Experimental works on Concrete by Partial Replacement of Coarse Aggregate with Fly ash Aggregate and Cement with Silica Fume

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Abstract : The present research mainly concentrated on replacement of coarse aggregate with Fly Ash aggregate and cement with silica fume in concrete. In present study, a mix design has been done for M30 Grade of concrete by using IS method. By utilization of fly ash aggregate in concrete can make the light weight aggregate concrete. In this investigation we are replacing the coarse aggregate by 20% with fly ash aggregate but cement was replacing by silica fume with 0%,8%, 12% and 16%. In the above mentioned explorations, the concrete cube, cylinder and beams are used to analyze their mechanical properties like Compressive Strength (CS) and Split Tensile Strength (STS) and Flexure strength at 3, 7 and 28 days. The results obtained from the concrete made with 12% replacement of cement with silica fume for using 20% of fly ash aggregate was found to be good performance in all mechanical properties when compared with normal concrete and other proportion mix.

Key Words: Fly ash Aggregates; silica fume: Compressive strength; splitting tensile strength; Flexure strength

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1. INTRODUCTION

Concrete is made up of four main ingredients such as coarse aggregates, fine aggregates, Portland cement and water. Concrete has relatively high compressive strength and low tensile strength For this reason reinforced concrete is made by embedding steel rods in concrete that increases its tensile strength. Innovation of new methods in intensification of concrete is under work for decades. The availability of raw materials for the construction is facing many problems in most of the world. The continuous usage of natural resources for the production of the concrete in some locations creates many threatens to the environmental conditions. Researchers have carried out extensive work on this area are trying for new alternative materials for this deficiency in the construction industry. In this condition, the present study focussed on artificial fly ash aggregates in place of coarse aggregates.Fly ash from thermal plants is creating environmental problems. One of the essential requirements of the green building is to use environmental friendly building materials such as the industrial waste products like fly ash [1]. A few companies in UK, USA, Japan etc. have introduced manufacture of such lightweight fly ash aggregate using a process of sintering the fly ash pellets at elevated temperature of around 1,200^{0}C. The process has a lot of similarities with the pyro-processing of normal materials for manufacturing Lightweight aggregate. silica fume byproduct producing silicon metal or ferrosilicon alloys. Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material.Silica fume is added to Portland cement concrete to improve its properties, in particular compressive strength, bond strength, abrasion asilica fume from 0 to 16% with constant fly ash aggregate.

2.LITERATURE REVIEW

Manikandan et al., investigated that the durability properties of concrete made with fly ash aggregate cured by different methods and found that sintered aggregates produce better strength compared to cold bonded aggregates [2].

Priyadarshiny et al.,have observed that the fly ash aggregates produced by normal curing showed comparable results with the aggregates produced with other methods of curing, when the experimental study on cold bonded fly ash aggregates with number of days of curing period is increased [3].

In conventional concrete, weight of concrete on the parameter compare with weight fly ash aggregate concrete. Normally density concrete i the order of 2200 to 2600 kg/m3. This heavy self weight makes uneconomical structural material compared to low self weight of fly ash aggregate concrete. In order produce concrete desired density suit the required application, the self weight structural ,non structural members are be reduced. Hence economy achieved the design of supporting structural elements which lead the development of light weight concrete. This paper is reviewed on the suitability of using fly ash aggregate with cement replacement of silica fume of M30 grade to study mechanical properties.

3. EXPERIMENTAL INVESTIGATION

Ordinary Portland cement (similar to ASTM Type I) meeting the requirements mentioned in IS: 12269 was used as the binder material. The physical and chemical properties of fly ash aggregate and silica fume used in the investigation were analyzed based on standard experimental procedures laid down in IS, ASTM and BS codes. The experiments conducted on coarse aggregate are specific gravity and water absorption, Bulk density & Sieve analysis by using respective codes [7]. The experiments conducted on fine aggregates are specific gravity, moisture content, sieve analysis and bulking of fine aggregate using volume method.[6] The tests conducted on concrete are Compressive strength [9], Split Tensile strength [10,11], Flexural strength [12] are as per the respective IS, BS and ASTM codes.

3.1 Materials used

3.1.1 Fly ash Aggregate

The fly ash aggregate is produced by mixing materials, Then the mix is made into spherical shape and over dried at a temperature of 1100 ºC in muffle furnace. The properties of sintered fly ash aggregates are given in Table 3.1.The properties calculated as per IS 2386:1963 [4]

Table No:3.1 Physical Properties of fly ash aggregate

S. No.	Properties of Sintered Fly ash Aggregates	Values
1.	Fines modules	6.24
2.	Bulk density(gm/cc)	0.640-0.750
3.	Sizes produced(mm)	4.70-10.0
4.	Water absorption (%)	14.20
5.	Specific gravity	2.02
6.	Maximum dry density (kN/m3)	7.21
7.	Aggregate crushing strength (%)	18.36
8.	Aggregate impact value (%)	16.12
9.	Aggregate abrasion value (%)	35.32

Fig:3.1 Fly ash aggregate

3.1.2 Coarse aggregate

The coarse aggregate used broken granite-crushed stone it was free from clay, weeds, any other organic matters, they are non-porous. The water absorption capacity is less than 1%. The size which pass through 26 mm sieve and retained 19 mm sieve. The properties of the coarse aggregate are given by following

Table No:3.2 Physical Properties of coarse aggregate

Sr. No.	Physical Property	Test Result
1.	MaximumSize (mm)	20
2.	Fineness modulus	7.20
3.	Specific Gravity	2.65
4.	Bulk Density(gm/cc)	1.40-1.60
5.	Water Absorption (%)	0.16
6.	Aggregate Crushing Value (%)	15.85
7.	Aggregate Impact Value (%)	12.36
8.	Maximum dry density (kN/m3)	14.20
9.	Aggregate abrasion value (%)	30.14

3.1.3 Fine aggregate

The Fine aggregate use for casting in clean river and it was clean and dry. It is size pass through 1.19 mm sieve. Sand conforming Zone-III used the fine aggregate,

4. MIXTURE PROPORTIONS

In the present work, a proportion for concrete mix design of M30 was carried out according to IS: 10262-2009 recommendations [5]. The mix proportions are presented in Table :4.1

Table No:4.1 Mix proportion

Materials	Mix proportions
Cement Kg/m^3	350.22
Fine Aggregate Kg/m^3	714
Coarse Aggregate Kg/m^3	1224
Water Litrs	157.6
Super plasticizer (ml)	20

5. METHODOLOGY

In the course of investigation different specimens have been cast and tested.. The tests conducted on concrete are Compressive strength, Split Tensile strength, and Flexural strength as per the respective IS, BS and ASTM codes [8,9,10].

5.1 Compressive Strength test

The compressive strength of the GPC was conducted on the cubical specimens for all the mixes after 3, 7 and 28 days of curing as per code. 9 No's of 150 mm cube specimen were made for each mix and 3 samples in each were cast and tested for 3 days, 7 days and 28 days respectively. The average value of these 3 specimens was taken for study.

Fig:5.1 Compressive strength

The compressive strength (f'c) of specimen was calculated by dividing the maximum load applied to specimen by cross-sectional area the specimen as given below.

$$f'c = P/ A$$

Where, f'c = Compressive strength the concrete (in N/mm2)
P = Maximum load applied to specimen (in Newton)
A = Cross-sectional area of the specimen (in mm2)

5.2 Split Tensile Strength test

Splitting Tensile Strength (STS) test was conducted on the specimens for all the mixes after 3,7 and 28 days of curing as per code [13-14]. Three cylindrical specimens of size 150 mm x 300 mm were cast tested each age and each mix. The load was applied gradually till failure of specimen occurs. The maximum load applied was then noted. Length and cross-section of the specimen was measured. The splitting tensile strength (fct) was calculated as follows:[10,11]

$$fct = 2P/ (\Pi\, l\, d)$$

Where, fct = Splitting tensile strength of concrete (in N/mm2)
P = Maximum load applied the specimen (in Newton)
l = Length of the specimen (in mm)
d = cross-sectional diameter of the specimen (in mm)

Fig 5.2: Testing of cylinders for Split tensile strength

5.2 Flexural Strength test

Flexural Strength test was conducted on the specimens for all the mixes after 3,7 and 28 days of curing. Test beams 150×150×700 cubic mm size adopted. The load was applied gradually without shock and was increased until the specimen failed, and the maximum load applied which is on the meter to the prism during the test was recorded.. Three-point load method was used to measure the flexural strength of fly ash aggregate concrete[12]

Fig:5.3 Beam testing for flexural strength

6. RESULTS AND DISCUSSIONS

This section describes the Compressive strength, Split tensile strength and flexural strength of Fly Ash aggregate at water curing. The compressive strength values of different mixes were measured after 3,7 and 28 days of curing. The split tensile strength and flexural strength values of different mixes were measured at 3,7 and 28 days of curing.

6.1 Compressive Strength

The compressive strength of concrete mixes with 20% fly ash aggregates at different silica fume replacements (8%, 12% and 16%) as shown in the below table. Results showed that all the mixes attained less compressive strength at 3 days when compared to normal concrete. The compressive strength has been increased with the age of concrete. The increase of silica fume up to 12% increased the compressive strength at all ages. It is due to pozzolanic action of silica fume with fly ash aggregates which densifies the concrete and increases the compressive strength. But the further increase in silica fume (16%) shown the decreasing trend of compressive strength at all ages. It is noted that excess percentage of silica fume is not contributing to the additional strength.

Table No:6.1 Compressive strength (MPa)

Mix proportion	3 days	7 days	28 days
Normal concrete	33.81	35.78	39.51
8% silica fume with 20% fly ash aggregate	24.64	28.87	40.08
12% silica fume with 20% fly ash aggregate	26.43	37.66	41.5
16% silica fume with 20% fly ash aggregate	25.32	33.24	35.53

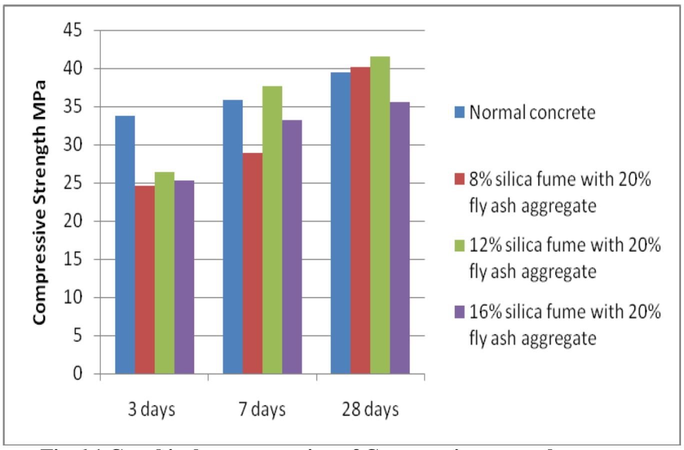

Fig:6.1 Graphical representation of Compressive strength

6.2 Split Tensile Strength

The split tensile strength of concrete mixes with 20% fly ash aggregates at different silica fume replacements (8%, 12% and 16%) as shown in the below table. Results showed that all the mixes attained less split tensile strength at 3 days when compared to normal concrete. The split tensile strength has been increased with the age of concrete. The increase of silica fume up to 12% increased the split tensile strength at all ages. It is due to the increase of compressive strength. At 16% silica fume, split tensile strength values are decreased as compressive strength of the concrete were decreased.

Table No:6.2 Split tensile strength (MPa)

Mix proportion	3 days	7 days	28 days
Normal concrete	8.84	10.26	14.18
8% silica fume with 20% fly ash aggregate	6.77	11.07	15.36
12% silica fume with 20% fly ash aggregate	9.03	11.16	16.31
16% silica fume with 20% fly ash aggregate	8.73	9.86	12.32

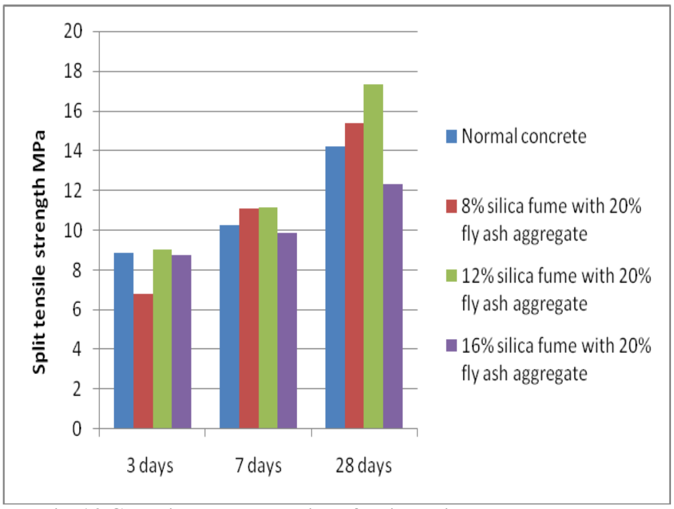

Fig:6.2 Graphical representation of split tensile strength

6.3 Flexure Strength

The flexural strength of concrete mixes with 20% fly ash aggregates at different silica fume replacements (8%, 12% and 16%) as shown in the below table. Results showed that all the mixes attained less flexural strength at 3 days when compared to normal concrete. The flexural strength has been increased with the age of concrete. The increase of silica fume up to 12% increased the flexural strength at all ages. It is due to the increase of compressive strength. At 16% silica fume, flexural strength values are decreased as compressive strength of the concrete were decreased.

Table No:6.3 Flexural strength (MPa)

Mix proportion	3 days	7 days	28 days
Normal concrete	2.69	2.84	3.53
8% silica fume with 20% fly ash aggregate	2.89	3.15	3.76
12% silica fume with 20% fly ash aggregate	2.92	3.21	4.07
16% silica fume with 20% fly ash aggregate	2.77	3.06	3.78

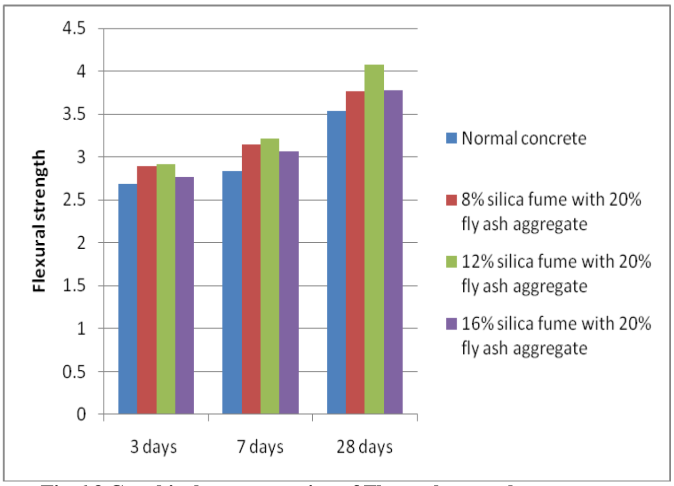

Fig:6.3 Graphical representation of Flexural strength

7. CORRELATIONS

An attempt was made establish the relation among compressive strength (MPa),split tensile and flexural strength . As it can be seen from figure that there is direct correlation among compressive strength split tensile strength and flexural strength. Linear regression analysis was performed and the result is shown in Figures. Correlation between compressive strength and split tensile strength showed R-squared value of 0.98. On the other hand, the correlation between compressive strength and flexure strength showed R-squared value of 0.97.Following equations are proposed for predicting the split tensile and flexural based on compressive strength.

Flexural strength MPa = 0.261x - 6.756

Split tensile strength MPa = 1.534x - 46.32

Where X = Compressive strength in MPa

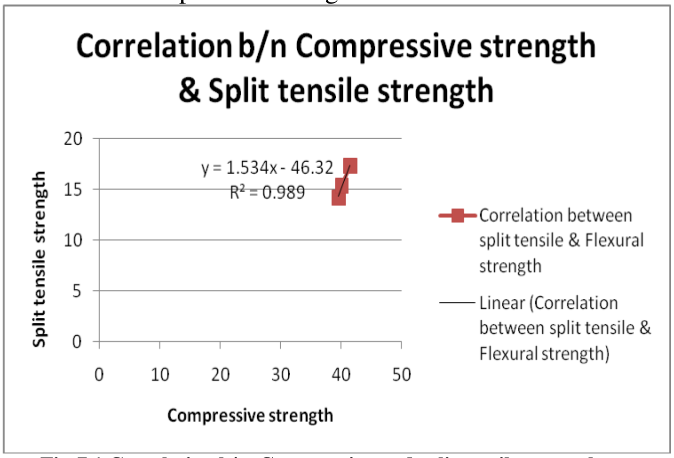

Fig:7.1 Correlation b/n Compressive and split tensile strength

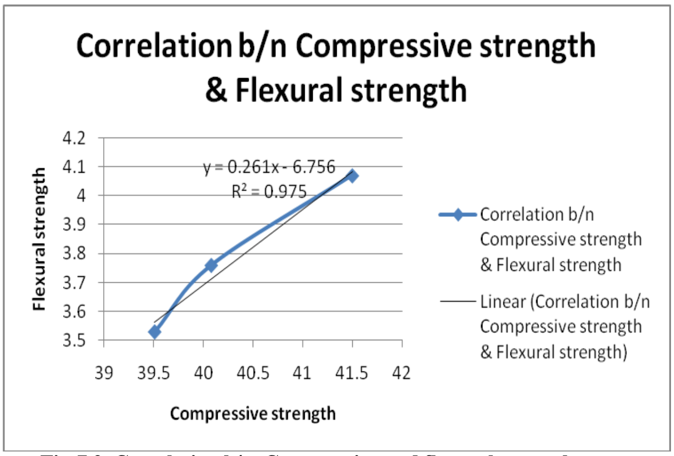

Fig:7.2 Correlation b/n Compressive and flexural strength

8. CONCLUSIONS AND SCOPE OF FUTURE WORK

The primary aim of this research was to develop concrete using 20% fly ash aggregate at different replacement levels of silica fume. Based on the investigation, the following conclusions have been drawn.

1. Mechanical properties of all silica fume replaced concrete mixes attained lesser values at 3 days when compared to normal concrete.
2. The increase of silica fume increased the mechanical properties up to 12%.
3. It is due to pozzolanic action of silica fume with fly ash aggregates which densifies the concrete and increases the strength properties.
4. The further increase in silica fume (16%) decreased the mechanical properties at all ages.
5. It is noted that excess percentage of silica fume is not contributing to the additional strength.
6. It is concluded that optimum percentage of silica fume replacement can be taken as 12% to attain the required strength.
7. Good correlations were observed for all properties.
8. Equations are proposed for predicting the split tensile and flexural strength based on compressive strength.

8.1 Scope of future work

Further research is recommended to study the bond strength between concrete and steel reinforcement and the other durability properties viz. water absorption, chloride penetration of different mixes.

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