ISSN (e): 2250 – 3005 || Vol, 04 || Issue, 12 || December – 2014 ||
International Journal of Computational

A Study on Partial Replacement of Natural Granite Aggregate with Pelletized Fly Ash Aggregate

[1]Dr. V.Bhaskar Desai , [2,] A.Sathyam

[1] Professor, Dept. of Civil Engineering, JNTUA College of Engineering, Anantapuramu – 515002, A.P.
[2] Conservation Assistant Gr-I, Archaeological Survey of India, Anantapuramu Sub Circle, Central Stores Road,
Anantapuramu & Research Scholar, JNTUA College of Engineering, Anantapuramu – 515002, A.P.

ABSTRACT : *In this paper the use of pelletized fly ash aggregate in concrete as a partial replacement of granite aggregate has been examined. The concrete so produced is light weight in nature and the development of such concrete with cold bonded pelletized fly ash aggregate is to minimize the conventional aggregate, which results in protection of the natural environment. With the partial replacement (0%, 25%, 50%, 75% and 100%) of natural granite aggregate by pelletized fly ash aggregate, the strength properties of concrete such as compressive strength, split tensile strength, flexural strength and young's modulus of elasticity are studied.*

KEY WORDS: *Pelletization, cold bond, fly ash, light weight aggregate.*

I. INTRODUCTION

Presently, in the construction industry throughout the world most of the concrete prepared is with natural granite aggregate as a major constituent. It's extensive usage results in geological and environmental imbalance. Also naturally available granite aggregate resources get depleted and it will be left nothing for future generations. Hence there is a necessity for preparing artificial aggregates making use of waste materials from agricultural products and industrial wastes. From the earlier studies, it appears that much less attention has been made towards study of usage of artificial coarse aggregate. An attempt has been made to use fly ash as the basic ingredient in preparing the artificial coarse aggregate which is also light in nature.Fly ash, a by-product of coal based material collected from Rayalaseema Thermal Power Plant (RTPP), Muddanur village of Andhrapradesh state has been used in this investigation. It consists of vitreous particles with a surface area is around 8.20 m^2/gm when measured by nitrogen absorption techniques with particles approximately 100 to 150 times smaller than the cement particle. Because of its extreme fineness, it is an effective pozzolanic material and is used in concrete to improve its properties. One of the main properties of fly ash is its pozzolanic reactivity; hence it is suitable for most of its applications in various areas.

II. REVIEW OF LITERATURE

The Pelletization process is used to manufacture light weight Coarse aggregate. Some of the parameters need to be considered for the efficiency of the production of pellets are speed of revolution of pelletizer disc, moisture content, and angle of pelletizer disc and duration of Pelletization (HariKrishnan and RamaMurthy, 2006)[1]. In the cold bonded method increase of strength of pellets is by increase the fly ash / lime & cement ratio by weight. Moisture content and angle of drum influence the size growth of pellets. Different types of pelletizer machines earlier were used to make the pellets such as disc or pan type, drum type, cone type and mixer type. With mixer type pelletizer small grains are formed initially and are subsequently increased. The dosage of binding agent is more important for making the fly ash balls. Initially some percentage of water is added to the binder and remaining water is sprayed during the rotation period because while rotating without water in the drum, the fly ash and binders (Lime & Cement) tend to form lumps and do not ensure the even distribution of particle size. The pellets are formed approximately in duration of 6 to 7 minutes. The cold bonded pellets are hardened by normal water curing method. The aggregates so prepared are fly ash based light weight aggregates(Gal'pern et al. 1990; Voortam et al. 1998; Watanable)[2-4]. The pelletized fly ash aggregate is light weight in nature and its use in concrete reduces the self weight of the structure (Bomhard, 1980; Roberts, 1992)[5, 6] besides attaining better thermal insulation properties. It is known that from the recent basic studies that the pelletized silica fume aggregate gives satisfactory strengths (Bhaskardesai and Sathyam, 2013)[7]. The setup of machine for manufacture of fly ash aggregate is as shown in plate 1.

(Owens, 1993)[8] has stated that Light weight aggregate concrete is used for structural purposes since the 20th century. As per this study, the Light weight aggregate concrete is a material with low unit weight and often made with spherical aggregates. The density of structural Light weight aggregate concrete typically ranges from 1400 to 2000 kg/m³ when compared with that of normal weight aggregate concrete whose density is around 2400 kg/m³.(Siva lingaRao et al. 2011)[9] concluded that 60 percent replacement of conventional aggregate with cinder by volume along with cement replaced by 10 percent of silica fume by weight, yields the target mean strength of M20 concrete. It is worth to be noted that there is a slight increase in strength and other properties due to extended curing periods and the unit weight of the cinder concrete varies from 1980 kg/m³ to 2000 kg/m³ with different percentages of cinder.

III. MATERIALS:

The following materials are used for this investigation and properties of materials are shown in table 1.

Tab. 1 MECHANICAL PROPERTIES OF MATERIALS

Sl.No	Name of the material	Properties of material	Result
1	OPC – 53 Grade	Specific Gravity	3.07
		Initial setting time	60 min
		Final Setting time	489 min
		Fineness	4.00 %
		Normal consistency	33.50 %
2	Fine Aggregate passing 4.75mm sieve	Specific Gravity	2.60
		Fineness modulus	3.24
3	FA Aggregate passing 20 – 10 mm	Specific Gravity	1.70
		Fineness modulus	4.69
		Bulk density compacted	1056 Kg/m³
4	Natural Aggregate passing 20 – 10 mm	Specific Gravity	2.68
		Fineness modulus	3.37
		Bulk density compacted	1620 Kg/m³
5	Water	Locally available potable water which is free from concentration of acids and organic substances has been used in this work.	

The constituent materials are presented from plate 2 to 7.

IV. EXPERMENTAL INVESTIGATION

An experimental study has been conducted on concrete with partial replacement of conventional coarse aggregate i.e., granite by light weight aggregate i.e., FA aggregate. The test program consists of carrying out compressive tests on cubes, split tensile tests on cylinders, modulus of elasticity tests on cylinders and flexural strength on beams. Analysis of the results has been done to investigate effect of FA aggregate on the properties such as compressive strength, split tensile strength, flexural strength and modulus of elasticity. Variations of various combinations have been studied.

V. CASTING OF SPECIMENS

The M_{20} concrete mix is designed using ISI method which gives a mix proportion of 1:1.55:3.04 with water cement ratio of 0.50. Five different mixes have been studied which are designated as follows as presented in table 2:

Tab. 2 DESIGNATION DETAILS OF SPECIMENS

Sl. No	Name of the Mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		No of specimens cast and tested		
		Natural aggregate	Pelletized Fly Ash Aggregate	Cubes	Cylinders	Flexure beams
1	FA-0	100	0	6	12	6
2	FA-25	75	25	6	12	6
3	FA-50	50	50	6	12	6
4	FA-75	25	75	6	12	6
5	FA-100	0	100	6	12	6
	Total specimens			30	60	30

To proceed with the experimental program initially steel moulds of size 150x150x150 mm were cleaned brushed with machine oil on all inner faces to facilitate easy removal of specimens afterwards. First fine aggregate and cement were added and mixed thoroughly and then conventional coarse aggregates with partially replaced FA aggregate was mixed with them. All of these were mixed thoroughly by hand mixing. Each time 3 no of cubes and 6 no of cylinders were cast. For all test specimens, moulds were kept on the plat form and the concrete was poured into the moulds in three layers each layer being compacted thoroughly with tamping rod to avoid honey combing. Finally all specimens were vibrated on the table vibrator after filling up the moulds up to the brim. The vibration was effected for 7 seconds and it was maintained constant for all specimens and all other castings. However the specimens were demoulded after 24 hours of casting and were kept immersed in a clean water tank for curing. After 28 and 90 days of curing the specimens were taken out of water and were allowed to dry under shade for few hours.

VI. TESTING OF SPECIMENS

The cube or cylindrical specimen was kept vertically between the platens of the testing machine. The load is applied uniformly until the specimens fails, and ultimate loads were recorded. The test results of cube and cylinder compressive strengths are furnished in table 3 and 4 respectively. The cylindrical specimen was kept horizontally for finding the split tensile strength and the test results are furnished in table 5. The density and the ratio of cylinder to cube compressive strength results are furnished in table 6 & 7 respectively. An attempt to find out the modulus of elasticity has been done by the 3000 KN automatic compression testing machine with 0.5 KN/sec rate of loading. The results of modulus of elasticity are furnished in table no 8. The loading arrangement to test the specimens for flexural strength is simply supported over the span of 500mm. The loading was applied on the specimen using 15 ton pre-calibrated proving ring at regular intervals. The load was transmitted to the element through I- section and two 16mm diameter rods were placed at 166.67mm from each support. For each increment of loading the deflection at the centre and at 1/3rd points of beam were recorded using dial gauge. Continuous observations were made. Before the ultimate stage the deflection meters were removed and the process of load application was continued. As the load was increased the cracks got widened and extended to top and finally the specimen collapsed in flexure. At this stage the load was recorded as the ultimate load. The results have been tabulated and graphical variations have been studied. The test results are tabulated in table 9 and test set up are represented in plate 8.

VII. DISCUSSION OF CRACK PATTERN AND TEST RESULTS:

In case of cubes under compression test initial cracks are developed at top and propagated to bottom with increase in load and then the cracks are widened at failure along the edge of the cube and more predominantly along the top side of casting. In case of cylinders under compression cracks are developed at top and bottom and with increase in load the cracks are widened at central height. In case of cylinders subjected to split tensile strength the cylinder is splitted into two pieces. In case of beams the first crack developed at bending zone on tension side of beam and propagates to compression side of beam and the major crack is developed at bending zone only.

VIII. INFLUENCE OF FA AGGREGATE ON CUBE COMPRESSIVE STRENGTH

The superimposed variation between compressive strength versus percentage of pelletized fly ash aggregate replacing natural aggregate for 28 and 90 days curing periods are shown in fig 1. It is observed that with the addition of FA aggregate the cube compressive strength decreases continuously up to 100% replacement of Granite by FA aggregate. More than the target mean strength of M_{20} concrete i.e., 26.6 N/mm² has been achieved even when the natural granite aggregate is replaced with 75% of FA aggregate as tabulated in table 3 i.e. 31.87 N/mm^2 for 28 days curing period. With the increase in curing period from 28 days to 90 days the compressive strength is found to increase marginally.

IX. INFLUENCE OF FA AGGREGATE ON CYLINDER COMPRESSIVE STRENGTH

The superimposed variation between compressive strength versus percentage of pelletized fly ash aggregate replacing natural aggregate for 28 and 90 days curing periods are shown in fig 2. It is observed that with the addition of FA aggregate the cylinder compressive strength decreases continuously up to 100% replacement of Granite by FA aggregate. The values are tabulated in table 4. With the increase in curing period from 28 days to 90 days the cylinder compressive strength is found to increase marginally.

INFLUENCE OF FA AGGREGATE ON SPLIT TENSILE STRENGTH ON CYLINDER SPECIMENS:
With increase in percentage replacement of granite by FA aggregate, the split tensile strength is found to decrease continuously up to 100%. The superimposed variation between split tensile strength versus percentage of pelletized fly ash aggregate replacing natural aggregate for 28 and 90 days curing periods as

shown in fig 3, and the values are tabulated in table 5. With the increase in curing period from 28 days to 90 days the split tensile strength is found to increase marginally.

INFLUENCE OF FA AGGREGATE ON DENSITY : The superimposed variation of density and percentage of FA aggregate replacing natural aggregate is presented in fig 4. From the fig it is observed that with the addition of FA aggregate the density of the specimens decreases continuously up to 100% replacement. The corresponding values are tabulated in table no 6. With the increase in curing period from 28 days to 90 days the densities are found to increase marginally.

INFLUENCE OF FA AGGREGATE ON YOUNG'S MODULUS (E) : The young's modulus is calculated by two approaches. i.e. by I.S.Code method[10] and using an empherical formula for light weight concrete[11].
As per I.S.Code formula

$E_1 = 5000\sqrt{f_{ck}}$ N/mm^2

Where f_{ck} = Characteristic cube compressive strength of concrete at 28 days of curing.

Secondly another formula suggested by Takafumi Naguchi et.al[11] for light weight aggregate concrete, is given by

$$E_2 = k_1 x\, k_2 (1.486 \; x \; 10^{-3}) \; x \; \sigma_b^{1/3} \; x \; \gamma^2 \; N/mm^2.$$

Where k_1 = correction factor for coarse aggregate i.e. 0.95
k_2 = correction factor for mineral admixture i.e. 1.026
σ_b = compressive strength of concrete in MPa.
γ = Density of concrete in kg/m^3

The superimposed variation between young's modulus versus percentage of pelletized fly ash aggregate replacing natural aggregate for 28 and 90 days curing periods are shown in fig 6 & 7 respectively. With increase in percentage of replacement of granite by FA aggregate, the E values are found to decrease continuously up to 100% replacement. These values are tabulated in table 8. From these results it can be found that the E-values calculated using I.S.Code formula are higher than those calculated from the suggested empherical formula for light weight concrete.

INFLUENCE OF FA AGGREGATE ON FLEXURAL STRENGTH ON BEAMS: The flexural strength is also calculated by two approaches. In the first approach the flexural strength is calculated by using the following standard formula. i.e.

$$f_{th} = \frac{PL}{bd^2} \text{ in N/mm}^2$$

Where f_{th} = Flexural strength of the beam in N/mm^2
P = Ultimate Load in N
L, b, d = Sectional dimensions of the beam

Another formula as per I.S.code method[10] is

$$f = 0.7\sqrt{f_{ck}}$$

Where f = Flexural strength of beam in N/mm^2
f_{ck} = Characteristic cube compressive strength of concrete at 28 days of curing.

The superimposed variation between flexural strength versus percentage of pelletized fly ash aggregate replacing natural aggregate for 28 and 90 days curing periods are shown in fig 8 & 9 respectively. With increase in percentage of replacement of granite aggregate by FA aggregate, the flexural strength values are found to decrease continuously up to 100% replacement. Further by extending the curing period from 28 days to 90 days the flexural strength values are found to increase. These values are tabulated in table 9.

X. CONCLUSIONS

On the basis of limited experimental investigations conducted and the analysis of results, the following conclusions are drawn to be valid.

[1] From the experimental investigation it is observed that the production of structural light weight aggregate concrete from cold bonded pelletized fly ash aggregate is possible.

[2] The pelletized fly ash aggregates are lighter and porous in nature; having bulk density around 1056 kg/m^3 which is less than that for conventional aggregate and hence it is light weight aggregate.

[3] The cold bonded pelletized fly ash aggregates are spherical in shape and hence it improves the workability of content mixes with lesser water content when compared with conventional concrete.

[4] From the study it is concluded that the compressive strength, split tensile strength, young's modulus, flexural strength and density are decreased continuously with the increasing FA aggregate concrete replacing the natural aggregate; and also increased with increasing curing period.

[5] E_1 values calculated as per I.S.Code formula are higher when compared with E_2 values calculated using another empherical formula suggested for light weight aggregate concrete.

[6] Flexural strengths calculated as per I.S.Code formula are lower when compared with those flexural strengths calculated experimentally.

Tab. 3 CUBE COMPRESSIVE STRENGTH RESULTS

Sl. No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		Compressive strength N/mm^2	
		Natural aggregate	Pelletized Fly Ash Aggregate	28 days	90 days
1	FA-0	100	0	41.08	47.39
2	FA-25	75	25	34.80	34.96
3	FA-50	50	50	32.74	34.03
4	FA-75	25	75	31.87	32.47
5	FA-100	0	100	22.93	23.76

Tab. 4 CYLINDER COMPRESSIVE STRENGTH RESULTS

Sl. No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		Compressive strength N/mm^2	
		Natural aggregate	Pelletized Fly Ash Aggregate	28 days	90 days
1	FA-0	100	0	28.01	28.04
2	FA-25	75	25	18.04	18.31
3	FA-50	50	50	16.48	17.72
4	FA-75	25	75	13.84	16.23
5	FA-100	0	100	12.99	15.84

Tab. 5 SPLIT TENSILE STRENGTH RESULTS

Sl. No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		Split Tensile strength N/mm^2	
		Natural aggregate	Pelletized Fly Ash Aggregate	28 days	90 days
1	FA-0	100	0	3.58	4.00
2	FA-25	75	25	2.84	3.40
3	FA-50	50	50	2.65	3.12
4	FA-75	25	75	2.52	3.30
5	FA-100	0	100	2.00	2.65

Tab. 6 DENSITY RESULTS

Sl. No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		Density in Kg/m^3	
		Natural aggregate	Pelletized Fly Ash Aggregate	28 days	90 days
1	FA-0	100	0	2309	2396
2	FA-25	75	25	2280	2350
3	FA-50	50	50	2230	2241
4	FA-75	25	75	2134	2138
5	FA-100	0	100	2007	2123

Tab. 7 RATIO OF CYLINDER TO CUBE COMPRESSIVE STRENGTH

Sl.No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		Compressive strength N/mm^2				Ratio of cube to cylinder compressive	
		Natural aggregate	Pelletized Fly Ash Aggregate	Cylinder		Cube		28 days	90 days
				28 days	90 days	28 days	90 days		
1	FA-0	100	0	28.01	28.04	41.08	47.39	0.68	0.59
2	FA-25	75	25	18.04	18.31	34.80	34.96	0.52	0.52
3	FA-50	50	50	16.48	17.72	32.74	34.03	0.50	0.52
4	FA-75	25	75	13.84	16.23	31.87	32.47	0.43	0.50
5	FA-100	0	100	12.99	15.84	22.93	23.76	0.57	0.67

Tab. 8 YOUNGS MODULUS

Sl. No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		E_1=Young's modulus in KN/mm^2 using I.S.Code formula		E_2= Young's modulus in KN/mm^2 using Takafumi formula		E_2 / E_1	
		Natural aggregate	Pelletized Fly Ash Aggregate	28 days	90 days	28 days	90 days	28 days	90 days
1	FA-0	100	0	32.05	34.42	26.32	29.71	0.82	0.86
2	FA-25	75	25	29.50	29.56	24.29	25.85	0.82	0.87
3	FA-50	50	50	28.61	29.17	22.78	23.30	0.80	0.80
4	FA-75	25	75	28.23	28.49	20.67	20.88	0.73	0.73
5	FA-100	0	100	23.94	24.37	16.40	18.57	0.69	0.76

Tab. 9 FLEXURAL STRENGTH RESULTS

Sl. No	Name of the mix	Percentage by volume of natural coarse aggregate and fly ash aggregate		Flexural Strength (f_{ex}) in KN/mm^2		Flexural strength (f_{th}) in KN/mm^2		$(f_{ex})/(f_{th})$	
		Natural aggregate	Pelletized Fly Ash Aggregate	28 days	90 days	28 days	90 days	28 days	90 days
1	FA-0	100	0	6.83	7.35	4.49	4.82	1.52	1.53
2	FA-25	75	25	4.20	4.73	4.13	4.14	1.02	1.14
3	FA-50	50	50	3.15	3.68	4.01	4.08	0.79	0.90
4	FA-75	25	75	2.63	3.15	3.95	3.99	0.66	0.79
5	FA-100	0	100	2.10	2.63	3.35	3.41	0.63	0.77

REFERENCES

[1] Harikrishnan KI, Ramamurthy (2006). Influence of Pelletization Process on the Properties of Fly Ash Aggregates. Waste Manag., 26: 846-852..

[2] E I Gal'pern, L A Kotkina and I O Mnskin. 'porous aggregates from beneficiated thermal power plant ash (USSR).' Energ stroit, vol 2, 1990, pp 38-39.

[3] H.Voortam, R Visser and B V Vastam. 'Light Weight Aggregate for advanced and Profitable Civil Engineering Production properties and Use.' Int conf on fly ash disposal and utilisation, CBIP, January 20-22, vol 1, 1998, New Delhi, pp IV-1-10.

[4] H Watanable. 'Artificial stone from fly ash for building materials (Watanable Hikotoshi).' Jpn kokai Tokyo Koho JP02, 116, 653, [90, 116, 653], (C1.C04 B28/02).

[5] Bomhard. "Light weight concrete structures, potentialities, limits and realities, in light weight concrete." Concrete society, The construction press Ltd, Lancaster, England, 1980, pp 277-307.

[6] J E Roberts. "Light weight concrete bridges for California highway system" in "structural light weight aggregate concrete performance." Holm T A, Vaysburd, AM(Ed), ACI, SP-136 Detroit, 1992, pp 255-272.

[7] V.Bhaskar desai, A.Sathyam. 'Basic properties of artificial light weight aggregate by using industrial by product (Silica fume)', RCEE, 2013, vol 1 (04), pp 195-201.

[8] Owens, P.L. (1993). "Light weight aggregates for structural concrete," Structural Light weight Aggregate Concrete, Chapman & Hall, London, pp.1-18.

[9] N. Siva lingaRao, G. VenkataRamana, V. Bhaskar Desai, B. L.P. Swamy, "Properties of lightweight aggregate concrete with cinder and silicafume admixture", International Journal of Earth Sciences and Engineering, Vol. 4, No. 6, October 2011, pp. 907-912.

[10] I.S.Code 456-2000 "Code of practice for plain and reinforced concrete" Bureau of Indian Standards, New Delhi.

[11] Takafumi Noguchi, et.al (2009) " A Practical Equation for Elastic Modulus of Concrete". ACI structural journal/Sept-Oct 2009, technical paper title no. 106-SXX.

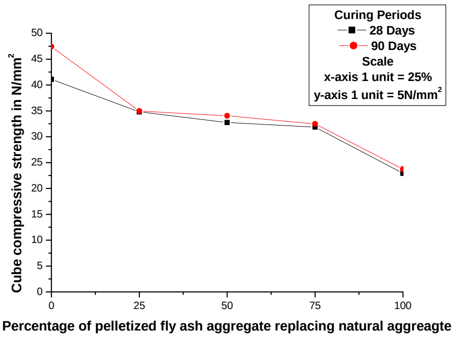

Fig 1. Superimposed Variation Between Cube Compressive Strength And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

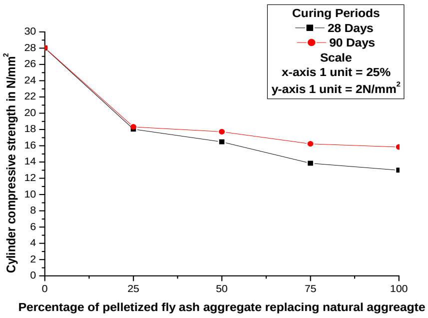

Fig 2. Superimposed Variation Between Cylinder Compressive Strength And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

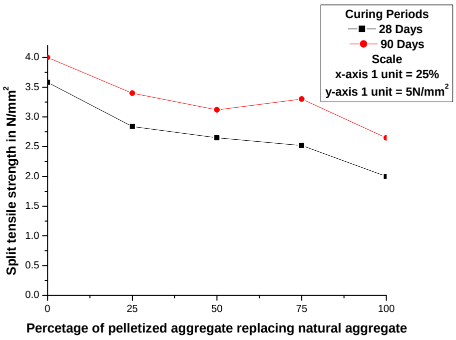

Fig 3. Superimposed Variation Between Split Tensile Strength And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

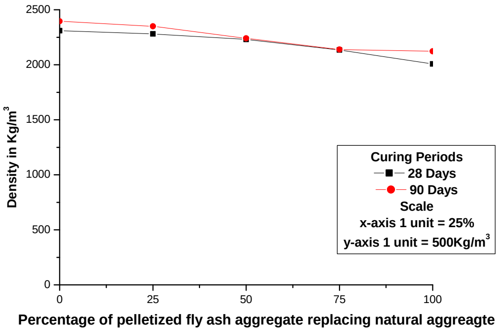

Fig 4. Superimposed Variation Between Density And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

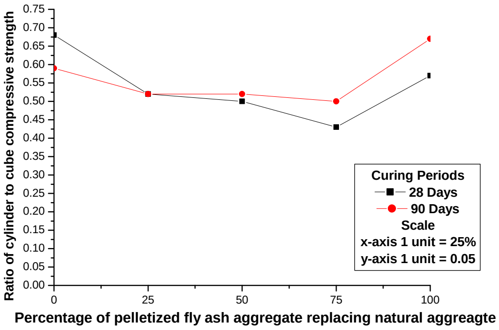

Fig 5. Superimposed Variation Between Ratio Of Cylinder To Cube Compressive Strength And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

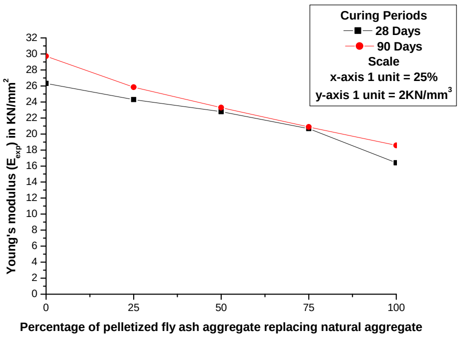

Fig 6. Superimposed Variation Between Young’s Modulus (E_{exp}) And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

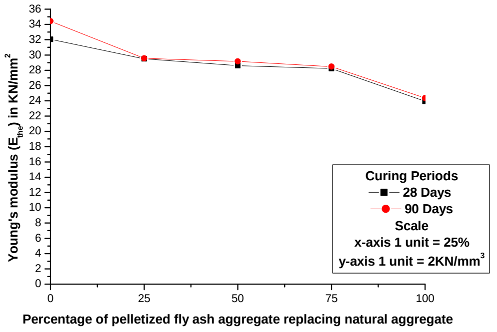

Fig 7. Superimposed Variation Between Young's Modulus (E_{the}) And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

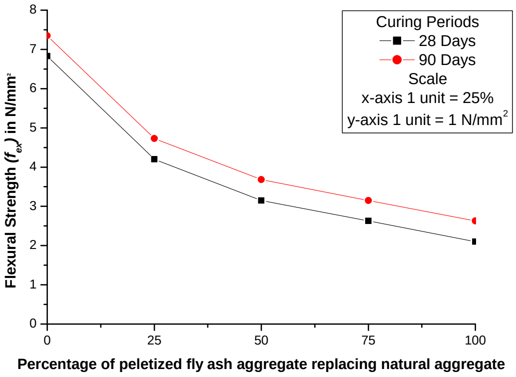

Fig 8. Superimposed Variation Between Fluxural Strength (F_{ex}) And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

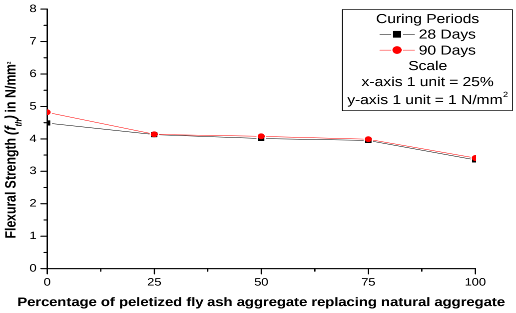

Fig 9. Superimposed Variation Between Fluxural Strength (F_{th}) And Percentage Of Pelletized Fly Ash Aggregate Replacing Natural Aggregate

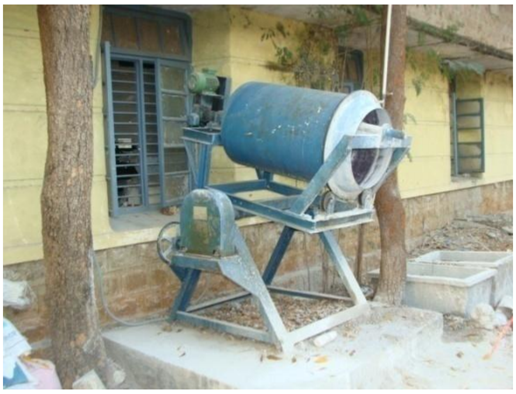

Plate 1. Pelletization Machine

Plate 2. Fly Ash Powder

Plate 3. Lime

PLATE 4. CEMENT

PLATE 5. PELLETIZED FLY ASH AGGREGATE

PLATE 6. FINE AGGREGATE

PLATE 7. NATURAL COARSE AGGREGATE

Plate 8: Test Set Up For Flexural Strength Before Testing