggregate concrete and conventional concrete were tested at the end of 7, 14, 21, 28, 56 and 90 days using compressive strength testing machine. The water cement ratio was taken as 0.50. Two cubes were casted for each sample and the average of two test samples is taken for the accuracy of the results. At room temperature, the concrete cubes were cured. The values of crushing loads obtained are tabulated in table and the values of compressive strength obtained are shown in table. The average reduction in compressive strength is nearly increasing up to 20% and decreasing after 20% i.e. at 30 and 40%.

Test day	Compressive strength of concrete containing Fly ash aggregate concrete N/mm^2				
	0%	10%	20%	30%	40%
3	17.5	22.18	24.21	22.53	21.2
7	21.7	24.66	26.88	25.3	24.215
14	23.8	24.78	26.9	25.77	24.22
21	26.25	26.83	28.21	26.78	25.32
28	33.8	28.7	35.67	28	26.12
56	37.1	32.45	38.9	30.85	29.1
90	42.1	42.9	43.6	33.55	31.99

Table 1: Compressive Strength values for Different Percentages of Fly ash Aggregate used in Concrete

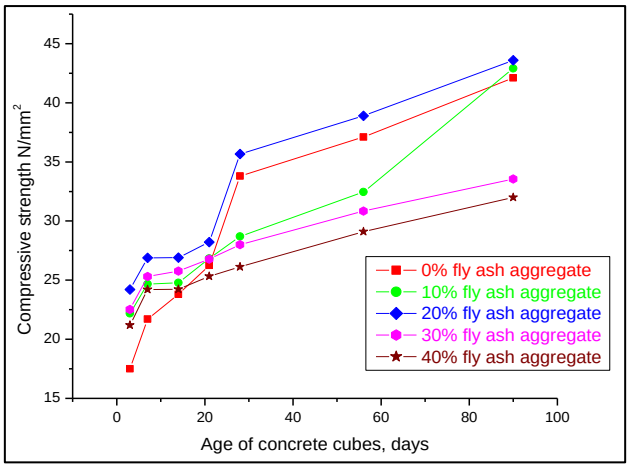

Fig. 2: The different ages of compressive strength for different percentages of fly ash aggregates

B. Split Tensile Strength

The test was carried out conforming to IS 5816-1999 to obtain Split tensile strength of concrete at the age of 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000KN. Then it is tested for different percentage fly ash aggregate replaced as sand in concrete.

S. No	Fly ash %	Tensile Strength for 28 days
1	0	2.2
2	10	2.264
3	20	2.123
4	30	2.112
5	40	2.045

Table 2: Split tensile Strength Values for Different Percentages of Fly ash Aggregate used in Concrete

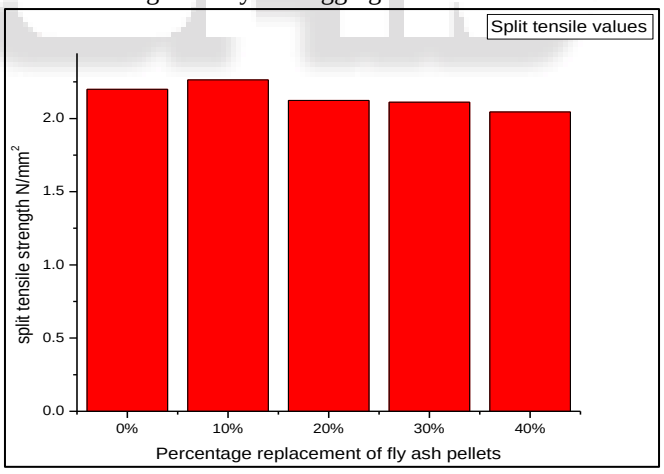

Fig. 3: Split Tensile Strength for 28 days

C. Acid Attack test

The action of acids on concrete is the conversion of calcium compounds into calcium salts of the attacking acid. These reactions destroy the concrete structure. The percentage of loss in weight was given in the following tables respectively. As per IS 516, cubes of sizes 150mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack 5% dilute hydrochloric acid is used. The cubes were to be immersed in acid solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were

taken from acid solution. The surface of specimen was cleaned and weights were measured.

Fly ash agg (%)	weight curing of the cubes (gm)	weight after 56 days	Weight reduced (gm)	% of weight reduced
0	8310	8125	185	0.022
10	8200	7990	210	0.025
20	7895	7615	280	0.354
30	7610	7440	170	0.023
40	7449	7350	99	0.013

Table 3: Weight Loss Acid Attack Values

S. No	Percentage of replacement of fly ash pellets	Normal Compressive strength N/mm^2	Acid attack Compressive strength N/mm^2
1.	0	42.1	42.1
2.	10	42.9	39.5
3.	20	43.6	36.8
4.	30	33	31.11
5.	40	31.99	26.66

Table 4: Comparison between Compressive strength values for conventional concrete cubes and acid attack

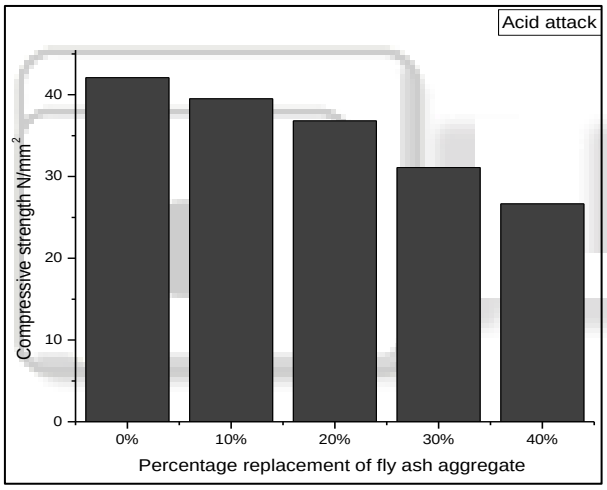

Fig. 4: Compressive strength values for acid attack test

D. Water Absorption Test

Water absorption (WA) tests were carried out on 150 x 150 mm cube specimen at the age of 28 and 90 days curing as per ASTM C 642. The specimens were weighed before drying. The drying was carried out in a hot air oven at a temperature of 105 oC. The dried specimens were cooled at room temperature and immersed in water. The specimens were taken out at regular interval of time, surface dried using a clean cloth and weighed. This process was continued till the weights became constant. The difference between the measured water saturated mass and oven dried mass expressed as % of oven dry mass gives the WA. The water absorption was calculated as % of water absorbed = (Ws-Wd) X 100/Wd. Where,

Ws = weight of specimen at fully saturated condition

W_d = weight of oven dry specimen

Fly ash agg (%)	weight curing of the cubes (gm)	weight after 28 days	Water absorbed (gm)	% of water absorption
0	8310	8407	97	1.168
10	8200	8285	85	1.036
20	7895	7973	78	0.988
30	7610	7673	63	0.828
40	7449	7504	55	0.73

Table 5: Water Absorption of Concrete Cubes

By adding different percentage of fly ash aggregate in concrete the split tensile values are recorded in the above table. With increasing of fly ash aggregate in concrete the split tensile values are slightly decreasing. By adding 10% replacement of fly ash aggregate as coarse aggregate in concrete the split tensile value is decreasing by 63.48%. At 20% replacement the split tensile strength value is decreased by 65.75%. At 30% replacement the split tensile strength value is decreased by 65.95%. At 40% replacement of fly ash aggregate as coarse aggregate in concrete the split tensile strength value is decreased by 67.01%. In this project the results of compressive strength values, split tensile strength values with replacement of fly ash aggregate in concrete obtained are compared to the results obtained without replacement of fly ash aggregate in concrete. The following conclusions are obtained from this project. To prepare the concrete by using fly ash aggregate used as fly ash aggregate replacement in concrete then the workability of concrete decrease with respect to increasing of fly ash aggregate content in concrete. By using water quantity constant (0.5) to the entire project then the workability is increased because fly ash aggregate absorbs more water quantity to prepare the concrete. So, workability improvement can be achieved.

Compressive strength of concrete is depending on the quality of aggregates and fly ash aggregate products in concrete. When best quality aggregates are used for the concrete production then the recycling products does not affect the compressive strength. In this project fly ash aggregate used as recyclable product. It is replaced as coarse aggregate into the concrete and it is slightly influence (increases) the compressive strength at 20% replacement level and then further replacement the compressive strength value decreases as compared to conventional concrete. The amount of water absorption is dependent on the aggregates and quantity of recycling fly ash aggregate particles. The replacement of fly ash aggregate content increase then the amount of water absorption is slightly increased. Water absorption is mainly dependent on the porosity of aggregates. Fly ash aggregate has less porosity then the concrete cube absorbs more water quantity because fly ash absorbs more water when compared to the other materials. Based on the results of the load tests on the cubes and cylinders, it is concluded that used coarse aggregate type and quantity has no significant influence on the pattern and width of cracks. First, crack appears in the middle of the span at a load level equal to about one third of the ultimate load regardless of the concrete type. The measured crack widths were approximately the same for all specimens.

E. X-Ray Powder Diffraction Analysis

X-Ray diffraction analysis has been used for the finger print characterization of pozzolanic material and for the determination of their crystal structures. The basis of the diffraction phenomenon is that the wavelength of the incident radiation (i.e., X-rays) is in the order of magnitude

of the inter atomic distance in the crystalline solids. Therefore, when an X-ray beam falls on a crystalline material, it will be diffracted by the incidence angle given by Bragg's law:

$2d \sin\theta = n\lambda$

The XRD results of ordinary Portland cement with partial replacement with 20%, 30% by fly ash pellets are presented

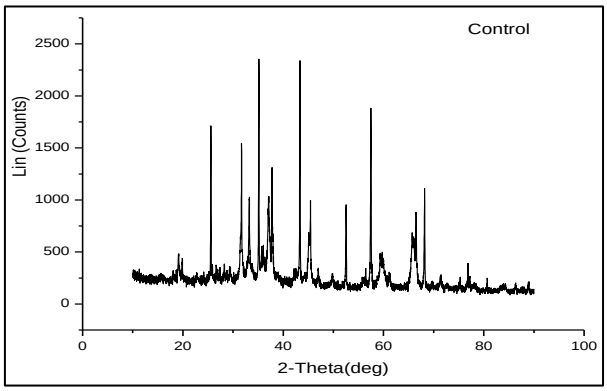

Fig. 5: XRD Results for Control Concrete Mix

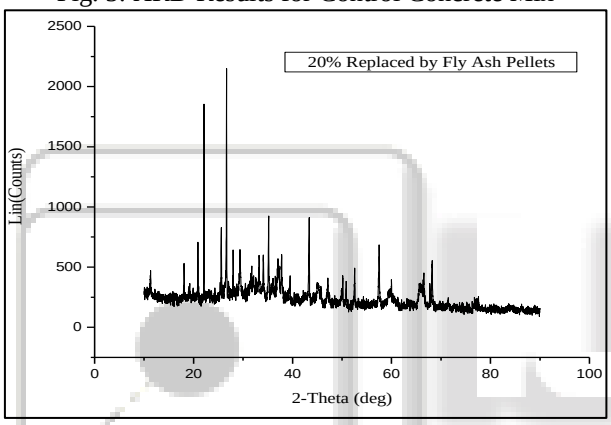

Fig. 6: XRD Results for 20% Replaced by Fly Ash Pellets

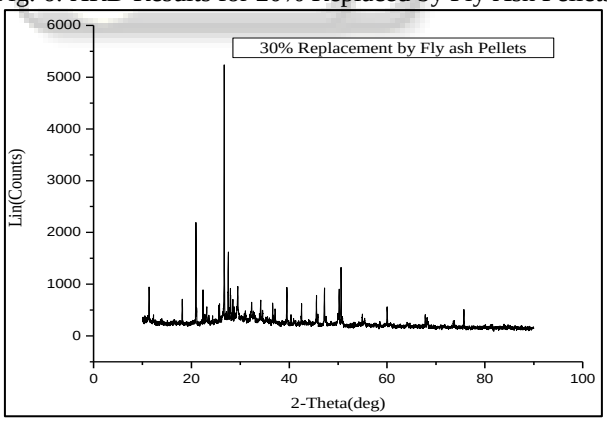

Fig. 7: XRD Results for 30% Replaced by Fly Ash Pellets

The XRD results show that the Hexagonal structure is changed to Monoclinic with the inclusion of Flyash pellets with replacement of 20%, 30% by weight and the 2θ angle is around 26^0 in both the cases, which are identified by comparing the results with standard JCPDS data.

VI. CONCLUSION

The following conclusions are made based on the comparative analysis of conventional concrete properties of test results to the replacement of fly ash aggregate as coarse aggregate into the concrete test result values.

- With increasing of fly ash aggregate as coarse aggregate into the concrete then the workability is decreased gradually as compared to the conventional concrete.
- By using fly ash aggregate particles into the concrete the water absorption quantity should be increases gradually with increasing of fly ash aggregate.
- Compressive strength of concrete is dependent on the use of fly ash aggregate product.
- By increasing the replacement of fly ash aggregate in concrete the compressive strength will be decreasing gradually.
- At 20% replacement level of fly ash aggregate used as coarse aggregate in concrete the compressive strength is increased as compared to conventional concrete and further it goes to decreasing.
- In developing countries like India it is difficult to dispose this waste because it causes different environmental problems.
- So, by this project it is proved that fly ash aggregate used as coarse aggregate replacement at 20% in conventional concrete practices.
- It can be seen that the replacement percentage of fly ash is between 5% to 20%, maximum strength is obtained at 20 %.
- Split tensile values are decreased by the replacement of fly ash aggregate
- While doing the acid curing test it is observed that the compressive strength of concrete replaced with fly ash aggregate is decreased.
- By the use of fly ash aggregate we can reduce the use of natural aggregate. Then the scarcity of aggregates can also be reduced.

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