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Brief Study On Concrete Modified With Artificial Cold Bonded Pelletized Light Weight Fly Ash Aggregates

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ABSTRACT: Cement concrete is a building material which consists major portion of hard inorganic materials called aggregates such as crushed stone aggregate. After few minutes of mixing, the various materials undergo a chemical combination and the mixture solidifies, the concrete hardens and attains greater strength with age. Due to continuous usage of natural resources within short length of time these natural 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 industrial wastes. This concrete withstands the conditions for which it has been designed, without much deterioration years together. In this process the concrete may face a variety of physical and chemical attacks due to the external causes or internal causes. The external causes may be due to the weathering, occurrence of extreme temperature, attack by natural or industrial liquids and gases, electrolytic action, abrasion etc. After reviewing briefly in this aspect, an attempt has been made to study the strength properties along with brief temperature studies of M_{20} concrete modified with pelletized artificial light weight aggregate made from an industrial waste i.e fly Ash.
The variables considered are five percentages of fly ash aggregate replacing the conventional coarse aggregate i.e. 0%, 25%, 50%, 75% and 100% with 28 days curing period.

Key words: Pelletization, cold bonding, light weight aggregate, fly ash aggregate
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I. INTRODUCTION

From the past few decades, the growth of population is being increased day by day. Accordingly urbanization is also increasing globally. To meet the minimum needs like food, shelter and clothes etc. to the society lot of industries are coming up. The construction industry is consuming lot of natural resources for production of concrete due to rapid growth of industrial ization and urbanization. Today, the rate at which concrete is used is much higher than that in past fast few years ago. The approximate consumption of concrete in the world is estimated to be more than 33 billion metric tons every year. Man consumes no material except water in such tremendous quantities. Due this abnormal usage an adverse impact on nature is exists. The major challenge of present society is to protect environment. To minimize the impact on nature, it is necessary to find alternate materials to produce concrete. It is therefore desirable that engineers should know more about concrete as well as building materials. To maintain the ecological balance, one of the possible ways is to utilize the wastes and by products produced by the industries globally. Concrete contains heterogeneous distribution of many solid components as well as pores of varying shapes and sizes. Concrete is the conventional construction material that has been continuously modified and developed to perform better in all situations, especially when exposed to elevated temperature in fires etc.

II. REVIEW OF LITERATURE

A brief review of available studies related to the present study is discussed here. Bijen, J.M.J.M., (1) 1986, investigated on manufacturing processes of artificial light weight aggregate from fly ash by different processes like autoclaving, cold bonding or sintering etc. W.C. Piasta et.al., (2) 1989, made their investigation on sulfate durability of concrete under constant sustained load. The aim of this paper is to study of durability of concrete with limestone and granite aggregate under simultaneous long-term compressive stress and sulfate attack. Min-Hong Zhang and Odd E. Gjorv, (3) 1991, had made study on "Characteristics of lightweight aggregate for high-strength concrete". K.D. Hertz., (4) 1992, had studied on "Davish investigation on silica fume concrete at elevated temperatures". This explains the fire tests in which the increased risk of explosive spalling of concrete densified by silica fume was first discovered. K.I.Harikrishnan and K.Ramamurthy, (5) 2006, studied on manufacturing of fly ash pellets. They concluded that the efficiency of production of pellets depends on speed of revolution of pelletizer disc, moisture content and angle of pelletizer disc and duration of Pelletization. A.Sivakumar and P.Gomati, (6) 2011, stated that fly ash is not a waste material and can be effectively used in concrete either as aggregate fillers or as replacement for fine aggregate or as fly ash brick material. Priyadharsini Perumal et.al., (7) 2012 presented review on artificial aggregates made out of various waste materials. The production of artificial aggregates solves two problems, conserves environment from pollution and prevents natural resource from depletion, thereby giving way to sustainable development.

Ke-cheng He et.al., (8) 2016 studied on Experimental Research on High Temperature Resistance of Modified Lightweight Concrete after Exposure to Elevated Temperatures. The results showed that the ordinary lightweight concrete specimens and the crushed limestone concrete specimens were completely spalled after exposure to target temperatures above 400°C and 1000°C, respectively, whereas the modified concrete specimens remained intact at 1200°C, at which approximately 25% to 38% of the residual compressive strength was retained. The modified lightweight concrete specimens have exhibited superior mechanical properties and resistance to thermal spalling after exposure to elevated temperatures. Vadims Goremikins et.al., (9) 2017 studied on Experimental investigation on steel fiber reinforced concrete behaviour under elevated temperature. The results showed that the compressive strength of SFRC is reduced by 38 and 66 per cent, tensile strength is reduced by 25 and 59 per cent and ultimate bending force is reduced by 33 and 56 per cent in case of 400°C and 600°C, respectively,comparing those with ambient temperature. From the brief literature survey conducted here it is observed that very little attention is paid to the study of concrete modified with pelletized light weight fly ash aggregate.Hence the present study has been under taken.

III. FLY ASH AGGREGATE

Fly ash, a byproduct from coal based thermal power plants, was used for the preparation of fly ash aggregate. Fly ash aggregates were prepared by pelletization process in drum pelletizer with the definite proportions using cold bonding technique in a laboratory of JNTUA College of engineering Ananthapuramu dist. Andhra Pradesh. The aggregate so prepared are cold bonded pelletized fly ash light weight aggregate and here after called as fly ash aggregate. The physical and chemical properties of fly ash as given by the supplier are presented in table 1 and table 2 respectively. Various physical test results of fly ash aggregate are presented in table 3. The fly ash aggregate can be really brought under light weight aggregate because the density of aggregate is around 1000 kg/m^3.

TABLE 1. PHYSICAL PROPERTIES OF FLY ASH

Property	Fly ash result
Specific Gravity	2.17
Grain size distribution	
Silt fraction (%)	94.50
Clay fraction (%)	5.50
Atterberg Limits	
Liquid limit (%)	29.00
Plastic Limit (%)	NP
Plasticity Index (%)	NP
Compaction characteristics	
Optimum moisture content (%)	23.80
Max. dry density (KN/m^3)	13.30
Surface area (m^2/gm)	8.20

TABLE 2. CHEMICAL COMPOSITIONS OF FLY ASH

Constituent	Test Results (% by weight)
Silica as SiO_2	56.88
Alumina as Al_2O_3	27.65
Iron Oxide as Fe_2O_3	6.28
Calcium Oxide as CaO	3.62
Magnesium Oxide as MgO	0.34
Sulphate as SO_4	0.21
Alkalis	1.38
Na_2O	0.19
K_2O	0.27
TiO_2	0.31
Loss of ignition	4.46

TABLE 3. VARIOUS TEST RESULTS ON COLD BONDED FLY ASH AGGREGATE

Sl. No	Name of the test conducted	Result	Reference
1	Specific gravity	2.68	IS:383-1970
2	Aggregate crushing value	21.50 %	IS:383-1970
3	Aggregate impact value	24.20 %	IS:383-1970
4	Abrasion test	31.70 %	
5	Density		
	Loose condition	915 kg/m^3	IS:383-1970
	Compacted condition	1055 kg/m^3	IS:383-1970
6	Fineness modulus	6.85	IS:383-1970
7	Water absorption	19.75 %	IS: 383-1970

MATERIALS USED FOR INVESTIGATION:

Cement: Ordinary Portland cement of 43 grade confirming to ISI standards IS:8112-1989 has been used. The specific gravity of cement is 3.07

Coarse aggregate: 20 mm and down sized crushed granite metal is used. The specific gravity of granite is 2.68, fineness modulus is 6.83.

Fly ash aggregate: properties are as shown in table 3

Fine aggregate: local river sand is used as fine aggregate and specific gravity is 2.60, and fineness modulus is 3.65.

Water: fresh potable water which is free from acids, organic substances etc. are used

MIXING OF FLY ASH AGGREGATE CONCRETE:

The mixing of fly ash light weight aggregate concrete was done in the same way as it was done for conventional concrete i.e. in two stages. In the first stage, cement, fine aggregate i.e. sand, and two-thirds of water were mixed and is called as mortar. In the second stage, coarse aggregate i.e. conventional coarse aggregate and fly ash aggregate which was pre soaked and in surface dry condition were added with the rest of the water, and these ingredients were mixed thoroughly. The concrete mixture of uniform in colour and consistency was achieved which was then ready for casting. Before casting of specimens workability was measured by slump and compaction factor tests. For the M_{20} designed mix, proportion of ingredients is 1:1.55:3.04 with w/c ratio 0.50. The various percentage of replacements of natural aggregate by artificial aggregated adopted are 0%, 25%, 50%, 75% and 100%. In the entire investigation wherever needed convenient dosage of super plasticizer SP-430 was added to have more or less same workability.

DETAILS OF SPECIMENS CAST:

Totally 60 numbers of specimens were cast for five percentage replacements with 28 days of curing. Out of 60 number of specimens, 30 numbers of cubes of size 150 x 150 x 150 mm were cast to find out compressive strength and 30 numbers of beams of size 100 x 100 x 500 mm were cast to find flexural strength.

On completion of workability tests on these samples, moulds were placed on vibrating table and concrete was filled into moulds in 3 layers, each layer was compacted thoroughly with tamping rods to avoid "honey combing". Finally all the samples were thoroughly vibrated on table vibrator for 6 to 7 seconds filling all the moulds to the brim. Vibration was maintained constant for 6 to 7 seconds for all samples and all the other castings throughout the study.

CURING PROCEDURE:

After casting the cube and beam specimens were kept 24 hours at room temperature for air curing after proper marking. However the specimens were de moulded after 24 hours of casting and allowed for 28 days of curing. After desired age of curing the specimens were taken out of water and were allowed to dry under shade for some time. The designation of different mixes is as follows. FA-0, FA-25, FA-50, FA-75 and FA-100. FA represents pelletized cold bonded fly ash light weight aggregate and 0, 25, 50, 75 and 100 represents percentage of fly ash aggregate replacing the natural aggregate. The details of different mixes adopted with designation are presented in table 4.

TABLE 4 DESIGNATIONS OF DIFFERENT MIXES

Name of the Mix	Percentage of aggregate		Total no of specimens cast for 28 days curing	
	Conventional Aggregate	Fly ash Aggregate	Cubes of size 150x150x150mm	Beams of size 100x100x500mm
FA-0	100	0	6	6
FA-25	75	25	6	6
FA-50	50	50	6	6
FA-75	25	75	6	6
FA-100	0	100	6	6
		Total	30	30

COMPRESSION TEST ON PLAIN CUBES:

The compression test on the plain cubes was conducted on 2000 KN digital compression testing machine. The rate of load applied was 0.5 KN/sec. Compression test is done as per IS: 516-1959.

The specimens after being removed from water were allowed to dry under shade for 24 hours and white washed for easy identification of minute cracks, while testing. The plain cube specimens were placed on the plate of the hydraulic ram of the compression testing machine such that load was applied centrally. The top plate of the testing machine was brought into contact with the surface of the plain cube specimen to enable loading. One set of 30 cubes were tested at room temperature the other set exposed to 100^{o}C for 24 hours were tested in the same manner.

Compressive strength = $\frac{P}{A}$ N/mm^2

Where P = Load in 'N'

A = Cross sectional Area ($A = b^2$) of the specimen in mm^2

b = width of the specimen in 'mm'

The obtained results from the tested specimens are presented in table 6 and the super imposed variation of cube compressive strength vs percentage of FA aggregate replacing natural aggregate is presented graphically in fig 2.

TESTING OF BEAMS FOR FLEXURAL STRENGTH:

The loading arrangement to test the specimens in flexure used is two point loading with loading at 1/3 points The element is simply supported over an effective span of 400mm. The specimen is checked for its alignment longitudinally and adjusted if necessary. Required packing is given using rubber packing. Care is taken to ensure that two loading points are at the same level. The loading is applied on the specimen using 15 tones pre-calibrated proving ring at regular intervals. The load is transmitted to the element through I - section and two 16mm diameter rods placed at 166.67mm from each support. For each increment of loading the deflection at the centre and at 1/3rd points of beam are recorded using sensitive dial gauges. 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 are widened and extended to top and finally the specimen failed. Ultimate loads were recorded. Making use of the above data flexural strength has been calculated as follows.

The flexural strength of beam is calculated using the formula (f) $= \frac{M}{Z} = \frac{WL}{bd^2}$ in N/mm^2

Where f = Flexural strength of beam in N/mm^2

M = Bending moment in N.mm

Z $= \frac{I}{y}$ = Section modulus in mm^3

W = Ultimate load and L, b and d are section dimensions

A set of 30 beam specimens were tested at room temperature and other set exposed to 100^{o}C in 24 hours were also tested in the same manner. The results are presented in table 7 and superimposed variations are presented graphically in fig 3 for 28 days curing period. The flexural strength results are also calculated using IS code method

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

Where f = Flexural strength of beam in N/mm^2

f_{ck} = Compressive strength of cubes in N/mm^2

The obtained results are presented in table 8 and the superimposed variation of flexural strength versus percentage replacing natural aggregate with pelletized fly ash aggregate is represented graphically in fig 4.

IV. DISCUSSION OF TEST RESULTS

INFLUENCE OF FLY ASH AGGREGATE ON DENSITY:

In the present study the influence of cold bonded FA aggregate on density has been studied with percentage replacement of cold bonded fly ash aggregate by natural coarse aggregate in different percentages i.e. from 0% to 100% with an interval of 25%. All the cubes were initially weighed before subjecting them to temperature test. After exposing the cube specimens to sustained elevated temperature (100^oC) they were again weighed. Results of density of concrete were measured and variations are plotted. The density results at 28 days curing are presented in Table 5. And also density vs percentage of fly ash aggregate replacing natural aggregate is presented graphically in fig 1.

From the table and figure, it is observed that with increasing the percentage of fly ash aggregate replacing conventional aggregate, the density decreases continuously from 0% to 100% replacements both at room temperature and at 100^oC elevated temperature. And also the densities are found to decreased marginally at the elevated (100^0 c) temperature, when compared with these at room temperature.

INFLUENCE OF FLY ASH AGGREGATE ON CUBE COMPRESSIVE STRENGTH:

In the present study the influence of fly ash aggregate has been studied by percentage replacement of fly ash aggregate by natural coarse aggregate in different percentages from 0% to 100% with an interval of 25%. The obtained tested results at 28 days are presented in Table 6 and the graphically represented vide fig 2.

From the results, it is observed that with the increase in replacement of fly ash aggregate the cube compressive strength decreases continuously from 0% to 100%. And also the compressive strengths are increased marginally at elevated (100^0 c) temperature, when compared to those at room temperature.

The residual strength at a particular temperature is defined as the ratio of the strength obtained at the elevated temperature to the strength obtained at normal temperature.

The percentage of residual strength = $\frac{Rx*100}{Rn}$

Where R_x = Strength at 100^oC elevated temperature

R_n = Strength at normal temperature

It is found that the residual strengths are increased with the temperature increase.

INFLUENCE OF FLY ASH AGGREGATE ON FLEXURAL STRENGTH:

In the present study the influence of fly ash aggregate has been studied with the replacement of fly ash aggregate by natural coarse aggregate in different percentages of 0% to 100% with an interval of 25%. The flexural strength results at 28 days curing are presented in table 7 & 8 at room temperature and at elevated temperature respectively and also presented graphically in figures 3 & 4 at room temperature and elevated temperature respectively.

From the above results, it is observed that with the increase in replacement of fly ash aggregate the flexural strength decreases continuously from 0% to 100%. And also the flexural strengths are increased at elevated (100^0 c) temperature, when compared at room temperature.

INFLUENCE OF FLY ASH AGGREGATE ON MODULUS OF ELASTICITY: APPROACH-I

From the results of cube compressive strength the youngs modulus results are also calculated using IS code method [10]

$$E_1 = 5000\sqrt{f_{ck}}$$

Where E_1 = youngs modulus in N/mm^2

f_{ck} = Compressive strength of cubes in N/mm^2

The modulus of elasticity results with various percentage replacements of natural aggregate by fly ash aggregate is presented in table 9. The graphical representation is presented in fig 5.

From the results, it is observed that the behavior of theoretical modulus of elasticity varies more or less same as that of Compressive strength of concrete.

INFLUENCE OF FLY ASH AGGREGATE ON MODULUS OF ELASTICITY: APPROACH-II

In the 2^{nd} approach of young's modulus is calculated by Empherical formula suggested by Takafumi[11] for light weight aggregate concrete is given by

$E_2 = k_1 * k_2 * (1.486*10^{-3}) * f_{ck}^{1/3} * \gamma^2$ N/mm².

Where k_1 = correction factor for coarse aggregate i.e. 0.95

k_2 = correction factor for mineral admixture i.e. 1.026

f_{ck} = compressive strength of concrete in MPa.

γ = Density of concrete in kg/m^3

The modulus of elasticity results with various percentage replacements of natural aggregate by fly ash aggregate is presented in table 10. The graphical variation is presented in fig 6.

From the results, it is observed that the behavior of theoretical modulus of elasticity varies more or less same as that of Compressive strength of concrete.

V. CONCLUSIONS

1) One of the possible solutions to control the depletion of natural resources is by the manufacture of artificial aggregate by pelletization process using fly ash a byproduct of thermal power plants.
2) Due to its spherical in shape, the workability is enhanced. Due to its light weight there is an added advantage that it can reduce overall cost savings, especially in transportation and placing etc.
3) From the investigation presented here, it can be construed that it is possible to produce structural grade concretes from pelletized fly ash aggregate which have been made from pelletization and cold bonding technique.
4) The water absorption of cold bonded pelletized aggregate is 18.00 to 21.50%. Due to its high absorption nature, the heat of hydration can be controlled.

5) The pelletized Fly ash aggregate is light in weight and porous in nature; having bulk density around 915 to 1055 kg/m^3 which is less than that for conventional aggregate and hence it comes under light weight aggregate category.
6) It is concluded that the properties like density, compressive strength, young's modulus, and flexural strength are decreased continuously with increasing fly ash content replacing the natural aggregate.
7) At 28 days of curing the cube compressive strength of FA-100 mix is 22.23 N/m^{m2} which is 83.57% of target mean strength (26.60 N/m^{m2}). While coming to that at elevated temperature, it is 24.20 N/mm^2, which is 90.98% of target mean strength.
8) The use of pelletized Fly ash aggregate has exhibited marginal increase in mechanical strength properties of concrete at elevated temperatures.
9) Comparing the experimental results of flexural strength with those calculated results calculated using IS code formula, it is observed that experimental results are on higher side. The reason for this may be due to that fact that IS code formula may not be suitable for Light Weight Aggregate Concrete.
10) E values calculated as per I.S.Code formula are higher when compared with E values calculated using another empherical formula suggested by earlier researchers in the literature for the light weight aggregate concrete.
11) Fly ash is not a waste material and it can be effectively used in concrete either as aggregate fillers or as a replacement for coarse aggregate with pelletization.
12) The cost effective and simplified production techniques for manufacturing Fly ash aggregate can lead to mass production and can be an ideal substitute for the utilization in many infrastructural projects. In the near future the depletion of the natural resources for aggregate can be suitably compensated from the manufacture and usage of Fly ash aggregate.

TABLE 5. DENSITY RESULTS

Name of the Mix	Percentage of aggregate		Density in kg/m^3 at 28 days curing period	
	Conventional Aggregate	Fly ash Aggregate	At room temperature	At 100^{o}c elevated temperature
FA-0	100	0	2270	2130
FA-25	75	25	2182	2089
FA-50	50	50	2085	1964
FA-75	25	75	2027	1837
FA-100	0	100	1955	1807

TABLE 6. CUBE COMPRESSIVE STRENGTH RESULTS

Name of the Mix	Percentage of aggregate		Cube compressive strength in N/mm^2 at 28 days curing period	
	Conventional Aggregate	Fly ash Aggregate	At room temperature	At 100^{o}c elevated temperature
FA-0	100	0	40.85	41.95
FA-25	75	25	34.80	35.85
FA-50	50	50	32.74	33.65
FA-75	25	75	31.87	32.65
FA-100	0	100	22.93	24.20

TABLE 7. FLEXURAL STRENGTH RESULTS

Name of the Mix	Percentage of aggregate		Flexural strength in N/mm^2 at 28 days curing period	
	Conventional Aggregate	Fly ash Aggregate	At room temperature	At 100^{o}c elevated temperature
FA-0	100	0	3.94	3.58
FA-25	75	25	3.76	3.40
FA-50	50	50	3.58	3.40
FA-75	25	75	3.58	3.40
FA-100	0	100	3.05	2.69

TABLE 8. FLEXURAL STRENGTH RESULTS BASED ON THE I.S.CODE METHOD

Name of the Mix	Percentage of aggregate		Flexural strength in N/mm^2 at 28 days curing period	
	Conventional Aggregate	Fly ash Aggregate	At room temperature	At 100^{o}c elevated temperature
FA-0	100	0	4.47	4.53
FA-25	75	25	4.13	4.19
FA-50	50	50	4.01	4.06
FA-75	25	75	3.95	4.00
FA-100	0	100	3.35	3.44

TABLE 9. YOUNGS MODULUS RESULTS BASED ON THE I.S.CODE METHOD

Name of the Mix	Percentage of aggregate		Youngs modulus in x10^4 N/mm^2 at 28 days curing period	
	Conventional Aggregate	Fly ash Aggregate	At room temperature	At 100^{o}c elevated temperature
FA-0	100	0	3.20	3.24
FA-25	75	25	2.95	2.99
FA-50	50	50	2.86	2.90
FA-75	25	75	2.82	2.86
FA-100	0	100	2.39	2.46

TABLE 10. YOUNGS MODULUS RESULTS BASED ON EMPHERICAL METHOD SUGGESTED BY TAKAFUMI

Name of the Mix	Percentage of aggregate		Youngs modulus in x10^4 N/mm^2 at 28 days curing period	
	Conventional Aggregate	Fly ash Aggregate	At room temperature	At 100^{o}c elevated temperature
FA-0	100	0	2.57	2.28
FA-25	75	25	2.25	2.08
FA-50	50	50	2.01	1.80
FA-75	25	75	1.89	1.56
FA-100	0	100	1.57	1.37

TABLE 11. RESIDUAL STRENGTH RESULTS

Name of the Mix	Percentage of aggregate		Cube compressive strength in N/mm^2 at 28 days curing period		Percentage of Residual strength $\frac{Rx*100}{Rn}$
	Conventional Aggregate	Fly ash Aggregate	At room temperature (R_n)	At 100^oc elevated temperature (R_x)	
FA-0	100	0	40.85	41.95	102.693
FA-25	75	25	34.80	35.85	103.017
FA-50	50	50	32.74	33.65	102.779
FA-75	25	75	31.87	32.65	102.447
FA-100	0	100	22.93	24.20	105.539

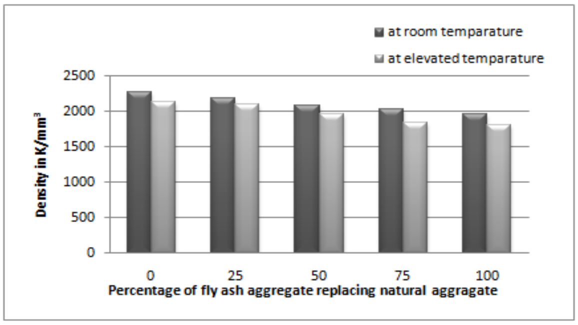

Fig 1. Superimposed variation of Density vs FA

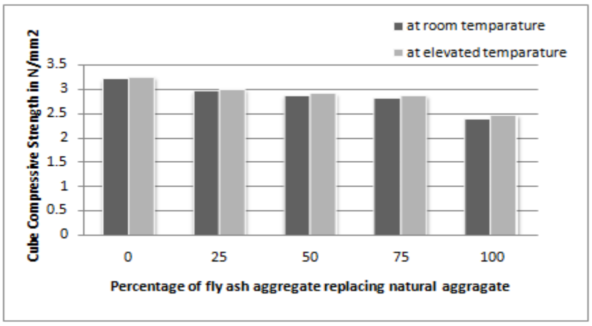

Fig 2. Superimposed Variation of cube Compressive strength vs FA

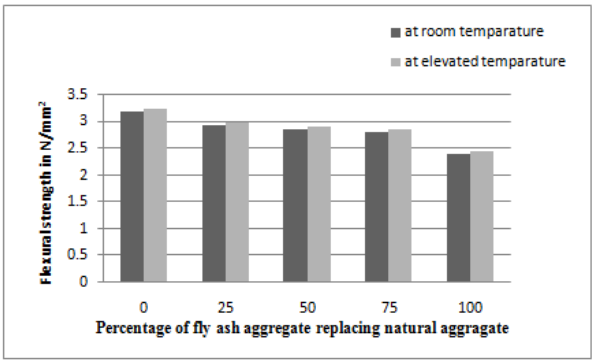

Fig 3. Superimposed Variation of flexural strength vs FA

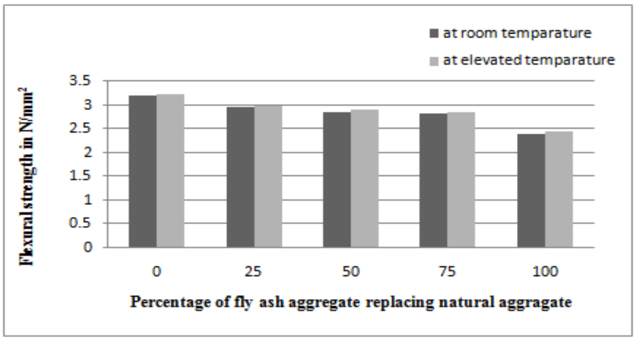

Fig 4. Superimposed Variation of flexural strength based on I.S.Code vs FA

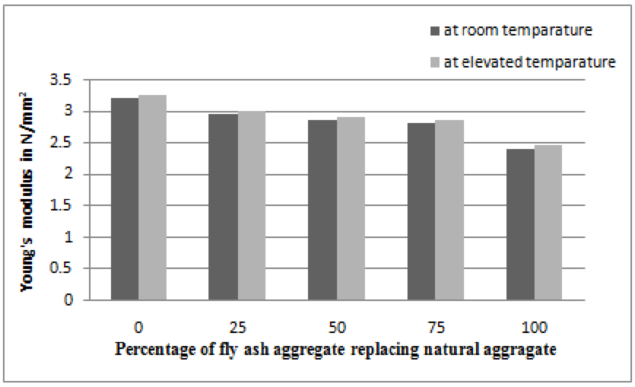

Fig 5. Superimposed Variation of young’s modulus based on I.S.code vs FA

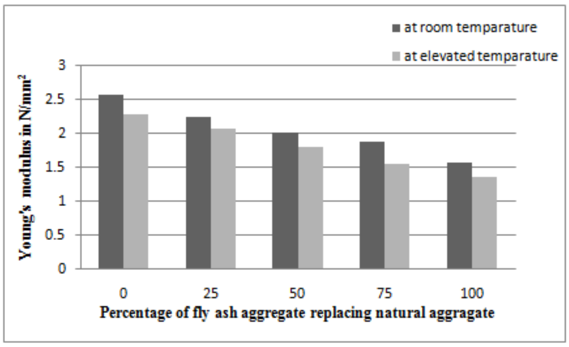

Fig 6. Superimposed Variation of youngs modulus based on empherical formula vs FA

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